UNIVERSITY OF PADOVA

Department of Civil and Environmental Engineering
Master Science in Environmental and Territorial Engineering

M.Sc. Thesis

COMPARISON OF WASTEWATER DISINFECTION SYSTEMS AND MICROBIOLOGICAL IMPACT ALONG THE VENICE PROVINCE COAST

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A.Y. 2012-2013

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Stefano e Leonardo

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Acronyms

Acronym	Meaning
ARPAV	Veneto Regional Environmental Prevention and Protection Agency
BSL	Venice Lagoon catchment
CFU	Colonies forming units
DBP	Disinfection by-product
ISPRA	National Chief Istitute for Environmental Protection and Research
EC	Escherichia coli
EQS	Environmental Quality Standard
FC	Faecal coliform
FIB	Faecal Indicator Bacteria
FS	Faecal streptococci
HAA	Haloacetic acid
HAN	Haloacetonitrile
HK	Haloketone
HNM	Halonitromethane
HYPO	Sodium hypochlorite
IE	Intestinal enterococci
ISPRA	National Environmentl Research Chief Institute
ISS	National Health Chieh Institute
IWA	International Water Association
LOD	Limit of Detection
LOQ	Limit of Quantification
MEQ	Management of Environmental Quality - Emerald
NTA	Norme Tecniche di Attuazione – Regulation for Technical Criteria
PAA:	Peracetic acid
PCP	Pentachlorophenol
PE	Population Equivalent
PFA	Performic acid
PLM	Pollution Levels expressed by Macro-descriptors
PRRA	Veneto Regional Water Restoration Plan (effective till end 2009)
PS	Priority substance
PHS	Priority hazardous substance
RBMP	River Basin Management Plan
SIRAV	Veneto Regional Environmental Informative System
TC	Total coliforms
THM	Trihalomethane
WFD	Water Framework Directive
WPP	Water Protection Plan
WW	Wastewater
WWTP	Wastewater Treatment Plant
WST	Water Science & Technology - IWA

Abstract

The study assesses the microbiological contamination in the wastewaters of the public owned treatment plants with potentiality higher than 10,000 Population Equivalents in the province of Veneice. The different disinfection systems are considered and their by-products (DBPs) are investigated and evaluated according to reference regulations and the european framework (Directive 2000/60/EC).

The disinfections systems with Sodium hypochlorite, Peracetic acid, Ozone, UV rays are studied with managers' data on a subset of 7 plants. Moreover a new system with Performic acid (PFA) has been experimented by a plant manager and the last full scale experimental phase on the plant has been followed; integrative samplings have been performed to investigate DBPs.

To support the evaluations on disinfection systems and DBPs, the functionality verification approach, developed for the institutional controls performed by the Environemental Protection Agency, has been applied on the subset of 7 plants. The general microbiological pollution level has been investigated along the whole coastal belt of the province of Venice with an integrated areal analysis, considering together data from rivers, bathing waters, marine-coastal waters and coastal urban discharges, to assess the microbiological impact according to the *water profile* requirements of Directive 2000/6/EC on bathing waters and the DPSIR approach.

Indications for the Regional Water Protection Plant at the regional water planning level are defined and suggested.

Key-words: microbiological pollution, disinfection systems, disinfection by-products (DBPs), Escherichia coli, Enterococci.

Summary

Directive 2000/60/EC requires the achievement of a *Good chemical status* for surface water within pre-established dates. Disinfection is needed to achieve compulsory, final microbial limit values (in Italy *Escherichia coli* is imposed by law with a maximum limit value of 5,000 cfu/100 mL for wastewater) according to the use of the receiving water body. Disinfection by-products (DBPs) must be considered when designing appropriate monitoring of dangerous substances on WWTPs' discharges; specific analytical techniques with Limits of Detection (LOD) lower than the discharge limit values must be applied.

The study aims to present the control on WWTPs' discharges for microbiological parameters and dangerous substances with particular reference to the by-products of disinfection systems. All the WWTPs of the Province of Venice with more than 10,000 PE have been considered and analysed. The available institutional data produced by the Veneto Regional Environmental Prevention and Protection Agency (ARPAV) in the period 2005-2012 have been elaborated and presented. Among these plants a specific set of six WWTPs (n. 1 managed by Veritas SpA, n. 5 managed by ASI SpA) has been studied according to the different disinfection systems used. In addition, a medium size WWTP (Paese plant with 45,000 PE, managed by SIBA SpA) from the province of Treviso with ozone disinfection process is presented as a case study.

Functionality verification, according to the European Recommendation 2001/331/EC approach, has been performed for the chosen set of seven WWTPs with different disinfection technologies. Abatement efficiencies have been assessed in the chosen set of Veritas, ASI and SIBA WWTPs. Assessment of by-products has been performed with data produced by official controls by ARPAV.

The ban of chlorine and its compounds by Veneto region since December 2012 according to the *Water Protection Plan* (Deliberation n. 107/2009 of the Veneto Region) poses the need to have valid alternatives but also to verify the microbiological abatement efficiencies and the effective presence of disinfection by-products and their levels. From by-products data, chloration (with NaClO) appear to produce THMs but always at very low levels compared with the considered regulatory limit values (discharge limit values, environmental qualitity standards, water reuse standards, drinking water qulity standards). The same conclusion has been pointed out for the other systems. It appears not completely necessary the ban of chlorine and compounds in disinfection. In any case more effort is necessary in the monitoring of DBPs.

To have a general view of the criticalities in the receiving water bodies of the province of Venice an *integrated areal analysis* for the microbiological investigation in homogeneous stretches along the coast was performed for a preliminary characterization of the *bathing water profile* considering water quality status and existing pressure sources. The choice of the disinfection system has to be based on the effective need according to the use of the receiving water body and its level of microbiological contamination; bathing waters appear to be particulary sensitive to microbiological pollution due to sanitary risk. DPSIR scheme is suggested for the definition of the intervention measures to be activated for the achievement of the environmental objectives of the water bodies.

PART I: BACKGROUND ELEMENTS

1. Introduction

The need of disinfection systems for wastwaters to achieve sanitary and environmental objectives is a fundamental issue for political as well for technical authorities to improve and to apply effective regulations and at the same to guarantee the use of resources and the reduction of by-products production. The protection of water resources is of significant importance for people's health, for the safeguard of the environment and for the growth of industrial activities in a context of a harmonious and well-balanced economic development.

Water protection is one of the priority objectives of environmental policies in Europe, as ratified in the Water Framework Directive 2000/60/EC (WFD), where the need of an *integrated approach* for the control (monitoring and management) of point and no-point discharge sources control is highlighted. The main objective of the WFD is to achieve a *Good Ecological Status*, protecting water resources from pollution phenomena in order to also guarantee the supply of drinking water. To attain environmental objectives, an adequate preventive, as well as, successive control activity on pressure sources is required. In this sense, the European Community has developed the "command and control" policy, modified by the V^{th} Environmental Action Program, through the voluntary certification environmental systems (EMAS, ISO 14000) and through the introduction of the Integrated Prevention and Pollution Control authorization (IPPC) according to Directive 96/61/EC, as modified by Directive 2008/1/EC.

The *Water Framework Directive* (WFD) 2000/60/EC (EC, 2000) sets out a new approach for the assessment and management of chemical pollutants (i.e. formerly "dangerous substances" in Directive 76/474/EEC – EC, 1976) in water bodies. The Directive introduced the idea of an *integrated approach,* aimed at the assessment of the *ecological status* of a water body. It fixes environmental quality objectives and establishes that measures must be implemented by member States to achieve these objectives. The ultimate goal of the WFD is to ensure the achievement of a *High ecological status* through the short- to mid-term (2008 to 2015) achievement of a *Good ecological status*. The good status for chemo-physical quality elements, especially for synthetic and non-synthetic priority pollutants, depends on Environmental Quality Standards (EQS). Priority (P) and priority hazardous (PH) substances must exhibit concentrations below the corresponding EQSs if they are to achieve a *Good chemical status*. Moreover, the Directive requires additional priority substances to be identified both at national and river catchment levels (Ostoich et al., 2009).

Wastewater disinfection is necessary to reduce the microbiological presence, particularly where water use can affect human health (Cabelli, 1983). Various are the available disinfection technologies theoretically applicable in wastewater treatments, among these chlorine compounds, ozone and UV represent those more known and largely applied, whereas peracetic acid (PAA) constitutes a more recent acquisition, used above all in Europe. Nevertheless for needing to balance conflicting factors as the disinfection targets required and the qualitative obligations imposed as well as to consider all the implications involved in disinfection system using, for reasons of effectiveness or by-products or operational complexity and costs or safety, choosing the most appropriate disinfection technology remains a complicated process.

In general, wastewater disinfection due to the presence of organic and inorganic materials can produce by-products, where dangerous substances can also be found. The standards for microbiological water quality represent the bacterial concentrations that should not be exceeded if human health is to be safeguarded from pathogens (Fiksdal et al., 1997); FC bacteria are widely used as indicator organisms to signal the possible presence of faeces and pathogenic organisms (Glasoe & Christy, 2004). Zann and Sutton (1995) have suggested FC and/or FS (which include *Enterococci*) as indicator bacteria of faecal pollution. In Italy, the maximum limit values for urban wastewater discharge is set at 5000 cfu/100 mL for parameter *Escherichia coli* (Decree n. 152/2006); the same parameter is included among the parameters used for the classification of the *ecological status* of water bodies.

According to water quality standards (chemical status) specific concerns arise from the by-products of disinfection systems (based on chlorine and chlorine compounds, per-acetic acid, ozone, less with ultra-violet rays systems). The issue of ozone and peracetic acid disinfection, as well as other non-chlorine systems, has now gained importance in the Veneto region (Northern Italy) since December 2012, as the regional *Water Protection Plan* (Veneto Region, 2009) forbids the use of chlorine and its compounds for wastewater disinfection in the whole region due to by-product toxicity.

The ban of chlorine and its compounds poses the need to have valid alternatives but also to understand the microbiological abatement and the effective presence of disinfection by-products and their levels. As far as screening assessment is concerned, this thesis work presents the results of institutional controls of WWTP discharges in the province of Venice (Veneto region − Northern Italy) in the period 2005-2012; data from a set of 6 WWTPs and, as a preliminary approach, historical data set of the Paese WWTP (province of Treviso, Veneto region), which uses ozone disinfection system for microbiological abatement (ozone is used in the specific case as a decolouring agent), have been assessed.

Although ozone is a very effective disinfectant in fact, because of its high tendency to react with reduced compounds and the high costs and risks involved in its production and use, it becomes a suitable system mainly in big installations or in industrial effluents treatment. The same occurs for UV disinfection system that, despite its few or any impact in water quality, remains a too sophisticated and expensive technology to apply in all the conditions and installations. Furthermore its reduced effectiveness at low doses often requires its combination with another chemical disinfectant. So the chemical compounds like chlorine hypochlorite and PAA remain the wastewater disinfection systems easier to apply. Chlorination however, because of its by-products potential formation, is becoming less and less used and in some cases (Venice, Italy) even forbidden. So today PAA would represent the most realistic alternative to chlorine use; performic acid apperars promising for costs, efficiency and by-products formation.

The study aims to investigate: the level of microbiological pollution; the disinfection efficiency and dangerous substances (where possible, priority and priority hazardous - European list - EC, 2008) levels in discharges in order to satisfy *Environmental Quality Standards* (EQSs) in the receiving water body; the abatement efficacy of the disinfection system for the chosen set of 7 WWTP for which the plant managers supplied data on WW entering disinfection system. At the same time is assessed.

To support the activity control on WWTP for the chosen 7 WWTPs a functionality verification has been performed in order to aquire data on the same plant and perform integrated controls according to Recommendation 2001/331/EC. The proposed approach takes account of the institutional obligations in environmental control activities but also of the self-controls performed by the industrial settlements' managers, the environmental management systems for the sites and the innovations introduced with the IPPC directive. This approach appears as a new perspective on the environmental governance of pollution problems (Ostoich et al., 2010).

Moreover the study presents a preliminary study of the *water profile* with reference to microbiological parameters, required by Directive 2006/07/EC (EC, 2006) concerning the management of bathing water quality, in the coastal belt of the Province of Venice. A historical data-base has been implemented with monitoring data for the period 2000–2006 (data on rivers, bathing and marine-coastal waters and on the characterization of Wastewater Treatment Plant − WWTP − discharges) from the institutional activity of ARPAV (Veneto Regional Environmental Prevention and Protection Agency). From the integrated areal analysis of microbiological parameters in the homogeneous stretches along the coast of all the investigated matrices, high mean levels of faecal contamination were found in some cases..

1.1 Background references

This thesis study starts from previous experiences of comparison of different disinfection systems (see Ostoich et al., 2007) made through a specific study funded by the Province of Venice in the period 2002-2004 to which I had the opportunity to participate as expert and coordinator, and has been developed during my institutional activity in the Regional Environmental Prevention and Protection Agency (ARPAV) in collaboration with ASI (San Donà di Piave), Veritas and Paese plant managers. With ASI Jesolo WWTP, ARPAV performed an integrative campaign for the investigation on dangerous and priority substances in 2012 as screening activity (the campaign according to the fact that no funds were available was performed with the aim to investigate only the presence/absence of dangerous, priority and priority hazardous classes of substances with the quantitication of only part of the investigated substances); the results are reported and commented in the thesis.

A set of n. 15 WWTPs (chosen as > 10,000 PE) with different disinfection systems has been analysed. Among these plants a subset was chosen for the assessment of the abatement using plants' managers data (not for all of them the assessment was possible). This set is localized in the province of Venice (n. 6 plants) where the issue of the good quality of the bathing waters is particularly important from the economic point of view (bathing activities have a huge importance for the local economy). One WWTP was selected from another province (Paese plant) as was considered a useful case study for ozone disinfection system.

As a general conclusion a comparison of the different disinfection systems, with the new case study with performic acid, has been produced in particular for the requests made by

Veneto region to the Regional Environmental Prevention and Protection Agency (ARPAV) about DBPs.

1.2 Thesis activity

The study activity has been developed to deepen aspects already followed during my working activity and specifically in the activity of WWPTs' controls performed for institutional duty. Specifical aspects like the functionality verifications and the comparison of different wastewater disinfection systems have been developed too with the support of the Engineering faculty in Padua.

For the thesis development official data produced during institutional controls where used and at the same time support and collaboration was obtained from the involved plants' managers (Veritas in Venice, ASI in San Donà di Piave for the province of Venice and ATS-SIBA-Veolia in Paese for the province of Treviso). In the thesis data produced by ARPAV and plants' managers laboratories have ben used and elaborated; the analythical methods are reported.

My personal activities and contributions were about the following aspects:

- area of study definition and planning;
- wastewater discharge and river characterization data gathering and organization;
- data elaboration and critical assessment;
- approach on WWTPs' control and WWTPs functionality verifications;
- comparison of WWTPs' disinfection systems;
- integrated analysis of the microbiologic impact in coastal area;
- integrative discharge control campaign on Jesolo plant during performic acid disinfection sprimentation;

Experimental activity focused on:

- choose, recover and organize data from a significant set of Wastewater Treatment Plants (WWTPs) with different disinfection systems;
- choose, recover and organize data for rivers and bathing waters in the province of Venice;
- disinfection by-products research;
- integrative campaign in Jesolo plant (PFA disinfection system),
- functionality plant verification;
- integrated coastal analysis on microbiooogical impact.

1.3 Objectives of the study

The thesis aims to achieve the following objectives:

- characterization of wastewaters treatment plants' discharges with specific elaborations;
- characterization of rivers' quality with specific elaborations;
- characterization of bathing waters' quality with specific elaborations;
- assess, according to available analytical techniques applied in ARPAV, by-products presence in WWTPs discharges in the Province of Venice;

- define the functionality of the chosen set of WWTPs;
- compare the selected disinfection systems according to abatement capacity and the by-products production;
- define the microbiologic impact in the coastal area of the province of Venice.

It must be underlined that disinfection systems' comparison takes care that the different abatement technologies are not applied on the same plant but on different plants and on different conditions. The baseline is in any case the assessment of the plant functionality with the specific analysis proposed in the thesis work.

I want to point out that I developed this Msc. Thesis tied to my professional activities as I have been involved for nearly 10 years in water protection and WWTPs control activity; moreover in this period the prohibition since December 2012 of chlorine and compounds for WW disinfection required much more attention on the topic. Data used in the thesis were officially required to the plants' managers and are used only for this thesis; with the basis of the thesis I am going to prepare a report for Veneto region about the disinfection by-product as it is under discussion the possibility to revise the chlorine prohibition; the report will be discussed with plant managers.

2. Legal framework for water protection and urban wastewater treatment

2.1 European surface water and wastewater legal framework

To present the situation of surface water monitoring a brief legal framework of EC regulations is detailed. The EC framework requires the following Directives:

- Directive 91/271/EEC on wastewater treatment which indicates the discharge limit values for the treatment plants and the definition of the agglomerations for the wastewater treatment.
- Directive 2000/60/EC Water Framework Directive (WFD).
- Directive 2006/7/EC on bathing water quality (repealing Directive 76/160/EEC).
- Directive 74/464/EEC on dangerous substances, Directive 2008/105/EC on environmental quality standards.

With concern to this study in the following the main aspects of Directives 91/271/EEC (urban wastewater treatment), 2000/60/EC and 2006/7/EC (bathing water quality management) are highlighted.

2.1.1 Directive 91/271/EEC and agglomeration concept

The directive aims to prevent the environment from being adversely affected by the disposal of insufficiently-treated urban waste water, and indicates the general need of secondary treatment of urban waste water; in ***sensitive areas*** (to be identified according to criteria indicated in the same directive) the directive prescribes a more stringent treatment; whereas in some less sensitive areas a primary treatment can be considered appropriate. Industrial wastewaters entering collecting systems as well as the discharge of wastewaters and disposal of sludge from urban wastewater treatment plants (WWTPs) are subject to general rules or regulations and/or specific authorizations.

The directive concerns the collection, treatment and discharge of urban wastewater and the treatment and discharge of wastewater from certain industrial sectors. The objective of the Directive is to protect the environment from the adverse effects of the above mentioned wastewater discharges (art. 1). For the purpose of the directive (art. 2):

- "*urban wastewater*" means domestic waste water or the mixture of domestic wastewater with industrial wastewater and/or run-off rain water;
- "*domestic wastewater*" means wastewater from residential settlements and services which originates predominantly from the human metabolism and from household activities;
- "*industrial wastewater*" means any wastewater which is discharged from premises used for carrying on any trade or industry, other than domestic waste water and run-off rain water;
- "*agglomeration*" means an area where the population and/or economic activities are sufficiently concentrated for urban wastewater to be collected and conducted to an urban wastewater treatment plant or to a final discharge point;
- "*collecting system*" means a system of conduits which collects and conducts urban wastewater;

- "*P.E. (population equivalent)*" means the organic biodegradable load having a five-day biochemical oxygen demand (BOD_5) of 60 g of oxygen per day;
- "*primary treatment*" means treatment of urban wastewater by a physical and/or chemical process involving settlement of suspended solids, or other processes in which the BOD_5 of the incoming wastewater is reduced by at least 20 % before discharge and the total suspended solids of the incoming wastewater are reduced by at least 50 %;
- "*secondary treatment*" means treatment of urban wastewater by a process generally involving biological treatment with a secondary settlement or other process in which the requirements established in Table 1 of Annex I are respected;
- "*appropriate treatment*" means treatment of urban wastewater by any process and/or disposal system which after discharge allows the receiving waters to meet the relevant quality objectives and the relevant provisions of this and other Community Directives;

The directive indicated that Member States had to ensure that all *agglomerations* were provided with collecting systems for urban waste water (art. 3) according to the following deadlines:

1. at the latest by 31 December 2000 for those with a population equivalent (P.E.) of more than 15.000 P.E., and
2. at the latest by 31 December 2005 for those with a P.E. of between 2.000 P.E. and 15.000 P.E.

For urban wastewater discharging into receiving waters which are considered **sensitive areas**. Member States had to ensure that collection systems are provided at the latest by 31 December 1998 for agglomerations of more than 10.000 P.E. For the purposes of the Directive, Member States had by 31 December 1993 to identify *sensitive areas* according to the criteria laid down in the same Directive (art. 5). Moreover the Directive prescribes that Member States had to ensure that urban wastewater entering collecting systems had before discharge into sensitive areas to be subject to more stringent treatment than that described in Article 4, by 31 December 1998 at the latest for all discharges from agglomerations of more than 10.000 P.E. The Directive establishes also that discharges from urban wastewater treatment plants which are situated in the relevant catchment basins of sensitive areas and which contribute to the pollution of these areas have to be subject the same regulation of discharges into sensitive areas.

The identification and characterization of the **agglomerations** according to Directive 91/271/EC must guarantee a satisfactory level of treatment for urban wastewaters and the achievement of the quality objectives for water bodies established by Directive 2000/60/EC. The Directive (art. 2) defines an “agglomeration” as *an area where the population and/or economic activities are sufficiently concentrated for urban waste water to be collected and conducted to an urban waste water treatment plant or to a final discharge point*. For practical purposes an agglomeration should be an area in which the population or the productive activities are concentrated in a measure in which it is both technically and economically feasible and environmentally beneficial to collect and convey urban wastewaters towards a treatment plant (WWTP) or towards a final receiving point.

The existence of an agglomeration is neither dependent on the existence of a wastewater collection system nor of a treatment plant. Therefore “agglomeration” can also indicate areas with low urban population density, but where a collection system does not yet exist and/or where wastewaters are collected through individual systems or other alternative systems. The term *agglomeration* used in this report must not be confused with administrative entities (such as the communes) which may use the same terminology; the boundaries of an agglomeration may or may not correspond to those of an administrative entity. Briefly, some administrative entities can constitute an agglomeration and, vice versa, a single administrative entity could be formed by various distinct agglomerations if they represent sufficiently concentrated areas as a consequence of historical and economic development.

The division of a single administrative entity into more than one agglomeration must not be considered acceptable if it reduces treatment standards or delays the collection process. This would not happen if the same administrative entity was considered to be a unique agglomeration. Agglomerations have a dynamic characteristic which is linked to the development of the local population and/or the growth of economic activities. Consequently, the generated load and the boundaries/delimitations of an agglomeration (i.e. the dimension of the agglomeration expressed in population equivalent–PE) should be constantly revised and updated.

The agglomeration can be served by one or more urban WWTPs (1:1 relationship or 1:n relationship respectively); moreover, a single agglomeration can be served by more than one collecting system, each of which is connected to one or more plants (EC, 2007). In the same way different collection systems can be connected to the same plant. In short, the agglomeration should therefore include:

1) sufficiently concentrated areas where the collecting system is active and the wastewaters are or should be transferred to a final treatment plant;
2) sufficiently concentrated areas in which urban wastewaters are conveyed into individual systems or other appropriate systems which do not achieve the same level of environmental protection as a collecting system;
3) other sufficiently concentrated areas in which urban (domestic + industrial) wastewaters are not conveyed at all.

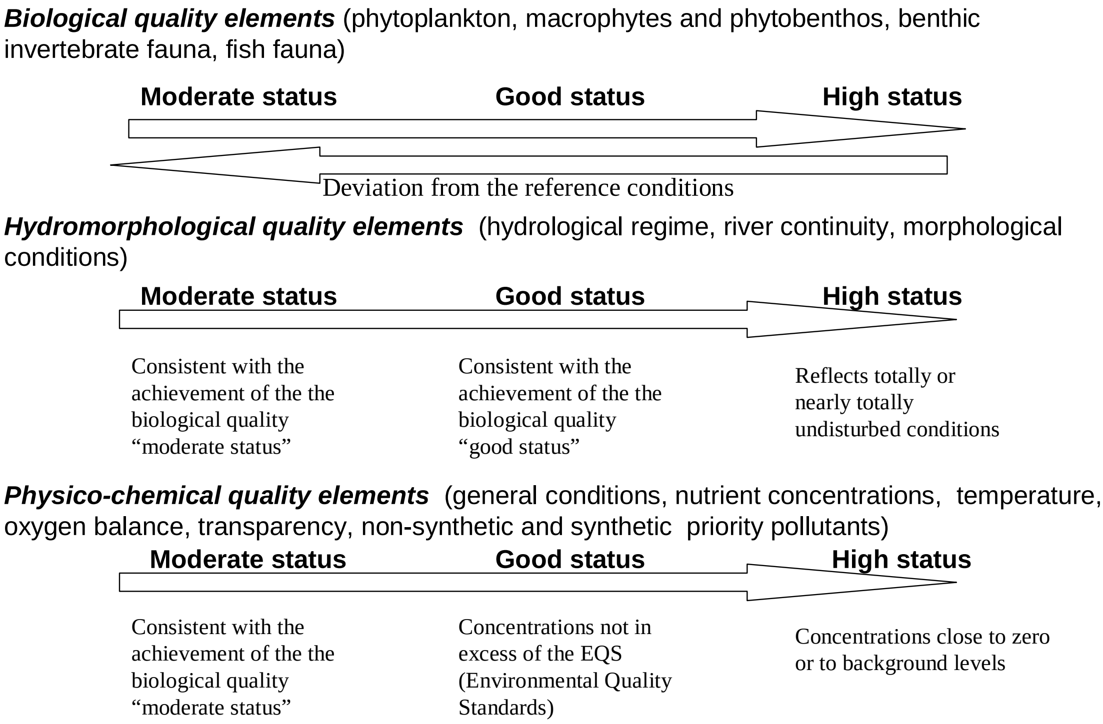
2.1.2 Directive 2000/60/EC: principles and water bodies classification

The Directive 2000/60/EC establishing a framework for community action in the field of water policy (Water Framework Directive – WFD) indicates that the member States should define the *ecological* and *chemical status* of their water bodies by means of monitoring programmes. The sustainable use of water resources must be guaranteed through qualitative and quantitative aspects; as strategic objective member States have to adopt measures to reduce the emissions of *priority substances* and to phase out the emissions of *priority hazardous substances*.

Water monitoring and the control of discharges are performed with the aim of achieving the quality objectives established in the directive. The WFD indicates that, regarding surface waters, a "Good" status shall be reached within 15 years from its enforcement; a Good surface water status is considered to be that achieved by a water body when both its *ecological* and *chemical status* are at least "Good" (art. 2). This Directive coordinates the other existing Directives on water protection and management.

The surface water status is the general expression of the status of a body of surface water, determined by the poorer of its *ecological status* and its *chemical status* (its is described in **fig. 2.1**); the *ecological status* is an expression of the quality of the structure and functioning of aquatic ecosystems associated with the surface waters classified in accordance with Annex V of the WFD. Both the *ecological* and *chemical status* contribute to the establishment of the criteria for surface water monitoring.

Figure 2.1 *– Criteria for the evaluation of the "surface water status" through ecological and chemical status*



The elements of the *ecological status* (according to Annex V) are the following ones: biological, hydro–morphological, chemical and physico–chemical. The *ecological status* is then confirmed or not confirmed with the *chemical status*. In order to measure the environmental quality of a water body and establish the biological and hydro–morphological parameters, a comparison with the reference conditions is made. A "Good" chemical quality status is defined according to the *environmental quality standards* (EQSs); that is, the concentration of a particular pollutant or group of pollutants in waters, sediments and biota that must not be exceeded, in order to protect human health and the aquatic environment. Therefore, this type of approach requires an integrated protection system, both for the protection of human health and for the quality of the aquatic ecosystem. Non–synthetic and synthetic priority substances are included among the chemical parameters for the definition of the chemical status; their EQSs are now fixed in Directive 2008/105/EC.

As regards the assessment of the *ecological* and *chemical status*, the WFD has for the first time in the European legal context (Annex V), established three types of water monitoring: 1) surveillance monitoring; 2) operational monitoring; 3) investigative monitoring. The specific methodologies to define monitoring and water classification for the *ecological status* are left to member States although a monitoring guidance is supplied at European level (EC, 2003).

2.1.3 Objectives and tools of the Water Framework Directive 2000/60/EC

According to WFD, protection of surface waters must aim to:

- prevent and reduce pollution through the remediation of polluted water bodies;
- to obtain the improvement of water quality status and the protection of water to be intended to specific uses;
- to promote sustainable uses in the long time of hydric resources, with priority to drinking waters;
- to maintain the natural auto-depuration capacity of water bodies, as well as the capacity to sustain large and with high diversity animal and vegetal communities;
- to mitigate floods and droughts’ effects in order to guarantee a sufficient supply of good quality surface and ground waters for a sustainable, balance and equal water use;
- to protect and improve the status of aquatic ecosystems, earth ecosystems and protected areas and avoid their depletion.

To guarantee the achievement of the aims and objectives of the water protection and management national and regional policies the following tools must be developed:

- identifications of the environmental objectives and specific destination objectives for the surface water bodies;
- integrated protection of qualitative and quantitative aspects for each hydrographic basin/district and an appropriate system of controls and penalties;
- the satisfaction of limit values for discharges function of the quality objective of the water body;
- the realization/improvement of sewage systems for discharges in the integrated cycle service;
- identification of the prevention measures for the pollution reduction in *sensitive areas* and in *zones vulnerable to nitrates of agricultural origins as well as phyto-pharmaceuticals products*;
- identifications of measures to water resources’ protection, saving, reuse and recycle;

- adoption of measures for a progressive reduction of discharges of dangerous substances, as well as the elimination of hazardous priority substances, in order to achieve base values for substances of natural origin.

When in the same water body or stretches of the same water body different objectives are identified, the most restrictive objective must be respected. According to European Directives the following intervention measures must be fulfilled:

- *«**sensitive areas**»* according to Directive 91/271/EEC;
- *«**vulnerable zone to nitrates of agricultural origin**»* Directive 91/676/EEC;
- *«**zones vulnerable to phyto-sanitary** products»* and «*zones vulnerable to desertification»* Directive 91/676/EEC;
- *«**safeguard area for surface and ground waters intended for human consumption**»* Directive 75/440/EEC.

Particular attention must be paid to protected areas (Directives 79/479/EEC and 92/43/EEC); these must be considered in the *River Basin Management Plan* (RBMP) in the definition of quality objectives. In the definition of intervention measures to achieve the water quality objectives and intermediate date for a less stringent level must be defined in order to verify the improvement process.

2.1.4 Dangerous, priority and priority hazardous substances

A description of the shift from the former to actual approach to the regulation is presented in **fig. 2.2**, which gives a schematic classification of dangerous substances and outlines the formulation of the EQSs regarding the protection of human health and natural ecosystems at European, national and local (i.e. river basin) scale (Ostoich et al. 2009).

The "old approach" was based on lists I and II of the dangerous substances contained in the 76/464/EEC directive, which was aimed at eliminating the emission of substances in list I and a reduction in the emission of the substances in list II. The WFD replaced the former lists I and II with a new generic list of substances and classes of substances, i.e. "*the indicative list of main pollutants"* which is given in Annex VIII of this directive.

In **tab. 2.1**, the combining of lists I and II with the new *indicative list of main pollutants* is reported. Noticeably, the new list of main pollutants extended the former list I to include substances "which may affect steroidogenic, thyroid, reproduction or other endocrine-related functions in or via the aquatic environment".

In addition to the generic list of main pollutants, the WFD provided a list of priority pollutants, identifying two categories of substances for which specific measures (i.e. interventions) should be taken: *Priority Substances* (PS) [substances listed in Annex X of the WFD (modified following decision n. 2455/2001/EC)] and *Priority Hazardous Substances* (PHS). The PSs are those substances which pose a significant risk both to, or via, the aquatic environment, including the risks associated with the use of surface waters in drinking water production. The PHSs are the PSs which are toxic, persistent and liable to bio-accumulate, and other substances or groups of substances which give rise to an equivalent level of concern.

Figure 2.2 *– Dangerous, substances, priority and priority hazardous substances for chemical status*

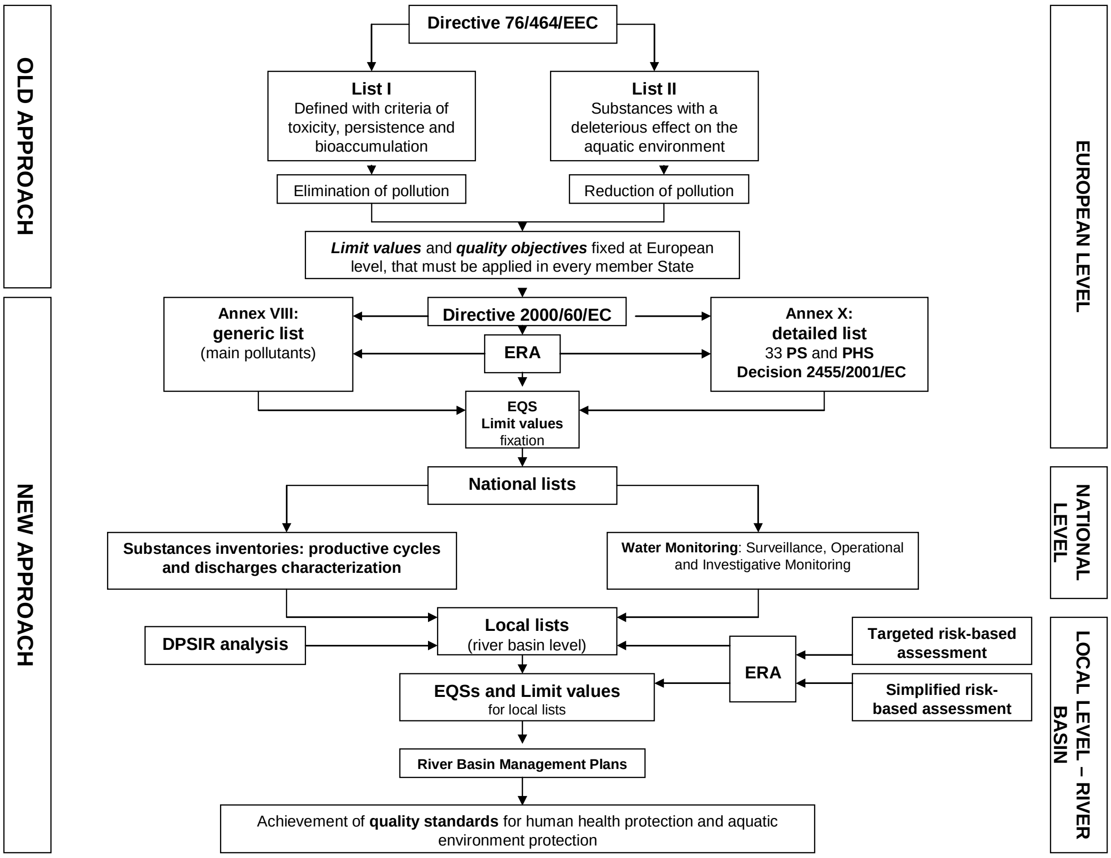


Table 2.1 *– List of main classes of pollutants in accordance to the WFD (Annex VIII) together with the indication of the corresponding classes in Lists I and II of Directive 76/464/EEC*

List of main pollutants (Directive 2000/60/EC)	Correspondence with list in Directive 76/464/EEC
1. Organohalogen compounds and substances which may form such compounds in the aquatic environment.	List I point 1
2. Organophosphorous compounds.	List I point 2
3. Organotin compounds.	List I point 3
4. Substances and preparations, or the breakdown products of such, which have been found to possess carcinogenic or mutagenic properties, or properties which may affect steroidogenic, thyroid, reproductive or other endocrine-related functions, in or via the aquatic environment.	List I point 4 (enlarged)
5. Persistent hydrocarbons and persistent and bioaccumulable organic toxic substances.	List I points 7 and 8 enlarged
6. Cyanides.	List II point 7
7. Metals and their compounds.	List I points 5, 6 and List II point 1
8. Arsenic and its compounds.	List II point 1
9. Biocides and plant protection products.	List I point 8, List II point 2
10. Materials in suspension.	List II point 8
11. Substances which contribute to eutrophication (in particular, nitrates and phosphates).	List II points 5 and 8
12. Substances which have an unfavourable influence on the oxygen balance (and can be measured using parameters such as BOD, COD, etc.).	List II point 8.

As far as chemical substances are concerned, the WFD demands to achieve a "*good chemical status*" regarding surface waters and ground-waters within 15 years from its enforcement (i.e. by the year 2015). The above refers to the status to be reached in a water body, which should indicate concentrations of chemical pollutants not exceeding the EQSs as defined in the same directive. In regards to chemical pollutants, the substances mentioned in Annex VIII of the WFD, together with the PSs and PHSs, must be considered.

The ultimate goal of the WFD is to ensure the attainment of a *High ecological status* by means of a short to mid-term (2008 to 2015) achievement of a *Good ecological status*. Biological, hydro-morphological and physico-chemical quality elements all contribute to the ecological status of a water body. The PSs, PHSs and other dangerous substances must show concentrations below those stipulated by the EQSs, which is the indicator of a good chemical status. The procedure regarding the definition of the EQS is outlined in Annex V of the WFD. Tests for both acute and chronic toxicity, plus the use of specific *safety factors* for the determination of the final standards, are required in this case.

According to the new European policy on priority substances (the "*new approach*" in figure 1), the number of substances to be controlled has increased considerably, due to the integration of the criteria regarding *toxicity*, *persistence* and *bioaccumulation* with those concerning the *risk for the aquatic environment*. The setting of the PSs, PHSs and EQSs should be based on the risk assessment, as indicated in art. 16 of the WFD, in accordance with the reference procedures (regulation n. 793/1993, directive 91/414/EEC, directive 98/08/EC). Furthermore, the need to prioritise interventions concerning the risk to, or via, the aquatic environment, triggers of a *simplified risk-based assessment procedure*, "based on scientific principles". However, in regards to the implementation of this simplified procedure, the following guidelines must be taken into account:

- evidence regarding the intrinsic hazard within each substance of concern and, in particular, of its aquatic eco-toxicity and toxicity to humans via aquatic exposure routes;
- evidence of widespread environmental contamination, received from monitoring procedures;
- other proven factors which may indicate the possibility of widespread environmental contamination, such as the production of, or use in volume, of the substance of concern, combined with the patterns of use of the same substance.

The list of PSs (WFD Annex X - "*Priority substances*"), established by the European Council Amendment n. 2455/2001/EC, contains 33 substances, or classes of substances, which were selected using a procedure based on the principles of monitoring and modeling: COMMPS (the combined monitoring-based and modeling-based priority setting procedure) (EC, 1999). It should be noted that a further period of testing of some PSs is required before they can definitively be listed as priority substances.

In addition to the list of 33 priority substances already identified by the WFD, it is to be expected that a further list of PSs will be provided by each Member State on a national scale, and another list should be drawn up on a river basin scale. In Italy, the identification of these substances should be made by the local Authorities (Regions) which must propose the local list to the National Authority (State, Ministry of the Environment) responsible, by law, for the setting of the water EQSs.

2.1.5 Environmental quality standards for dangerous and priority substances

The control and management of dangerous and priority substances needs the implementation of an environmental management model with a sound knowledge of environmental concentrations and pressure sources. Article 10 of the WFD establishes that all point and non-point (i.e. diffuse) emission sources into surface waters must be controlled using a *combined approach*: i.e. the control of the emissions based on the use of the Best Available Technologies (BAT); the control of the emission limit values; the application of the best environmental practices concerning diffuse sources. In regards to the characterisation of the pollution from the anthropogenic point and the diffuse pressure sources, the information concerning pollution caused by substances contained in Annex VIII of the WFD (list of main pollutants) must be consulted. An inventory analysis of industrial cycles and diffuse pollution sources is of utmost importance.

The WFD has established a methodological approach regarding both environmental quality assessment and management, in accordance with Arts. 5, 8, 10 and 13, which are in practice based on the DPSIR (Driving force-Pressure-State-Impact-Response) conceptual model. The DPSIR model is a decisional framework for environmental management. It had previously been proposed by the OECD and was subsequently modified by the European Environmental Agency (1998). Moreover, it is anticipated that the *Environmental Risk Assessment* (ERA) approach, which uses water quality monitoring and characterization of the pressure sources, will be employed for the identification of the priority pollutants, the definition of the emission limits regarding discharges and in regards to the identification of the EQSs for the receiving water bodies. The objective to be considered here is to establish of a support mechanism concerning the DPSIR framework, with the aim of defining the specific measures needed to reach the fixed quality objectives. The DPSIR model had already been used at river basin level and is widely recognized as an effective assessment and intervention method; this model appears to be particularly suitable for the integration of the monitoring and management of dangerous and priority chemical substances within the *River Basin Management Plans* (RBMPs) as indicated in the WFD Directive (Cave et al., 2003; Scheren et al., 2004).

Most priority substances have, in practice, already been regulated by means of national EQSs, which vary considerably from State to State. The EQSs for priority substances should be established on a European scale, in order to ensure the maintenance of similar levels of environmental protection. This criterion must be reached, in order to meet the specific demands of the WFD, achieving harmonisation and consistency among the Member States concerning Community legislation, while leaving each Member State free to fix their EQSs for other main pollutants. In regards to the eight dangerous substances (DDT, Aldrin, Dieldrin, Endrin, Isodrin, Carbontetrachloride, Tetrachloroethylene, Trichloroethylene) which have not been considered as PSs but are included in list I of Directive 76/464/EEC, it was decided to fix their EQSs at a Community level too.

In accordance with art. 16 paragraph. 7 of the WFD, the EC Commission presented a proposal regarding the establishment of quality standards concerning the 33 priority PSs contained in Decision n. 2455/2001. At a European level, the setting of the EQSs for the PSs and PHSs of the substances on the "European list" was proposed by EC COM(2006)397. By means of this proposal, which was confirmed by the adoption of a common position on the 20/12/2007 (ENV 378 CEDEC 757) and then approved with Directive 2008/105/EC on environmental quality standards for waters, the EQSs concerning the 33 priority and priority hazardous substances, plus the additional 8 dangerous substances, were set in such a way as to ensure a high level of protection against risks to, or via, the aquatic environment. The common position fixes two values for each substance: 1) a *maximum allowable concentration*, as a means for avoiding serious, irreversible consequences for ecosystems exposed to acute contact in the short term, and 2) the *annual average EQS*, used to prevent irreversible consequences in the long term. As far as metals are concerned, the Member States are allowed to adapt the compliance regime to their own needs, as background levels and bioavailability have to be taken into account in each case. The necessity to identify a transitional area concerning limit values in the vicinity of the point source discharges was decided upon for those areas of water bodies where EQSs cannot be met, due to the elevated levels of pollutants in the effluents.

With regards to the question of pollution control measures, the common position leaves the decisions concerning additional specific measures up to the Member States, who have to draw up an inventory of the emissions, discharges and losses from their river basins. Consequently, the national list should contain the PSs and PHSs fixed by the European Commission, those fixed by each Member State, plus the other dangerous substances, as a means of ensuring a complete analysis of the list of main pollutants in accordance with the actual existing pressure sources, in order to guarantee the achievement of the WFD's objectives.

Before the introduction of the COM 398 proposal (2006), each Member State had to define the EQSs for the PSs established by the Commission in 2006 in accordance with art. 16 of the WFD. In Italy, the EQSs at both national and local (river basin) level were fixed by using existing European references, whenever possible, or by introducing new EQSs. The emission values and EQSs for 18 specific pollutants were established using the "daughter directives" of the Directive 76/464/EEC and were also added to the Italian national list of dangerous and priority substances.

The introduction of the Italian regulation (Decree n. 367 of 6/11/2003 amended by Decree n. 152/2006) finally completed the section of Directive 76/464/EEC ("the old approach") not transposed up to then into the Italian legal framework concerning the definition of the EQSs for surface fresh waters, marine-coastal waters and lagoons, combined with the definition of programmes to reduce and eliminate the pollution caused by dangerous substances. This Italian regulation identified the PSs and PHSs (according to the WFD list) and fixed the EQSs for 160 substances, distributed over a range of 10 classes of substances or categories.

The Italian national list (Decree n. 367/2003) fixed two EQSs for each substance in surface waters: one to be achieved in the short term (within the year 2008) and another, more restrictive one, to be achieved in the medium-long term (within the year 2015) according to the time frame of the WFD. As for the substances not included in the national list (e.g. new synthetic substances), the ERA was identified as the methodology for fixing the EQSs for these substances. The possible application of restrictions to the water body could be introduced, based on the results of the risk assessments.

The finding that some EQSs could not be achieved using even the most advanced analytical techniques (fixed by Italian Decree n. 367/2003 for the year 2008) prompted the enforcement of a new decree (decree 3/04/2006 n. 152), as stated before, which fixed higher EQSs for selected substances on a temporary basis (table 3), while maintaining the same EQSs up to the year 2015. The Italian national list contains the PSs, PHSs and dangerous substances, but the EQSs of COM 398 (2006), now Directive 2008/105/EC, are not included. This list is now under review, so that the implementation of the proposed European standards concerning the PSs and PHSs and the parameters indicated in the "daughter Directives" can be integrated.

The main challenge that the Regional Environmental Agencies in Italy and Europe are facing, concerning the implementation of the WFD, is the newly required monitoring system project: new parameters have to be monitored, inventories of emission sources have to be drawn up, effective measures of intervention have to be identified and new analytical methods have to be set up.

2.1.6 Requirements of Direcive 2006/7/EC on management of bathing water quality

In order to increase efficiency and correct use of resources, the directive 2006/7/EC needs to be closely coordinated with other Community legislation on water, such as directive 91/271/EEC concerning urban wastewater treatment and directive 2000/60/EC establishing a framework for Community actions in the field of water policy.

The directive refers the "pollution" as the presence of microbiological contamination or other organisms or waste affecting bathing water quality and presenting a risk to health of bathers as referred to in articles 8 and 9 and Annex I, column A of the same directive.

The ultimate goal of the WFD is to ensure the attainment of a *High ecological status* by means of a short to mid-term (2008 to 2015) achievement of a *Good ecological status*. Biological, hydro-morphological and physico-chemical quality elements all contribute to the ecological status of a water body. The PSs, PHSs and other dangerous substances must show concentrations below those stipulated by the EQSs, which is the indicator of a good chemical status. The procedure regarding the definition of the EQS is outlined in Annex V of the WFD. Tests for both acute and chronic toxicity, plus the use of specific *safety factors* for the determination of the final standards, are required in this case.

Quality objectives for bathing waters established by the directive are reported in **tab. 2.2**.

The bathing water profiles

Member States shall ensure that ***bathing water profiles*** are established in accordance with Annex III of the directive 2006/7/EC. Each bathing water profile may cover a single bathing water or more than one contiguous bathing waters. Bathing water profiles shall be established for the first time by 24 March 2011.

Table 2.2 *– Quality objectives of bathing waters – Directive 2006/7/EC*

For coastal waters and transitional waters

	A	B	C	D	E
	Parameter	Excellent quality	Good quality	Sufficient	Reference methods of analysis
1	Intestinal enterococci (cfu/100 ml)	100 (*)	200 (*)	185 (**)	ISO 7899-1 or ISO 7899-2
2	Escherichia coli (cfu/100 ml)	250 (*)	500 (*)	500 (**)	ISO 9308-3 or ISO 9308-1

(*) Based upon a 95-percentile evaluation. See Annex II.
(**) Based upon a 90-percentile evaluation. See Annex II.

The *bathing water profile* referred to in art. 6 consists of:

- a description of the physical, geographical and hydrological characteristics of the bathing water, and of other surface waters in the catchment area of the bathing water concerned, that could be a source of pollution, which are relevant to the purpose of this Directive and as provided for in Directive 2000/60/EC;
- an identification and assessment of causes of pollution that might affect bathing waters and impair bathers' health;
- an assessment of the potential for proliferation of cyanobacteria;
- an assessment of the potential for proliferation of macro-algae and/or phytoplankton;
- if the previous assessment shows that there is a risk of short-term pollution, the following information:
  - anticipated nature, frequency and duration of expected short-term pollution,
  -details of any remaining causes of pollution, including management measures taken and the time schedule for their elimination,
  -management measures taken during short-term pollution and the identity and contact details of bodies responsible for taking such action;
- location of the monitoring points.

Technical criteria for the identification of the bathing water profile are defined in Annex III of the Directive. From what reported above the catchment area with direct effect on bathing and coastal wastes must be identified and analysed. The bathing water profile, according to Directive 2006/7/EC appears to be a tool to ass pollution risks (Jeanneaeu et al., 2012).

2.1.7 Diffuse pollution sources

Diffuse pollution is generated by: atmospheric deposition, indirect drainage of deep groundwater reservoirs, agriculture, traffic and non urban infrastructure, accidental spills, release from materials, release from landfills and from contaminated sites. For the purposes of this report urban drainage as well as agricultural diffuse pollution are of main interest.

The approach that must be followed for the control and reduction of diffuse pollution is the "*combined approach*" indicated by art. 10 of the WFD 2000/60/EC. In particular the WFD art. 10 establishes that 2. Member States shall ensure the establishment and/or implementation of:

(a) the emission controls based on best available techniques, or
(b) the relevant emission limit values, or
(c) in the case of diffuse impacts the controls including, as appropriate, best environmental practices set out in:

- *Council Directive 96/61/EC (IPPC Directive) of 24 September 1996 concerning integrated pollution prevention and control,*
- *Council Directive 91/271/EEC of 21 May 1991 concerning urban waste-water treatment,*
- *Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources,*
- *the Directives adopted pursuant to Article 16 of this Directive,*
- *the Directives listed in Annex IX,*
- *any other relevant Community legislation at the latest 12 years after the date of entry into force of this Directive, unless otherwise specified in the legislation concerned.*

3. Where a quality objective or quality standard, whether established pursuant to this Directive, in the Directives listed in Annex IX, or pursuant to any other Community legislation, requires stricter conditions than those which would result from the application of paragraph 2, more stringent emission controls shall be set accordingly.

2.2 Italian national framework on water protection

2.2.1 Water protection and management tools

In the field of water protection and water management the mai planning tools to be considered are:

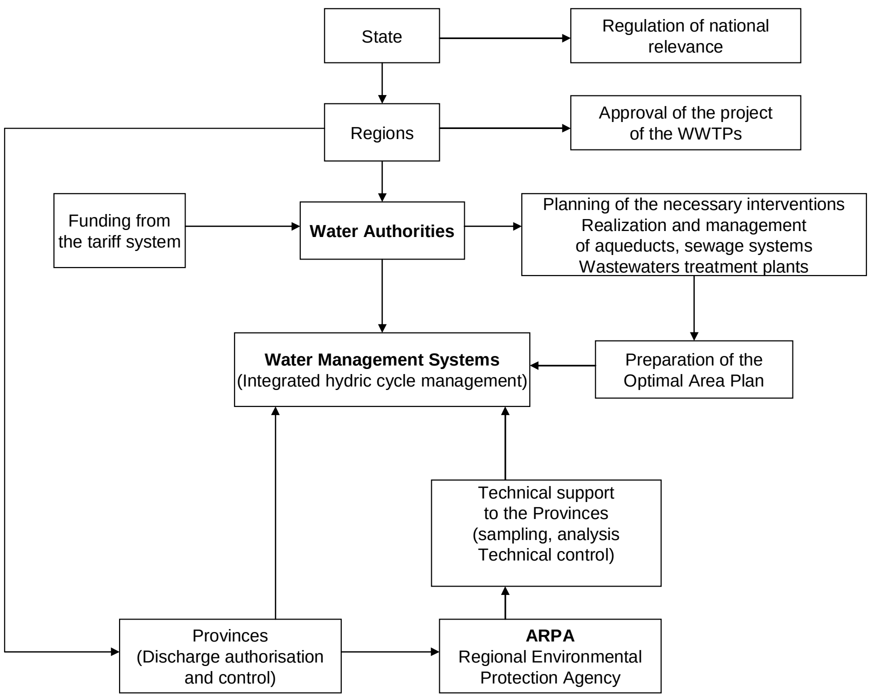
- **Water protection plan (WPP).**
- **River basin management plans (RBMP).**
- **Regional Water Resources Recovery Plan** (PRRA, since 2009 substituted with the *Water Protection Plan*).
- **Intervention Plans** of the Water Authorities (Venice Lagoon Water Authority-AATO Laguna).

New water supply must be considered by the Water Authorities in their interventions plans and must respect the Water Protection Plan (regional competence), conformal to the River Basin Management Plan. In Veneto region the identification and the protection of the abstraction points and the connected facilities through specific limited protection areas are defined by the Water Authorities (AATO).

2.2.2 Organisation of water services in Italy: supply and wastewater treatment

At present in Italy on the basis of EC directives (Directives 98/83/EEC on drinking water, 271/91/EEC on urban wastewater treatment and 2000/60/EC water framework directive - WFD) the management of the integrated water system (water intake, treatment, supply, wastewater collection and treatment for final discharge) is a duty of the Water Authorities established by each region (8 Authorities in Veneto); these Authorities do not manage directly the plants and infrastructures. The central State provides with general indications, with establishing the quality standard values; the definitions of the objectives fro each rivers basin is defined by the regions. The control of discharges into surface waters is performed by the Provinces with the technical support of the Regional Environmental Protection Agencies. The described framework of water protection and management is reported in **fig. 2.3**.

Figure 2.3 *– Italian institutional organization for water protection and management*



2.2.3 The Italian regulations for water protection

The Italian legal framework on water protection is basically referred to Part III of the Leg. Decree n. 152/2006 in which not only qualitative but quantitative aspects with soil proptection are considered too. The legal framework on waters at national level is fulfilled with the following regulations which are here recalled for completness:

- D.Lgs. 2/02/2001, n. 31 according to Directive 98/83/EEC on waters intended for human consumption.
- DM 12/06/2003 n. 185 on the reuse of wastewaters (according to previous D.Lgs. n. 152/1999).
- D.Lgs. 30/05/2008 n. 116, attuazione della Direttiva 2006/7/CE on bathing water quality.
- DM 16/06/2008, n.131, which gives the criteria for river body types'identification.
- D.Lgs. 16/03/2009 n. 30, on the protection of groundwaters from pollution.
- DM 14/04/2009, n. 56, which gives the tecnichal criteria for surface water bodies monitoring and the identification of reference conditions.
- DM 17/07/2009, about the identification on territorial environmental information for data Exchange according to communitary obligations.
- DM 30/03/2010, on criteria for bathing denial.
- DM 8/11/2010 n. 260 which guives the technical criteria for surface water monitoring and classification.

2.2.4 National goals for wastewater treatment

We assume, according to the Purchasing Authority, that wastewaters are of domestic and industrial; according to Italian Decree n. 152/2006 we speak of "urban wastewaters"; leachate from landfills and other special wastes will be received and treated only by biological process after a pre-treatment.

Limit values are applied to the WWTP's discharge in order to guarantee the respect of the quality objectives of the receiving water body. Objectives are fixed by the zed plants with adequate residual capacity and through ancompetent Authority according to Directive 2000/60/EC (see **fig. 2.1**).

As already mentioned we assume that the receiving water body of the WWTP's discharge is a **sensitive area**; therefore the limit values to be satisfied area the value in **tab. 2.3** for BOD_5, COD, TSS and, to meet the water quality requirements for sensitive areas (Directive 91/271/EEC), the valus reported in **tab. 2.4** for N_{tot} and P_{tot}. Discharge limit values for other parameters (tab. 3 Annex V Part III Decree n. 152/2006 and modifications/integrations) in case of the presence of industrial wastewaters reported in **annex I**.

Table 2.3 *– Limit values for urban wastewater treatment plants' discharges into surface waters*

	Plant potentiality (P.E.)			
	2.000 – 10.000		**> 10.000**	
Parameters (daily mean value)	**Concentration**	**% of reduction**	**Concentration**	**% of reduction**
BOD_5 (no nitrification) mg/L	≤25	70-90	≤25	80
COD mg/L	≤125	75	≤125	75
Suspended Solids mg/L	≤35	90	≤35	90

Table 2.4 *– Additional limit values for urban wastewater treatment plants' discharges in sensitive areas into surface waters*

	Plant potentiality (P.E.)			
	10.000 – 100.000		> 100.000	
Parameters (daily mean value)	**Concentration**	**% of reduction**	**Concentration**	**% of reduction**
Total Phosphorous (P mg/l)	≤2	80	≤1	80
Total Nitrogen (N mg/l)	≤15	70-80	≤10	70-80

2.2.5 Bathing water quality: from the old to the new monitoring system in Italy

In Italy since the 2010 season (till the 2009 season the regulations were the the Italian Decree n. 470/1982 shich had transposed the Directive 76/160/EEC)the bathing guidelines at present in force are the Legislative Decree n. 116/2008, which tranmsposed Directive 2006/7/EC) and the Min. Decree 30/05/2010. The new European Directive 2006/7/EC on management of bathing water quality drastically reduces the number of parameters from the previous 19 to 2 key microbiological parameters. This directive aims to establish more reliable microbiological indicators. The two faecal indicator parameters retained in the Directive 2006/7/EC are *Intestinal Enterococci* (IE) and *Escherichia coli* (EC), providing the best match between faecal pollution and health impacts in recreational waters according to available scientific evidence provided by epidemiological studies.

The policy on bathing waters must satisfy the general objective of "*good ecological status*" expressed in the directive 2000/60/EC *Water Framework Directive* (EC-WFD, 2000) to be achieved with the river basin management plans and programmes of measures and must follow a new approach based on an integrated management of water quality.

Limit for microbiological parameters on point sources (WWTPs, industrial discharges) should be fixed in order to guarantee the achievement of the quality objectives. A value of 5.000 UFC/100 mL for *Esherichia coli* should be suggested to the Control Responsible Authority (the Authority responsible of the release of the discharge authorization) according to Italian Law (Decree n. 152/2006).

For the eutrophication responsible parameters WWTPs and industrial plants must be in compliance with the limit values above indicated. The limit values should allow the achievement of the quality objectives of the water body. For agricultural diffuse pollution the *Good Practice code* should be implemented and specific measures with the action plans must be implemented in the vulnerable zones.

The Directive 76/160/EEC on bathing waters required the monitoring and fixed the threshold standards for the following parameters *Total coliforms* (TC), *Faecal coliforms* (FC), *Faecal streptococci* (FS), *Escherichia coli* (EC) and other physico-chemical parameters. With the Directive 2006/7/EC on management of bathing water quality there is a drastic reduction in the number of parameters, from 19 parameters in the Italian law (1982) (quality standards values: TC=2.000 UFC/100 mL; FC=100 UFC/100 mL; FS=100 UFC/100 mL, Salmonella/1 L=0) to 2 key microbiological parameters. The Directive 2006/7/EC aims to establish more reliable microbiological indicators and to a new approach based on an integrated management of water quality. The policy on bathing waters must satisfy the general objective of "good ecological status" of directive 2000/60/EC WFD to be achieved with the river basin management plans and programmes of measures.

The two faecal indicator parameters retained in the Directive 2006/7/EC are *Intestinal or Enteric Enterococci* (EE) and *Escherichia coli* (EC), providing the best available match between faecal pollution and health impacts in recreational waters. The choice of the microbiological parameters and corresponding values was based on available scientific evidence provided by epidemiological studies; the two parameters are representative of the most frequently reported episodes of contamination and they are correlated with health problems. Assessment of both indicators in coastal and fresh waters shall provide more information and could help determining the sources of contamination. Nevertheless, research on viral indicators remains necessary.

The control and monitoring of the quality of the coastal marine waters (Bartram and Rees, 2000) is particularly important in the coastal area of the Province of Venice, where many and important tourist sites are localized. Furthermore, the economic and urban development of the area produces significant discharges both into the rivers and into the marine waters, with the necessity of efficient WWTPs. The sanitary and environmental "quality" of the coastal belt of the Province of Venice, is very important from the environmental as well from the economical point of view (tourism).

2.2.6 Wastewater reuse requirements

Among the measures for a sustainable management of water resources the wastewater reuse is very important; it is strategic in the regions where the lack of water does not allow to satisfy the water demand. In Italy since 10 years ago, a specific regulation has been established for the characteristics for the reuse of wastewaters. The reuse, according to the specific case (irrigation, industrial reuse, etc.), requires particular precautions and conditions. The technical regulation for water reuse has been adopted with the Italian Decree n. 185/2003 and defines the conditions for the reuse of domestic, urban and industrial wastewaters through the regulation of the destination use and the relative quality requirements.

The reuse requirements cannot be applied directly to the water body quality as it cannot be considered like a "discharge"; in any case this decree can be a reference tool and be applied considering the water body in the "worst" condition. In **tab. 2.5** the values for the reuse of wastewaters are reported (only for the most significant parameters). Regions are charged by Decree n. 185/2003 with the duty, among others, to identify the WWTPs whose discharge must be adequated to respect the limts of the same decree. The characterization of the discharges of WWTPs appears one of the primary elemnts to be considered in the regional polcy on the wastewater reuse. In the table in grey the DBPs are highlighted.

A preliminary investigation according to the available data on discharges in the whole Veneto region has been performed by Ostoich & Lionello (2007). In this study the microbiological parameter (*Escherichia coli* – EC) was the most critical one according to the very low limit (10 cfu/100 ml) and the non compulsory activation of disinfection systems; in facts for WWTPs > 10000 PE it is compulsory that plants have the disinfection system but their activation is imposed by the Provinces with the authrizations according to the microbiological quality that has to be guaranteed in the receiving water body (with reference to its use: irrigation, bathing, drinking water withdrawl, etc.).

Table 2.5 *– Italian Decree n. 185/2003: limit values for the reuse wastewaters for some parameters*

Parameter	Measure unit	Limit value in the discharge
pH		6-9.5
SAR		10
Total Suspended Solids	mg/L	10
BOD_5	mg O_2/L	20
COD	mg O_2/L	100
Total Phosphorous	mg P/L	2
Total Nitrogen	mg N/L	15
Ammonium Nitrogen	mg NH_4/L	2
Conductivity	µS/cm	3000
Chlorides	mg Cl/L	250
Sulphates	mgSO_4/L	500
Cadmium	mg/L	0.005
Total Chromium	mg/L	0.1
Nickel	mg/L	0.2
Active Chlorine	mg/L	0.2
Total Phenols	mg/L	0.1
Total Aldehydes	mg/L	0.5
Tetra-chloroethilene, Trichloroethilene (sum)	mg/L	0.01
Total chlorinated solvents	mg/L	0.04
THMs (sum)	mg/L	0.03
Organic aromatic solvents		0.01
*Escherichia coli**	cfu/100mL	10 (80% of samples) 100 max point value
Salmonella	Presence/Absence	absent

* For the wastewaters from lagoon treatment and phytodepuration is established a limit value of 50 (for 80% of samples)

According to the cited study it was evident that the EC limit value is particularly restrictive: the decree requires the respect of a 10 cfu/100 ml limit value for EC for 80% of the samples with a poit max value of 100 cfu/100 ml; this vlue must be compared with the advised limit value of 5,000 cfu/100 ml in annex V of the Italian Decree n. 152/2006. Moreover, from the limits of THMs, chlorinated solvents and other DBPs, its is evident that if the EC limit must from one side be achieved increasing the dose (Cxt) of chemical agent for disinfection, from the other side there can be a negative effect on the value of by-products (Antonelli et al., 2006).

The Iitalian regulation appears particularly restrictive if compared with other international references for the parameters Escherichia coli: in Italy a limit value of 10 cfu/100 ml for WW reuse (irrigation) is required while the WHO requires a limit of 1,000 cfu/100 ml (WHO, 2006) for vegetables consumed without cooking.

2.3 The Veneto region framework on water protection

2.3.1 Regional goals for wastewater treatment

An important and decisive function to achieve the objectives of the Italian Decree n. 152/2006 on water protection is under the responsabilità of the Regions; they have the duty to organize and perform water monitoring (surface, groundwater, transitional, marine and coastal waters) for quality as well for quantity and the design and adoption of the *Water Protection Plan* (part of the *Riber Basin Management Plan*-RBMP).

The Regional Water Protection Plant was adoped by Veneto Region in December 2005 with DGRV n. 4453 of 29/12/2004. The Plan, after successive modifications and integrations, according to art. 121 of the Leg. Decree n. 152/2006 was finally approved by Veneto Region with DCR n. 107 of 5/11/2009 (Veneto Region, 2009). The Plan defines the interventions for protection and remediation of surface and ground-water bodies and the sustainable use of water resources; in particular it identifies the qualitative and quantitative protection measures to guarantee natural self-depuration of water bodies and their capacity to sustain large and diversified animal and vegetal communities. The plan gives rules for actual and future water uses according principles of conservation, saving and re-use; on the same time priority to drinking use is given and the minimum flow must be guaranteed to allow life in river bodies. During the preparatory studies for the Plan a specific investigastion on dangerous, priority and priority hazardous substances in surface water bodies had been performed (according Min. Decree n. 367/2003, now repelead). The Plan has been modified after the approval; the last indications have been given with the DGRV 15/05/2012 n. 842 (Veneto Region, 2012; modifications to Technical Regulation of the Plan).

Tab. 2.6 presents the discharge limits for public WWTPs as defined by the Italian Decree n. 152/2006 (third part, Annex V) and by the Regional Water Protection Plan (Veneto Region, DCR n. 107/2009 and previously by the PRRA *Piano Regionale di Risanamento delle Acque* (Regional Water bodies Remediation Plan) of 1989. In the same table considered values are highlighted in bold character. From the reported limit values the ones imposed by the Decree n. 152/2006 must always be respected (except for *Escherichia coli* if not fixed in the discharge permit); the regional limits of PTA from column A to column C are more restrictive (limits of column C are the most stringent); they are applied according to the plant potentiality (500-1.999 P.E.[1]; 2.000-9.999 P.E.; > 10.000 P.E. and to the specific area (mountain area, groundwater recharge area, coastal area etc.).

Restrictive values for total N and total P are established for discharges into *sensitive areas* (according to Directive 271/1991/EEC). For the specific case study I assume that the final discharge is in a sensitive water body and the WWTP has to comply with the limits of Decree n. 152/2006 (table 1 annex V for COD, BOD_5, TSS and table 2 annex V for total N and total P) and with the column C of the PTA above mentioned. For the application of the total N and total P limit values (Decree n. 152/2006 annex V part III, tab. 2) it must be observed that the plant potentiality is higher than 100.000 E.I. Moreover it is considered compulsory the limit for *Escherichia coli*.

[1] Population Equivalents.

Table 2.6 *– Discharge limits – Veneto regional Water Protection Plan and Italian Decree n. 152/2006 (IIIrd Part and Annex V)*

Parametro	D.Lgs. n. 152/2006 Tabb 1 e 2 all. 5	D.Lgs. n. 152/2006 Tab. 3 all. 5	Col. C PTA	Col. B PTA	Col. A PTA
COD (mg/L)	**125**	160	125	250	<380
BOD_5	**25**	40	25	80	<190
SST (mg/L)	**35**	80	35	150	200
N_{tot} (mg/L)	**15^**			55	55
P_{tot} (mg/L)	**2^**	10	10	15	20
NH_4 (mg/L)		15	**15**	30	30
N-NO_2 (mg/L)		0.6	**0.6**	2	2
N-NO_3 (mg/L)		20	**20**		
Escherichia C. (UFC/100mL)		**5000***			

^ Limit values for plant potentiality > 100.000 E.I.
* limit value suggested by Decree n. 152/2006 (annex 5).

2.3.2 The identification of the agglomerations in Veneto region

The Veneto Region has identified the agglomerations with DGRV n. 3856/2009 (Veneto Region, 2010). The methodological path proposed for the definition and characterization of agglomerations according to Directive 91/271/EEC and its application in Italy is presented below. The methodological proposal is divided into two consecutive stages:

- the first stage identifies the agglomerations from an exclusively geographical point of view; the final result is the map of current agglomerations in the Veneto region;
- the second stage relates to the current characterization of the agglomerations in terms of *generated, served* and *treated load*.

The total load of wastewaters generated within the agglomeration gives the measure of the dimension of the same agglomeration in technical terms and is the main criterion for determining collection and treatment requirements for wastewaters established by the Directive and the subsequent collection of data which must be reported to the European Commission concerning the quality of the waters. The definition of “agglomeration” according to Directive 91/271/EEC, establishes two basic principles around which the definition of agglomerations revolves:

- the concept of the “sufficient concentration” of population and/or of economic activities;
- the possibility of collection and transport of urban wastewaters.

For details of the procedure see Ostoich & Carcereri (2010). The dimension of an agglomeration (generated load) together with the typology (freshwater, estuary, coastal waters) and the characteristics of the receiving water body (sensitive area, normal area, etc.) determine the treatment requirements of Directive 91/271/EEC, summarized in **tab. 2.7**.

Most of the identified agglomerations (516) in Veneto region are of small dimensions (under 2,000 PE) but, as can be observed in **tab. 2.8**, more than 95% of the generated load in the agglomerations can be located in the more than 2,000 PE class; this percentage (%) drops to 88% if the contribution of the isolated nuclei and scattered houses is taken into consideration. Identification of agglomeration is a fundamental step to reduce duffuse pollution.

2.3.3 Regional regulations on disinfection systems for urban wastewater treatment

Since its first form the Veneto regional Water Protection Plan Plan in 2004 established that disinfection systems with the use of Chlorine and Chlorine compounds had to be dismitted and substituted with equivalent systems within 3 years from the approval. The text of 2009 (art. 23 of the Technical Annexed Regulation - NTA - of the Plan) and successive its successive delays established that the obligation for Chlorine dismission was effective since the 8th December 2012 (but practically since 8th March 2013 according to regional dispositions on the bathing season and the connected obligations for WWTPs' managers for the activation of disinfection).

Table 2.7 *– Summary of the Directive 91/271/EEC requirements according to the dimension of the agglomeration and the characteristics of the receiving water body*

Cases	Dimension of the agglomeration	Receiving water body	Treatment requirements	Discharge point requirements
Case A	< 2,000 PE (freshwaters and estuaries)	NA and SA + DBSA	Appropriate treatment	Following discharge, urban wastewaters allow receiving water bodies to fulfil the quality objectives and the dispositions of this and other directives
	< 10,000 PE (coastal waters)			
Case B	≥ 2,000 PE (freshwaters and estuaries)	NA and SA + DBSA	Secondary treatment	Annex IB – Table 1 Dir. 91/271/EEC
	≥ 10,000 AE (coastal waters)			
Case C	>10,000 AE	SA + DBSA	More stringent treatment	Annex IB – Table 1 e 2 Dir. 91/271/EEC

NA = normal area, SA = sensitive area, DBSA = draining basin in sensitive area

Table 2.8 *– Subdivision of agglomerations in the Veneto Region and generated civil load for potentiality class in PE*

PE	Number of agglomerations	Generated load (civil component)
More than 100,000	9	1,867,863
Between 10,000 and 100,000	77	2,549,206
Between 2,000 e 10,000	127	610,501
Under 2,000	516	205,777

Specifically art. 23 of the NTA of the Water Protection Plan establishes (line 1) that on all the treatment plants with potentiality higher tha 2000 PE the installation of a disinfection system is compulsory and its activation depends on the effective use (drinking water withdrawal, bathing waters, water intended for irrigation, etc.) of the receiving water body and is defined by the contro Authority (the Province in Veneto region). The activation of the disinfection system is compulsory for all the WWTPs higher than 10,000 PE and located at a distance not higher than 50 km from the sea mouth measured along the river. Except for specific cases that must be assessed as single situations, the indicative limit value for the microbiologic parameter *Escherichia coli* is 5,000 CFU/100 ml to be respected when disinfection has been established compulsory by the Control Authority.

Art. 23 of NTA with the modifications establishes that since 3 years from the date of publication of the approval act of the Water Protection Plan (the 8th December 2012) the use of Chlorine and Chlorine compounds for disinfection is forbidden.

2.4 The Europen approach on plants' environmental controls

This study has been developed considering that the new approach on environmental controls to achieve the environmental objectives (for water, air, soil, etc.) is not just the end-of-pipe control but requires an integrated system between the site/plant manager and Control Authority/ies.

WWTPs are able to guarantee a certain degree of microbiological pollution abatement satisfactory in many cases and in other not according to the effective use of the receiving water body. Moreover the issues of disinfection by-products must be analyzed in the framework of dangerous/priority/priority hazardous EC objectives (Directives 2000/60/EC and 2008/105/EC). The control of WWTPs can help to manage correctly plants with lower costs and lower impacts on water bodies.

2.4.1 The "command and control" approach an d the European change

On the 7th February, 1992 the Maastricht Treaty, established that the European Community promotes "a harmonious and balanced development of the economic activities ….". Through the 2nd Environmental Action Program (1977-1983) of the European Community the "command and control" principle was carried out to ensure environmental protection [8]. Since the '70s, in order to rectify and adapt the "command and control" principle, particular tools have been implemented, such as, self-certification, voluntary agreements, and voluntary adhesion to environmental normative systems (premium and voluntary systems).

The 5th Action Program tried to correct the conflicting relationship between economic development and environmental deterioration. With the Regulation n. 1836/1993 (EMAS) voluntary adhesion to certification tools began; the ISO 14000 standard norms and the regulation n. 761/2001/EC (EMAS II) soon followed. The approach to environmental controls on pressure sources was modified with the directive 96/61/EC on IPPC (updated with directive 2008/1/EC and then with directive 2010/75/EC). The voluntary certification, together with the IPPC approach, presents an important and significant change to the previous "command and control" approach. In this new legal framework, self-certification, environmental management systems of industrial settlements and the connected internal audits are laid out in detail.

2.4.2 The integrated approach in environmental controls

An important innovation in environmental controls comes from the Recommendation 2001/331/EC which focuses on the minimum criteria for environmental inspections. This Recommendation has not been wholly applied in Italy, as a national regulation has not yet been adopted. The Recommendation establishes that in order to carry out environmental inspections, the resource controls by way of tests and measures, held with the stipulated frequency and including self monitoring, must be guaranteed. Self-certification therefore assumes a more significant role than it has done in the past.

The Recommendation refers to all the industrial plants, enterprises, sites where authorization is necessary according to the existing environmental regulations (controlled plants). The Recommendation stipulates the objectives of the environmental inspections and these are: 1) verification of the plants' compliance to the environmental EC standards; 2) monitoring of environmental impacts of controlled plants. The Recommendation aims to guarantee the homogeneity and the efficacy of the environmental controls and establishes the following types of intervention: site visits; verification of the compliance of environmental quality standards; examination of the environmental audit declaration; examination of the monitoring activity performed by the plant managers; control of the plant and the adequacy of the environmental management in the site; control of the environmental registers (waste, discharges, plant maintenance, etc.) in the industrial site. The environmental inspections require (Ostoich et al., 2009; Ostoich et al., 2010):

A. *Documentary control*: assessment of the performed activities, control of authorization and environmental registers;
B. *Audit*: verification of the industrial site, control of the adequacy of technologies and the environmental management in the site;
C. *Industrial control*: monitoring the impact of the plant on the environment;
D. *Self-certification*: (audit) examination and verification of the monitoring activities performed directly by the plant managers.

The environmental inspection can be carried out using two approaches:

- the "old approach" characterized by a stiff sector and control system; different approaches in the control of emissions, authorization and limit values proposed for each matrix; in-field controls performed at the end of the productive cycle;
- "integrated approach" (IPPC approach): unity and adaptability of the system, with a unique authorization, procedure in order to avoid the transfer of pollution between the different matrices (environmental quality norms, plant management, Best Available Techniques (BAT), integrated control, self-certification verification (audit), preventive controls on the emission factors.

The IPPC directive establishes the same degree of attention in the administrative phase of the permit release as in the following phase of in-field verification and environmental conformity. The self-certification tools, introduced within the IPPC Directive, are required to fulfil the following aspects:

- the plant manager must possess self monitoring instruments and authorization limitations should contain the measures foreseen for controlling the emissions into the environment;
- Public Administration carries out the compliance control.

3. Area of study: the province of Venice

3.1 Geographycal aspects

3.1.1 Characteristics of the territory

The province of Venice is localized in the Veneto region in the Northern Italy. With a surface of **2,462.75 m^2** (Province of Venice, 2008) and a population of **832,326** inhabitants in 2005 (Province of Venice, 2008), the province is characterized with a plane with some areas under the sea level and with mechanical water drainage. The development, due to the existing communication infrastructures (trains, highways is approximately East-West (Province of Venice, 2008).

The largest urban centres are: the agglomerations of Venice-Mestre with 269.780 inhabitants, followed by Chioggia, San Donà di Piave, Mira, Mirano, Portogruaro and other minor centres. The boundaries of the province are with Padua, Treviso, Pordenone and Udine provinces. Moreover the province of Venice has the longest stretch in the Veneto region of the sea coast on the Northern Adriatic. Due to the presence of the sea and of the city of Venice, the touristic presences area very high with the highest values in the summer but also with high values in the rest of the year.

The territory of the Province of Venice presents some specifities tied to geographical and historical-urbanistic driving forces. This is a plain territory charcterized with the final stretches of medium-large rivers, originally ending into lagoons and coastal ponds, along the coastal line long nearly 100 km. In **fig. 3.1** the provincial and municipal boundaries are reported together with the main river networks. The grounds that constitute the territory derive from the alluvial depositions of the main rivers (Tagliamento, Livenza, Piave, Sile, Brenta and Adige); many soils derive from lagoons and ponds that have been recovered and there exist also the coastal dunes, old and recent (Provincia di Venezia, 2008; Bondesan *et al.*, 2004; Province of Venice, 2009). In **fig. 3.2** a synthetic map of the existing soil protection capacity according to the soil types and permeability is reported.

As described in the Provincial Territorial Coordination Plan adopted with Deliberation n. 104/2009 (Province of Venice, 2009) the historic geo-morphological structures which determined the settlement system in the province are:

- the lagoons (Venice, Caorle, Laguna del Mort Eraclea);
- the rivers (Tagliamento, Lemene, Livenza, Piave, Brenta, Adige);
- the irrigation networks and the irrigation basins (Tagliamento, Piave, Brenta, Adige);
- the central irrigation area (Brenta, Bacchiglione, Dese, Sile).

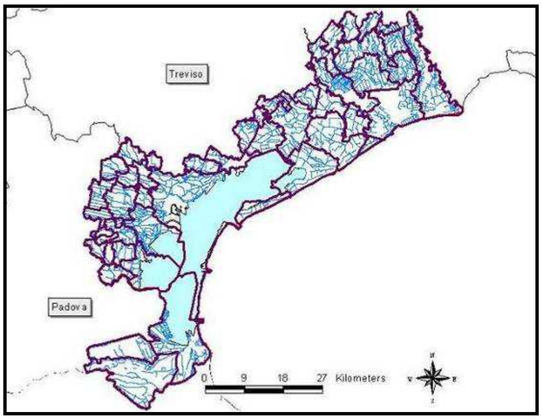
Unless constructions and houses, economic and touristic activities are spread significant agriculture resources are still present; on a total of nearly 2.5 millions of km^2 the natural and agricultural areas are 1.8 millions km^2: more than 88% (Province of Venice, 2009).

3.1.2 Climate

In the province of Venice, according to its morphology and to the sea presence, from tn climatic poit of view, two different zones can be identified: the coastal area and the plain. Unless the coastal area is charcterized with soft winds ("brezza") and wet winds which can be blown into the plain, it is not so influenced with the mitigatory effect of the sea, reaching low temperatures during winter season, in particular due to cold and dry winds from NE. The inner territory, instead, is characterized with a more continental climate with cold winters and hot summers: the main feature is the degree of humidity; during summer hot wet conitions are registerd while in winter foggy conditions can be observed.

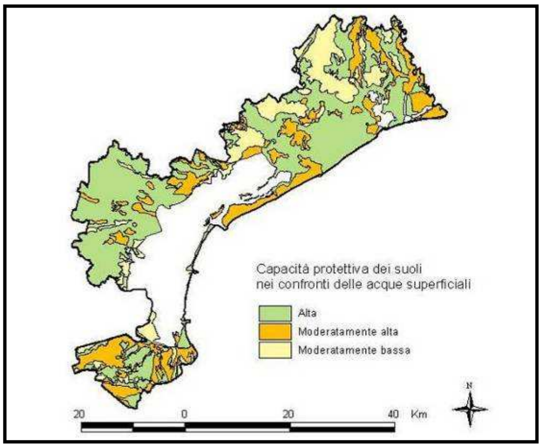
In **fig. 3.3** the mean monthly temperature during 2010 is reported; in **fig. 3.4** the total rain for each year in the priod 1975-2009 is reported; data have been produce by the Ente Zona Industriale of Porto Marghera and refer to the monitoring stations in Porto Marghera.

***Figure 3.1** – The province of Venice and hydrographic network*



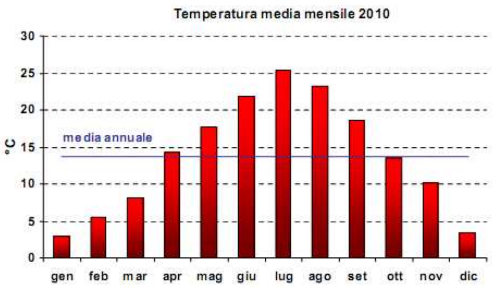
Source: ARPAV, 2011.

***Figure 3.2** – Soil protective capacity map*



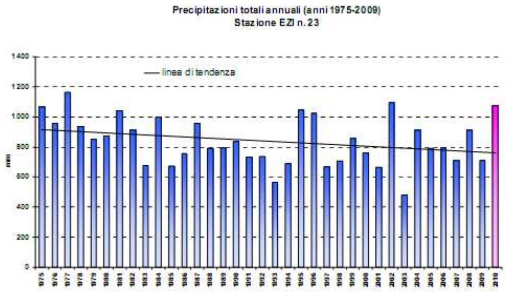
Source: ARPAV, 2011.

***Figure 3.3** – Mean temperatures of 2010 Porto Marghera*



(Source: Ente Zona Industriale, 2009)

***Figure 3.4** – Year total rain in the period 1975-2012 – Porto Marghera*



(Source : Ente Zona Industriale, 2009)

3.2 Demographic data

In **tab. 3.1** the population of the largest centres in the province of Venice is reported.

Table 3.1 *– Communes with > 20.000 inh. – Year 2005*

COMMUNE	N. INHABITANTS
VENEZIA (Venezia+Mestre)	269,780
CHIOGGIA	51,085
SAN DONÀ DI PIAVE	38,614
MIRA	37,723
MIRANO	26,236
PORTOGRUARO	24,992
SPINEA	24,798
JESOLO	23,766
MARTELLAGO	20,014

Source: Regione del Veneto, Sistema Informativo (Province of Venice 2008).

3.2.1 The city of Venice

In **tab. 3.2** and in **fig. 3.5** the demographic trend in the city of Venice is reported with detailed data for the hystorical centre, the inlands Murano, Burano, Cavallino, etc.) and the centre of Mestre-Marghera.

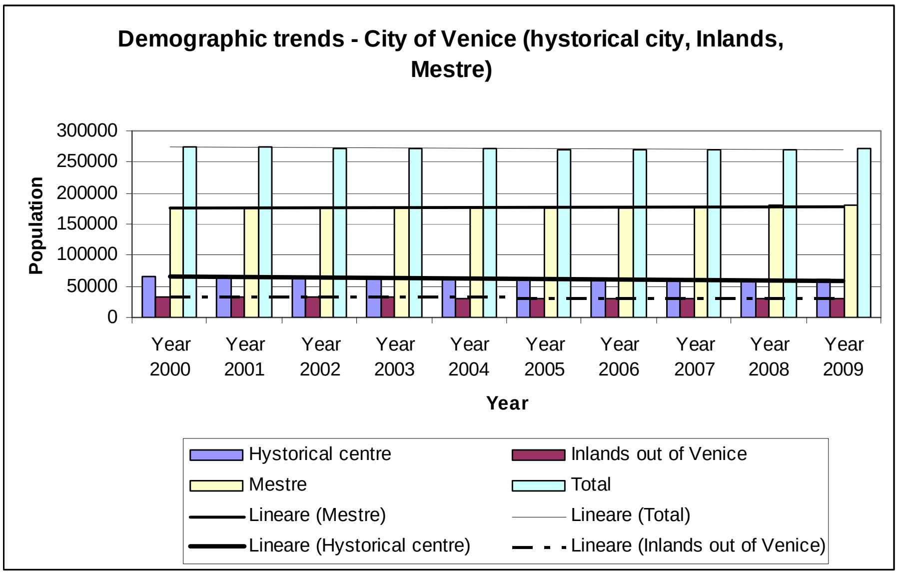
Table 3.2 *– Resident population in the commune of Venice in the period 2000-2009*

YEARS	Historical centre	Ilands (Veice hystorical centre)	Mestre-Marghera	Total
2000	66386	32451	176531	***275368***
2001	65695	32183	176290	***274168***
2002	64076	31767	174915	***270758***
2003	63947	31670	176046	***271663***
2004	63353	31393	176505	***271251***
2005	62296	31035	176449	***269780***
2006	61611	30702	176621	***268934***
2007	60755	30589	177649	***268993***
2008	60311	30415	179372	***270098***
2009	59942	30197	180662	***270801***

Source: Official web site of the city of Venice http://www.comune.venezia.it (accessed 2012).

From these data it is evident that between 2000 and 2009 the total population of the city of Venice has decreased of the **1,65 %**; in particular: while the population of the historical centre has reduced as well as the population of the inlands, the population of Mestre increased, but the total result is negative. In this situation no mathematical (arithmetic or geometric) projection is considered useful; for the dimensioning of the treatment plants' need the population of **270,800 people** (referred to the year 2009) is taken and considered constant for all the **30 years scenario**. To this population the tourist contribution must be added.

Figure 3.5 *– Resident population in the city of Venice in the period 2000-2009*



Source: Official web site of the city of Venice http://www.comune.venezia.it (accessed 2012).

3.2.2 Tourists' presence in the city of Venice

From data of the touristic presences in the commune of Venice, reported in **tab. 3.3** a decrease of the tourists' presences in the period 1998-2008 can be noticed. In the last column on the right in the table the mean touristic population on an annual base is considered.

Table 3.3 *– Tourists' presences in the city of Venice in the period 1998-2008 (source: city of Venice, 2011, official web site: www.comune.venezia.it)*

Years	Arrivals	Var. %	Presences	Var. %	days of mean presence	Additional Equivalent population
1998	3225449	3.63	11147646	-0.98	3.46	***105673.6***
1999	3193852	-0.98	11262458	1.03	3.53	***108921.9***
2000	2748614	-13.94	5909236	-47.53	2.15	***34807.83***
2001	2813878	2.37	6286780	6.39	2.23	***38409.64***
2002	2721656	-3.28	6033325	-4.03	2.22	***36695.84***
2003	2748733	0.99	6212412	2.97	2.26	***38465.89***
2004	3018609	9.82	6930073	11.55	2.3	***43668.95***
2005	3237623	7.26	7670433	10.68	2.37	***49805.28***
2006	3496160	7.99	8245154	7.49	2.36	***53311.13***
2007	3626853	3.74	8842874	7.25	2.44	***59114.01***
2008	**3433775**	**-5.32**	**8487539**	**-4.02**	**2.47**	***57436.22***
Mean 1998-2008						***56937***

For the period 1998-2008 it is evident that the tourists' trend is negative too.

3.2.3 The province of Venice

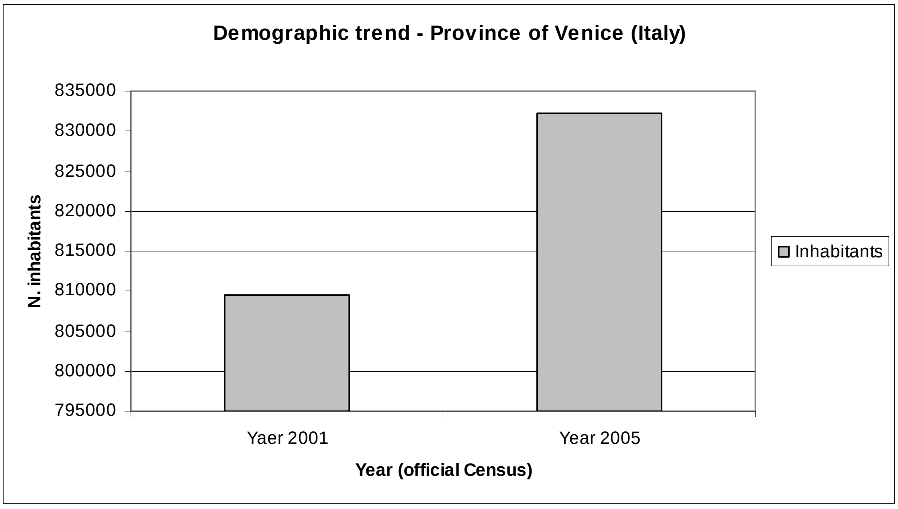
In **tab. 3.4** the list of the 44 communes of the province of Venice is reported. The comparison of 2001 and 2005 data for the population dynamic points out an increase of 2.8. In **fig. 3.6** the demographic trend from official data in the province of Venice is reported.

Table 3.4 *– List of the Communes of the province of Venice – 2010*

Annone Veneto	Campagna Lupia	Campolongo Maggiore
Camponogara	Caorle	Cavallino-Treporti
Cavarzere	Ceggia	Chioggia
Cinto Caomaggiore	Cona	Concordia Sagittaria
Dolo	Eraclea	Fiesso d'Artico
Fossalta di Piave	Fossalta di Portogruaro	Fossò
Gruaro	Jesolo	Marcon
Martellago	Meolo	Mira
Mirano	Musile di Piave	Noale
Noventa di Piave	Pianiga	Portogruaro
Pramaggiore	Quarto d'Altino	Salzano
San Donà di Piave	San Michele al Tagliamento	Santa Maria di Sala
Santo Stino di Livenza	Scorzè	Spinea
Stra	Teglio Veneto	Torre di Mosto
Venezia	Vigonovo	

Source: http://www.comuni-italiani.it/027/index.html

Figure 3.6 *– Population growth 2001-2005 in the province of Venice*



Source: Province of Venice, 2008.

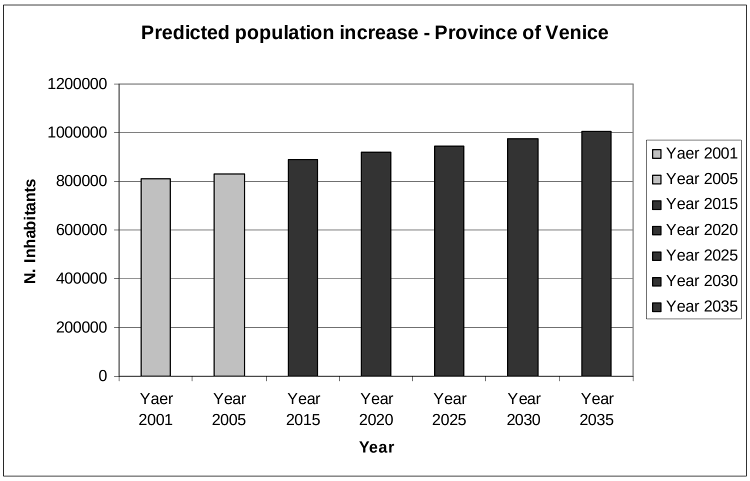
To determine the population growth projection, the population expected in a ten and thirty years scenario (P_{2015} and P_{2035}) can be calculated by arithmetic or by geometric increase methods. Considering the above figure an arithmetic increase can be accepted; therefore the growth per year for the period 1981-2001 (20 years base period) is:

Growth per year$_{2005-2001}$ = (P_{2005} – P_{2001})/4 years = 22740/4 = 5685 inhab. per year

Eq. 1: Population growth: arithmetic law

The population calculated with arithmetic population increase for 2005 and 2035 with reference to 2005 is reported in **fig. 3.7**.

Figure 3.7 *– Predicted population growth (arithmetic increase) for the province of Venice (source: ISTAT/Province of Venice, 2008)*



If we consider a geometric population increase on the same period 1981-2001:

$$\log_e P_{2005} - \log_e P_{2001} = r(2005–2001)$$

$$r = 0.027/4 = 0.0069$$

Eq. 2: Population growth: geometric law

The population calculated with geometric increase for 2015, 2025 and 2035 with reference to 2005 is:

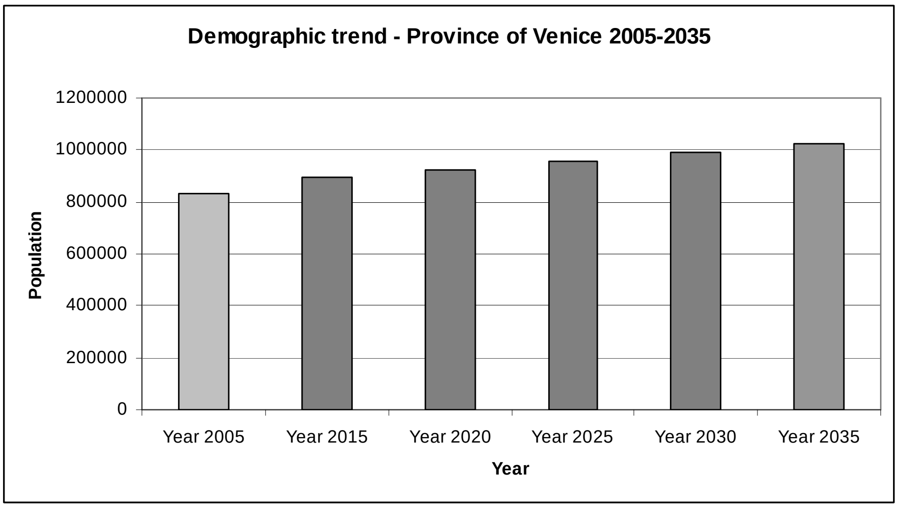
$$\mathbf{\log_e P_{2015}} = \log_e 832326+0.0069x10 = \mathbf{891,784\ inh.}$$

$$\mathbf{\log_e P_{2025}} = \log_e 832326+0.0069x20 = \mathbf{955,489\ inh.}$$

$$\mathbf{\log_e P_{2035}} = \log_e 832326+0.0069x30 = \mathbf{1,023,746\ inh.}$$

In **fig. 3.8** the geometric population growth for the province of Venice is reported. If we consider the population trend of the city of Venice (negative trend), we can consider - as a worst case - a constant population; therefore the 2035 population of the province of Venice without the city of Venice, with the geometric model, is: 1,023,746-327,801 = **695,945 inhabitants**.

***Figure 3.8** – Predicted population growth (geometric increase) for the province of Venice (source: ISTAT/Province of Venice, 2008)*



3.3 River basins in the province of Venice

3.3.1 River basins identification

The river basins that have been identified in the province of Venice by the Water Protection Plan (Veneto Rgion, 2009) are (ARPAV, 2011): **Tagliamento; Lemene; Livenza; Plain between Livenza and Piave; Piave; Sile; Laguna di Venezia; Brenta-Bacchiglione-Fratta-Gorzone; Adige.**

Moreover there exists a very dense secondary hydric network, with very small rivers, channels, irrigation drainages, etc. with branches all over the province. In the province the surface water bodies monitoring is performed by ARPAV and is referred to the following water bodies (ARPAV, 2011):

- **the rivers**: Adige, Sile, Brenta, Tagliamento, Reghena, Lemene, Gorzone, Dese, Marzenego, Zero, Livenza, Loncon e Piave;
- **the channels**: Fosson, Cuori, Morto, Nuovissimo, Maranghetto, Taglio di Mirano, Vela, Brian;
- **the drainages**: Fiumazzo, Pionca, Tergolino, Lusore, Ruviego.

The main river basins in the province of Venice are repored in **fig. 3.9**.

3.3.2 The river monitoring network for surface waters

The surface waters' monitoring quality network is managed by ARPA; monitoring are performer according to an annual plan defined with the Veneto Region. In year 2010 the surface water monitoring network had n. 269 points for the whole region with n. 48 points in the province of Venice and monitored by the ARPAV Provincial Department of Venice (**fig. 3.10**); stations with double indications are monitored for the Extended Biotic Indecx too.

Figure 3.9 *– River basins in the Province of Venice (ARPAV, 2011)*

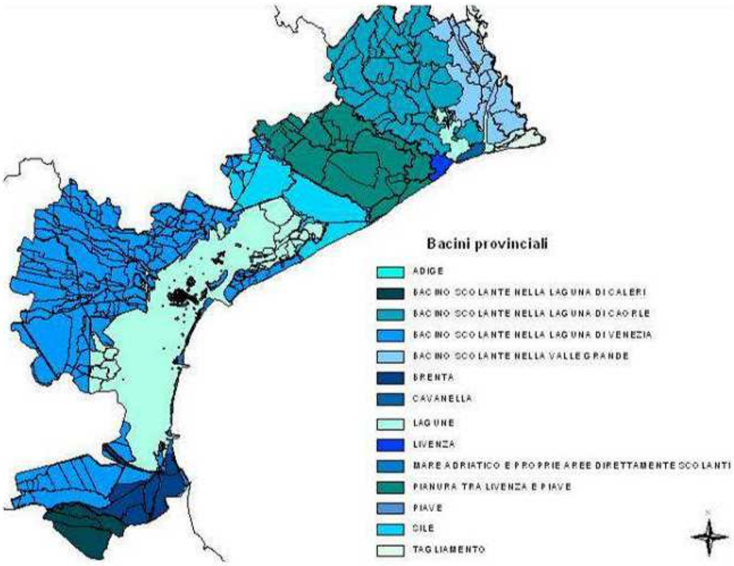
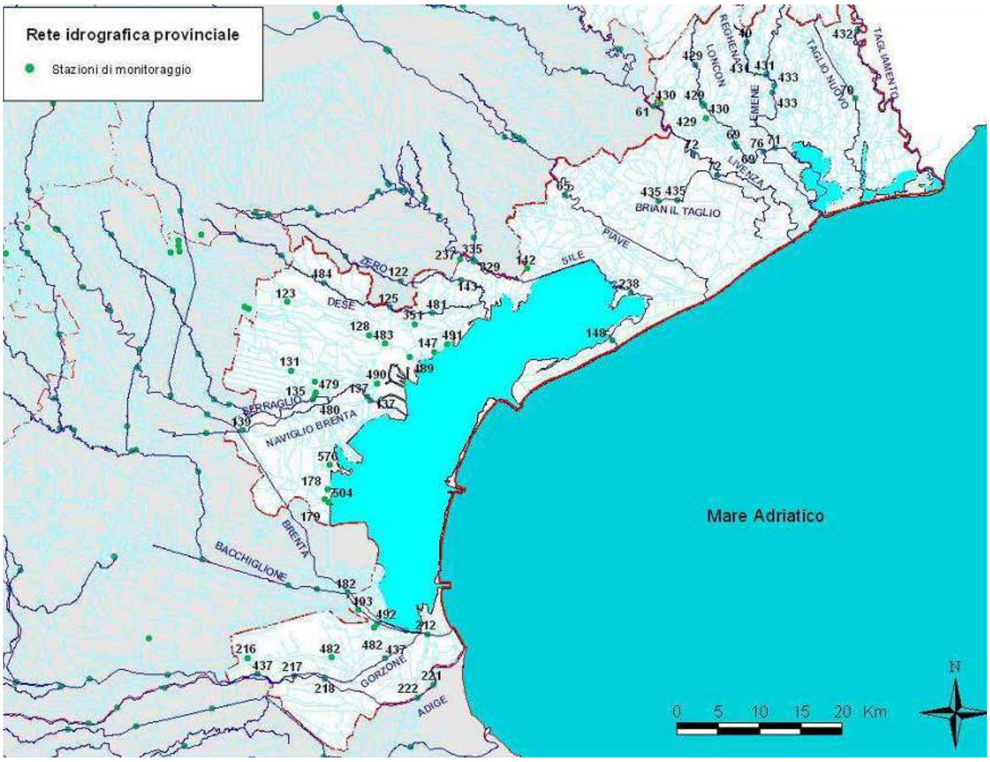


Figure 3.10 *– Surface water monitoring network in the Province of Venice (ARPAV, 2011)*



3.4 Coastal area

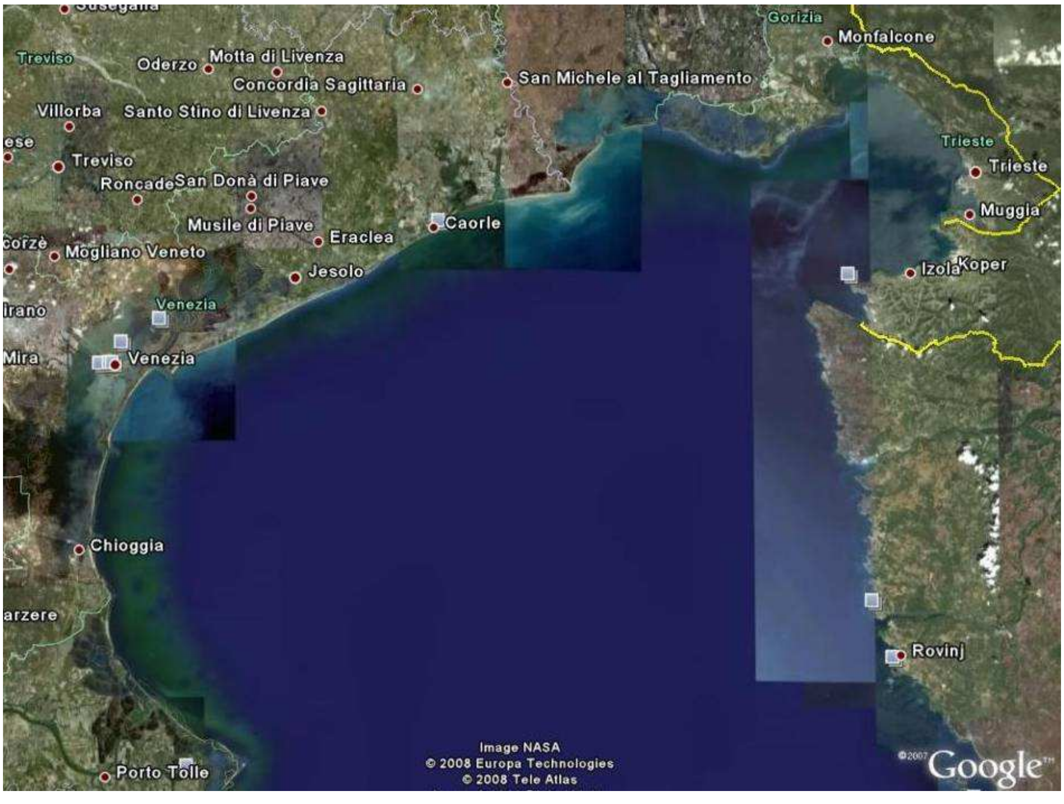
3.4.1 The characteristics of the Northern Adriatic Sea and water circulation

The Province of Venice is part of the North Adriati coastal area. The Northern Adriatic sea is the northernmost region of the Mediterranean Sea and it is considered a very sensitive area due the scarce water circulation, the shallow waters and the heavy organic, euthrophication substances and other pollutants discharged through the main rivers like Po, Adige, Brenta-Bacchiglione, Sile, Piave, Tagliamento and Isonzo.

The northern and western coasts of the northern Adriatic are generally sandy, and the nearby land is flat (alluvional plains). In contrast, the eastern coast is rugged and mountainous, including inlets, bays and coves. The dominant winds are the bora, a northeasterly cold, dry and gusty wind, mostly prevailing in winter, and the sirocco, a warm and humid wind, blowing from Southeast along the axis of the Adriatic basin. The hydrodynamic circulation reflects the typical scheme of the North Adriatic Sea, with a cyclonic circulation influenced by the dalmatian current, ascending/rising along the eastern coast of the basin, and by the descending current along the western coast. The current dynamic is strongly affected by the thermic seasonal variations, by the contributions of river and lagoon waters, combined with the action of tide and wind forcings (Mosetti, 1972). Tidal currents vary between 2 and 10 cm/s and are amplified up to 10-20 cm/s by the action of the wind.

The coastal side of the Veneto Region has a total length of about 150 km mainly localized in the province of Venice (withe the comune of San Michele al Tagliamento, Caorle, Eraclea, Jesolo, Cavallino-Treporti, Venezia e Chioggia) and for a small stretch in the Province of Rovigo (with the comune of Rosolina, Porto Viro e Porto Tolle). The coast is characterized morphologically with sandy beaches northern and southern from the lagoon of Venice. In **fig. 3.11** the considered area of the Northern Adriatic sea is represented.

Figure 3.11 *– Northern Adriatic sea (source: Google maps, 2012)*



3.4.2 Monitoring network for waters in the province of Venice: period 2000-2012

In **tab. 3.5** and in **fig. 3.12** are reported the monitoring points for surface internal waters, the monitoring points for bathing waters, the monitoring points for marine waters and the public WWTPs influencing directly the coastal water quality too, considered for this study in the territory of the Province of Venice and subdivided according to the identified homogeneous stretches according to the bathing *water profiles* (Directive 2006/7/EC). The monitoring stations and the used data refer to the period 2000-2006 (see integrated anlysis in **Chapt. 10**); water monitoring and discharge control data are performed by the Veneto Regional Environmental Prevention and Protection Agency (ARPAV).

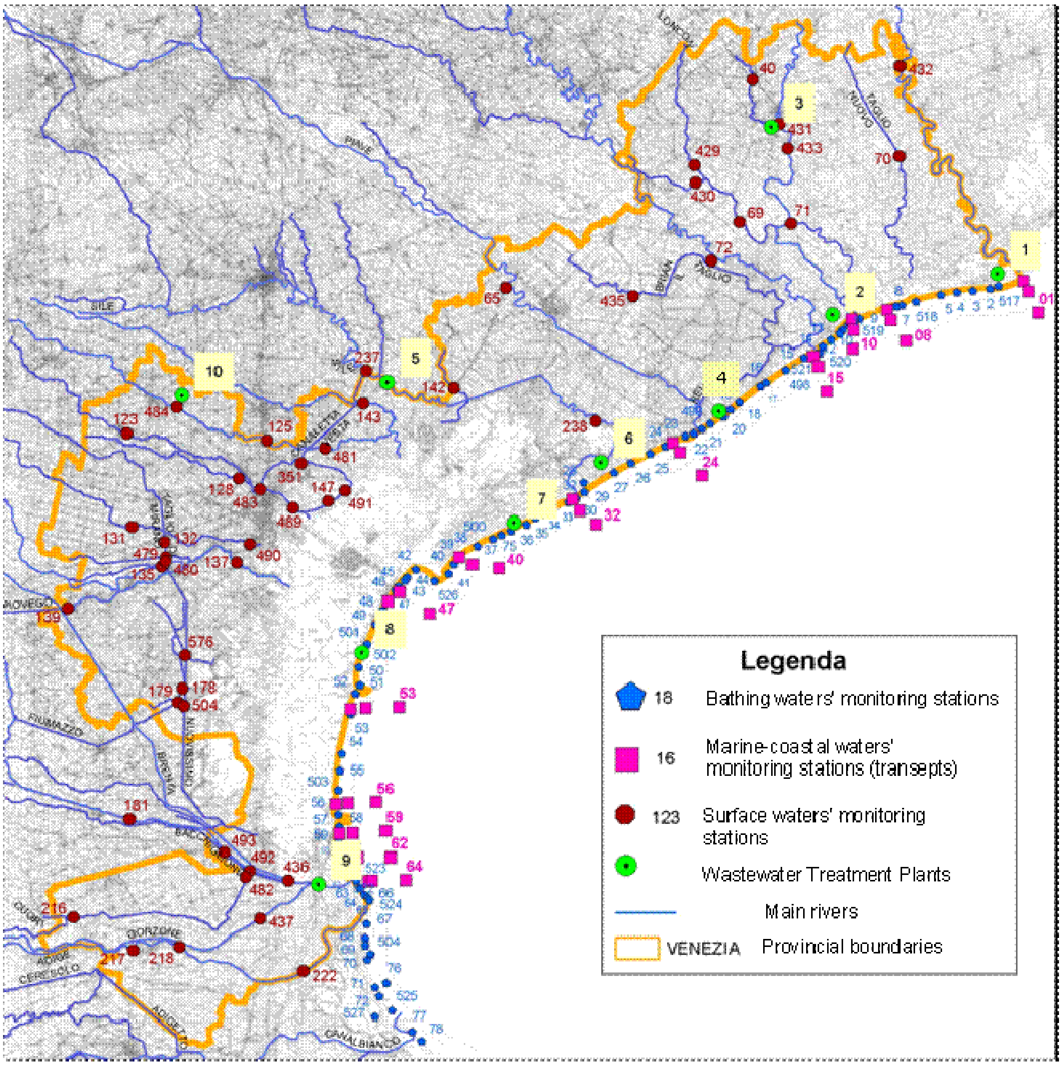
In **tab. 3.5** in bold type are highlighted the sea monitoring points which remained in 2004 (since this year the total number was reduced and the stations' codes were changed). In the same table the coast is subdivided into homogeneous stretches according to the main rivers flowing into the Adriatic sea; in two stretches (Lido and Cavallino) there are no rivers; the last stretch n. VIII is subdivided into two more parts for convenience of study, as there are two important rivers influencing the water quality on the coast with their mouths very close one to the other (Brenta and Adige rivers). The sea water monitoring network is constituted with transepts; only the stations nearest to the coast in each transept, were chosen in this study. The monitoring stations for bathing waters were integrated in years 2005 and 2006 with two stations n. 528 and 529 in the VIIIth stretch. The proposed stretches define the *water profile* requested by Directive 2006/7/EC (Ostoich et al., 2010).

Table 3.5 *– Subdivision of the Venice Province coast in stretches and correspondence of monitoring stations for surface, coastal waters (from 500 m from the beach, active till year 2001) to WWTPs (Source: Veneto Region-ARPAV). For the localization of monitoring points and WWTPs see **fig. 3.12**)*

Stretch	Reference river	Fresh waters monitoring stations	WWTP (provincial code and name)	Bathing monitoring stations	Marine-coastal monitoring stations*
I	Tagliamento river	432	1^	517, 002, 003, 004, 005, 518, 007	101, 108 (**10080** since year 2004)
II	Lemene river	71, 433	3^^	008, 009, 519, 010, 011, 012	110
III	Livenza river	72	2^	013,014,520, 521, 015, 498, 016, 017	115
IV	Piave river	65	4^	018, 019, 020, 499, 021, 022, 023, 024, 025, 026	124 (**10240** since year 2004)
V	Sile river, Sile-old Piave river	237, 238	5^^, 6^	027, 028, 029, 030, 032, 033, 034, 035, 036, 075, 037, 500	132
VI	Venice Lagoon San Nicolò mouth (no river)		7^	038, 039, 040, 041, 526, 042, 043, 044, 045, 046, 047, 048, 049	140 (**10400** since year 2004), 147
VII	Venice Lagoon Malamocco mouth (no river)		8^	501, 502, 050, 051, 052, 053, 054, 055	153 (**10530** since year 2004)
VIII	**A** Brenta mouth	436, 437	9^^	503, 056, 057, 058, 059, 060, 061, 522, 523, 063, 064, 065, 066, 524, **528, 529**	156 (**10560** since year 2004), 159, 162, 164 (**10640** since year 2004)
	B Adige mouth	217, 222			

* In the figure 1 with the last two digits are indicated the transepts of the monitoring stations of marine-coastal waters. The monitoring stations with only three digits were active only till 2001.
^ Disinfection activated only in the bathing season 1st April-30th September.
^^ Disinfection activated all over the year.

Figure 3.12 *– Localization of monitoring stations of surface internal waters, bathing waters' monitoring stations, marine-coastal waters' monitoring stations (from 500 m from the coast – stations working till year 2001). Study for the period 2000-2006.*



With reference to **fig. 3.12** it must be highlighted that:

- the reported monitoring networks and WWTPs have been used for the integrated anlysis on the period 2000-2006 (see **Chapt. 10**);
- the river monitoring stations are still the same; in the last two years, according to the enforcment of Directive 2000/60/EC, changes on monitoring parameters' list and sampling frequencies have been done according to the new surface waters monitoring program;
- bathing monitoring stations have just been integrated in mid 2000s with 2 new stations (highlighted in the figure); in this case a significant change in parameters' set has been performed with the enforcemente od Directive 2006/7/EC since the bathing season 2010 (since April 2014);
- for bathing waters since 2010 the monitoring of *Escherichia coli*, together with *Intestinal enterococci*, has started while in till 2009 it was not monitored in the bathing waters (but it was monitored since 2000 in rivers' monitoring stations and in the WWTPs' discharges

when required) while *Total coliforms*, *Faecal coliforms* and *Faecal Streptococci* were monitored;

- the reported WWTPs are all plants ≥ 10,000 PE with the exception of Portogruaro which has a lower potentiality (7,500 PE); their choice has been made on the historical knowledge of effective or influence of their discharges on the quality of the corresponding bathing waters on the coastal belt (for example Portogruaro is not only encompassed in this list but also the disinfection of its discharge must be active compulsory all over the year according to the discharge authorization of the Province of Venice);
- in the map are not considered the plants of Musile di Piave, San Donà di Piave and Cavarzere;
- the Musile di Piave WWTP discharges directly into the Piave river but its activation was made after the integrated analysis on the period 2000-2006;
- the San Donà di Piave WWTP discharges into the surface irrigation network (Tabina cannel) and therefore has not a direct access to the sea with the consequent impact on the coast); this plant has been considered as ASI provided IN/OUT disinfection data for microbiological abatement and a specific experimentatio of chlorine by-products has been conducted in the last years by the ASI laboratory;
- the CavarzereWWTP has not been considered in the study 2000-2006 as its potentiality was < 10,000 in this period, then it was restyled; this plant is still not considered in the present study as it discharges in the irrigation network with not direct influence on the coastal belt.

In **fig. 3.13** the last asset of bathing waters monitoring network is represented.

Figure 3.13 *– Bathing waters monitoring network 2010-2012*

4. Microbiological pollution and wastewater disinfection systems

4.1. Microbiological pollution

4.1.1 Importance of microbiological pollution

The protection and safeguarding of the water quality is one of the most important objectives because of the implications for the environment and particularly for the human health in areas where there could be direct or indirect contact (ingestion, aerosol/liquid inhalation, dermal contact through wounds in the skin, etc.) with pathogens. This is enhanced in coastal areas (Cabelli, 1983), characterized by high urbanization, concentrated recreational facilities and connected sources of faecal pollution from both human and animal wastes. On the other hand the same localities are uniquely productive, valuable and fragile environments. The increasing pressure on coastal areas due to urbanization, chemical and microbiological pollution is a tendency all over the world (Glasoe and Christy, 2004). Untreated or pourly treated wastewaters are a vehicle of trasmission of enteric pathogens to humans; pathogens like chemicals are reduced by WWTPs (Darakas et al., 2009).

To protect sea resources from enteric bacteria pollution and eutrophication, coming from discharges of the rivers and the treatment plants, management and safeguarding practices must be devised based on a sound knowledge of the water contamination and of the fate of pollutants in the environment. The microbial species and the relative residual concentrations found in the effluents of wastewater treatment plants (WWTPs) depend on the abatement capacity and on the final disinfection treatment systems applied to wastewaters before discharge into water bodies; the nutrient levels in the effluents depend on the presence and on its efficacy of an appropriate (tertiary) treatment step in the WWTPs.

Most waterborne pathogens, originated from human and animal faeces, include a wide variety of bacteria and viruses (Rose et al.., 1999). Wastewaters are a source of pathogens and not pathogens diffusion into the environment (Sobsey, 1989; Donnison & Ross, 1999); they are of human and animal origin (Glasoe and Christy, 2004) and they can be point or not-point sources (O'Keefe et al., 2005). The presence of specific pathogens in wastewaters reflects the underlying health of the human or animal population which have generated the wastewaters (Donnison & Ross, 1999). The standards of water microbiological quality establish the bacterial concentrations that should not be exceeded to protect human health from pathogens (Fiksdal et al., 1997).

Urbanization generates increasing loads of faecal wastes discharged into natural waters resources, due to the land degradation and the faecal contamination (Glasoe & Christy, 2004): in many cases the extent of pollution causes an increase in number of faecal indicator organisms to levels which exceed recommended limits for water to be used by humans for purposes such as drinking, recreation or irrigation of crops eaten raw (Griesel & Jagals, 2002).

4.1.2 Indices of microbiological pollution

The presence of specific pathogens in wastewaters reflects the underlying health of the human or animal population contributing to the wastewater (Donnison & Ross, 1999). *Faecal Coliform* bacteria are widely used as indicator organisms to signal the possible presence of faeces and pathogen organisms (Glasoe & Christy, 2004). Instead there is evidence that *Faecal Coliforms* do not reliably predict the occurrence and survival of enteric virus (Noble & Fuhrman, 2001; Noble et al., 2003). Faecal Indicator Bacteria (FIB) are commonly used to identify and assess risk from pathogens (Darakas et al., 2008).

Faecal coliform bacteria are widely used as indicator organisms to signal the possible presence of faeces and pathogen organisms (Glasoe & Christy, 2004). Instead there is evidence that *faecal coliforms* do not reliably predict the occurrence and survival of enteric viruses (Noble & Fuhrman, 2001; Noble et al., 2003). Zann and Sutton (1995) suggest as indicator bacteria of faecal pollution the following: *faecal coliforms* (FC) and/or *faecal streptococci* (FS). Bacterial groups of FC and FS correlate reasonably well with some of the bacterial pathogens such as Salmonellas (Moriñingo et al., 1992; Pommepuy et al., 1992).

Total coliforms (TC), FC, FS, *escherichia coli* (EC) and Enterococci are used as bacterial indicators for water quality monitoring and health assessment as they are much easier and less costly to detect and enumerate than the pathoges themselves (Meays et al., 2004). The different microbial species and the relative concentrations are tied to the local epidemiological situations and to the levels of abatement to which the raw waters (sewages) are subjected before their inflow in the receiving water bodies.

Pathogens detection is difficult because bacteria and viruses can be associated with particulate material and there are problems of die-off prediction (Zann & Sutton, 1995). The FC as indictor of enteric bacterial and viral pathogens is not proven, but their use survives because lacking of a better alternative (Craig et al., 2002). The different microbial species and their relative concentrations are tied to the local epidemiological situations and to the amounts of pollutants abatement achieved on wastewaters introduced into the receiving water bodies.

Cabelli *et al.* (1979) proposed *Enterococci* as a standard faecal indicator for marine waters. On the problem of the choice of faecal indicators Zann and Sutton (1995) point out that: a) traditional bacterial indicators do not reliably reflect the presence or absence of enteric pathogens in seawaters or sediments, but Enteric viruses should be regarded as indicators of faecal contamination, since they are probably more closely related to be conservative agents of infections acquired by users of recreational waters rather than *Faecal coliforms* or Enterococci; b) the discharge of not disinfected raw sewage, primary/secondary sewage effluents into bathing waters is expected to represent a local health risk without further dilution/die-off of at least 1000-fold, as can occur through deepwater sea outfall (for example Grohmann *et al.* (1993) observed a high incidence of presence for enteric viruses in Sydney on beach waters prior to commissioning three deepwater ocean outfalls).

Escherichia coli is recommended as indicator of faecal contamination in fresh waters (EC-WFD, 2000; Donnison et al., 1999). Obiri-Danso and Jones (1999) suggest to use as faecal indicators of *Faecal Coliforms* and *Faecal Streptococci*. Craig *et al.* (2003) have pointed out in an experimental study that the ability of the *Escherichia coli* to persist in the coastal environment is significantly less than Enterococcus and Coliphage, suggesting limited effectiveness for its use as an indicator of faecal contamination. Other studies suggest as faecal indicators FC and FS for water quality and for pathogens *Campylobacter* and Salmonella (Obiri-Danso and Jones, 1999).

The parameter EC is proposed as there is a high probable correlation between its occurrence and that of a pathogen. Sinton *et al.* (1993) suggest the FS as faecal pollution indicator. For the assessment of faecal contamination from sewage treatment facilities and for diffuse pollution *Escherichia coli* and Enterococci are strongly suggested (Rose et al., 1993).

With reference to disinfection systems, Zann & Sutton (1995) point out that it is important to note that though 99.9% reduction in pathogens may at first appear satisfactory, this is often not enough. In fact the discharge of not disinfected raw or primary/secondary sewage effluents into bathing waters is expected to represent a local health risk without further dilution/die-off of at least 1000-fold, as can occur through deepwater sea outfall. Grohmann *et al.* (1993) observed a high incidence of positive cases for enteric viruses in Sydney on beach waters prior to commissioning three deepwater ocean outfalls). EC is recommended as indicator of faecal contamination in fresh waters (Donnison & Ross, 1999; New Zealand Ministry for the Environment, 2002). Sinton *et al.* (1993) suggest the FS as faecal pollution indicator. Other studies suggested as faecal indicators FC and FS for water quality and for pathogens *Campylobacter* and *Salmonella* presence (Obiri-Danso & Jones, 1999). EC and Enterococci are indicated (EC, 2006) for the assessment of faecal contamination from sewage treatment facilities and for diffuse pollution.

In literature and EC directives (see WFD 2000/60/EC, bathing directive 2006/7/EC and shellfish harvesting directive 2006/113/EC) the consolidated FIB are *Escherichia coli* and enterococci. The reported FIB cannot distinguish between the potential sources of microbiological contamination; at research level a microbial source tracking (MST) toolbox including FIB has been developed to differentiate between human, bovine and porcine faecal contamination (Jeanneau et al., 2012). Experimentation has been performed for the quantification of the total etherotrophic microbial concentration using cytometric methods (Antonelli et al., 2006). As can be seen from previous references from scientific literature on the topic, there is not single indication of which parameter or parameters should be used as the best indicators of faecal pollution.

4.1.3 Directive 2006/7/EC: microbiological indices

The new European Directive 2006/7/EC on management of bathing water quality with comparison of the previous scheme drastically reduces the number of parameters from the previous 19 to 2 key microbiological parameters. This directive aims to establish more reliable microbiological indicators.

The policy on bathing waters must satisfy the general objective of "*good ecological status*" expressed in the Directive 2000/60/EC *Water Framework Directive* to be achieved with the river basin management plans and programmes of measures and must follow a new approach based on an integrated management of water quality. The two faecal indicator parameters retained in the Directive 2006/7/EC are *Intestinal enterococci* (IE) and *Escherichia coli* (EC), providing the best match between faecal pollution and health impacts in recreational waters according to available scientific evidence provided by epidemiological studies.

4.2 Reduction of faecal indicator bacteria in WWTPs and water bodies

4.2.1 WWTP abatement

Primary and secondary treatment unit processes are able alone to abate a significant fraction of the microbiological load of wastewaters (at least two logs; Ragazzo et al. 2007; 2011); normally this is not enough to satisfy the limit values for microbiological parameters for the receiving water body. For this reason in many plants the final disinfection unit after the secondary sedimentation is realized in order to respect legal limit values. Many disinfection systems exist: based on chemical substances (chlorine and compounds, peracetic acid, ozone, performic acid, etc.) or on physical processe (UV); microfiltration and ultrafiltration are able too to remove microbiological load. A good chemical disinfectant should:

- guarantee efficacy at low/very low doses with small contact time and fit for a large spectrum of microorganisms;
- do not produce toxic by-products;
- be easily dosable and not produce risks for operators;
- have a limited cost.

No disinfection system is good for all these aspects and conditions; each has some advantages and disadvantages. The surviving of enteric bacteria and in general pathogens depends on many environmental factors; in particular pH, salinity, temperature, UV rays etc. can determine the quick reduction of the concentration of these organisms. Very high doses of both PAA and UV irradiation are needed to remove bacteriophages and viruses (Lazarova et al, 2008).

4.2.2 Faecal indicator bacteria natural decay

All the microbiological organisms, pathogens and not pathogens present in a WWTP with suspended biomass, are subject to the natural process of decay due to time, temperature, pH variations/ranges, light, salinity, etc. We are interested in particular in the behaviour of enteric bacteria kinet survival. Among enteric bacteria the faecal indicator bacteria are used to measure the sanitary quality of water for reacreational, industrial, agricultural and water supply purposes (Darakas. 2002). In general faecal bacteria in natural environment are subject to a quick decay as they are adapted to live in the gastrointestinal tract.

Darakas in the study of 2002 assumes that pathogens similar to faecal indicator bacteria die at the same rate as faecal indicator bacteria. Among the factors that affect survival of enteric bacteria in natural water, temperature is of main importance. Moreover faecal indicator bacteria survive from few hours up to several days in surface waters, but may survive for days or months in lake sediments where they may protected from sunlight and predators (Darakas, 2002). We normally assume that if the level of faecal bacteria is high the likelihood of the pathogens' presence can be high too.

In planning the realization of WWTPs an important factor to be considered by engineers is the distance from points/water bodies for which the microbiological level can be important according to its use. The first reduction factor is the dilution of the discharge into the receiving water body (Darakas et al., 2009).

According to literature for faecal microorganisms the survival factors are physical, cemical, biochemical and biological; in particular we can remember: dilution, temperature, solar radiation, time, pH, osmotic pressure, salinity, nutrient starvation, plankton presence, bacteriophges presence. It must be observed that while the natural environment favours the decay of enteri bacteria for the cited factors, in environmments rich in foods (estuaries and sediment) there can be on contrary an increase of eneteric bacteria. Salinity contributes to a rapid destruction of bacteria due to the osmotic effect; dilution of enteric bacteria in the receiving water body can reduce significantly the connected health risks in case of effective exposure Darakas et al., 2009). Dilution can be not effective in case of the presence of available food (Hadjianghelou, Darkas, 2000). Darakas et al. (2009) have proved that the dilution of WW into seawater reduces the microorganisms population in the wastewater at a rate faster than that of the secondary biological treatment in WWTPs.

To determine enteric bacteria decay the general kinetics equation suggested by Darkas (2002) is:

$$C = C_0 e^{-kt}$$

Eq. 3: bacteria decay kinetics

where:

C = bacteria concentration at time t;

C_0 = bacteria concentration at time t=0;

T = time;

K = decay rate.

In the theoretical kinetics curve substantially three phases can be identified: *growth* (logarithimic), *stationary* (or *maintenance*) and *decay* phase. For environmental engineering planning the knowledge of the duration of the stationary phase, the transition period and the value of the constant k (decay rate) should be known. The same author observes that the disadvantage of this law is that the decay constant is empirical and for its estimation it requires expensive field investigations. Darakas (2002) suggests instead of the **eq. 3** a more detailed equation as folows:

$$\begin{cases} C = C_0 & \text{for } t \le t_E \\ \log \dfrac{C}{C_0} = -\left[\log \dfrac{t+1}{t_E + 1} \right]^5 & \text{for } t > t_E \end{cases}$$

Eq. 4: bacteria decay kinetics exponential curve

where:

C = *E. coli* concentration for $t > t_E$;

C_0 = *E. coli* concentration for $t \le t_E$;

t = time;

t_E = duration of the maintenance phase.

Eq. 4 can be applicable for a wider range of temperatures between 4 and 37 °C (Darakas, 2002). If we assume a first order kinet decay (simplified approach) it is possible from half-life time assess in how much time after the release in the water body the concentration is set lower than std acceptable for bathing waters according the river flow and time necessary to reach the river mouth.

$$\begin{cases} v = kC \\ C = C_0 / 2 \end{cases} \text{when } t=t_{1/2}$$

Eq. 5: first order decay law

where:

C = *E. coli* concentration at time t;

C_0 = *E. coli* concentration at time t=0;

t = time.

According to Darakas et al. (2009) in WWTPs located close to the sea the dilution of WW in seawater could reduce enteric bacteria and consequently the dose of chemical disinfectants could be reduced. Practically we can assume a 2 day decays in fresh water and 1 day decay in salt water (Cane & Moore, 1986, Scroccaro et al, 2010).

4.3 Tertiary wastewater treatments: disinfection systems

4.3.1 Introuction

Disinfection of secondary treated effluents is necessary to ensure microbiological emission limits are respected, especially when the receiving water body is used also for drinking water production, fish farming or bathing. The principal purpose of the wastewater disinfection treatment has always been the pathogens in-activation, nevertheless with the discovery of disinfection byproducts (DBP) and the potential direct toxicity of chemical disinfectants, public health and environmental protection have become goals much more complicated to reach. For this reason finding a disinfection system able to reduce the microbiological risk of the treated effluent preserving its chemical quality, has been one of the main researching goal in this field over many years. The increasing interest for wastewater reuse moreover, particularly for agricultural practices, and for bathing zones protection, has made this scientific topic more and more important (Ragazzo et al., 2007).

Chlorine and sodium hypochlorite are the most widespread disinfectants. Italian law bans chlorine as a disinfectant and antifouling agent in particularly sensitive areas such as the Venice lagoon and, since December 2012, in the whole of the Veneto region (Northern Italy) where alternative disinfectants must be used (Veneto Region, 2009). Alternative disinfection system to chlorine and its compounds are: ozone (O_3), peracetic acid (PAA), Performic acid (PFA), UV rays and filtration (membrane systems).

Although ozone is a very effective disinfectant, because of its high tendency to react with reduced compounds and the high costs and risks involved in its production and use, it becomes a suitable system mainly in big installations or in industrial effluents treatment. The same occurs for UV disinfection system that, despite its few or any impact in water quality, remains a too sophisticated and expensive technology to apply in all the conditions and installations. Furthermore its reduced effectiveness at low doses often requires its combination with another chemical disinfectant. So the chemical compounds like chlorine hypochlorite and PAA remain the wastewater disinfection system easier to apply. Chlorination however, because of its by-products potential formation, is becoming less and less used and in some cases (Venice, Italy) even forbidden. So at the moment PAA represent the used realistic alternative to chlorine disinfection.

Disinfection is a refining process therefore is located downward from secondary sedimentation and filtration (if present). The applied processes for wastewater disinfection can be divided into chemical and physical processes. Among physical lethods there are: filtration (Membrane Filtration and Ultra Filtration), UV rays and sterilization. Chemical methods are generally the most used; the most diffused oxidizing agents are: chlorine and its compunds (sodium hypochlorite, chlorine dioxide); peracetic acid; ozone. Recently the sperimentation of Performic Acid (PFA) has begun. In **tab. 4.1** the oxidation potentials of some oxidizing agents are reported.

Table 4.1 *– Oxydizing potentials*

Oxydizing agent	Oxydizing agent (V)
Fluoride (*)	3.0
Hydroxyl radical (•OH)	2.8
Ozone (O_3)	2.1
Hydrogen peroxyde (H_2O_2) (**)	1.8
Potassium permangan ($KMnO_4$)	1.7
Chlrine dioxide (ClO_2)	1.5
Chlorine (Cl_2)	1.4

(*) Fluoride is not used for wastewater treatment.
(**) Treatment with Hydrogen Peroxyde is expensive and is used in industrial processes.

The efficacy of a chemical disinfectant is strongly influenced by many factors: contact time, temperature, pH, agent and micro-organisms' concentrations, type of micro-organisms, presence of substances with potential interference.

The disinfection can be an effective intervention as long as its use is decided on the basis of specific requirements of protections defined with respect to a real risk. Therefore the knowledge of the existing pressure sources and the clear definition of the final objective to be achieved are the assumption of any decision.

Disinfection is necessary for the protection against pathogens. Its application depends on the following critical factors:

1. hygienical sanitary risk;
2. effluent qualitative acceptability for the environment;
3. energy saving;
4. management tecnichal and economical aspects.

For the pathogen it must be considered:

- the type of pathogen;
- its concentration in the considered point;
- the possibility of direct or indirect (delayed) contact.

4.3.2 Disinfection with chlorine and its compounds

The chlorine technology is well known and commonly used all over the world in disinfection. Chlorine and its compunds are the most used disinfectants for water for their efficacy, low costs and moreover because the chlorine techniques are well known and applied since long time. In the following details for each of the min disinfection agents are reported.

Chlorine

With 2 mg/l of active chlorine and contact time 30 min, 3 log coliform reduction is encountered, but protozoa are not inactivated; the most relevant disadvantage of chlorine is the formation of toxic by-products (Nurizzo, 2000). Normally chlorine reacts primarily with inorganic reduced Nitrogen (NH_3), always present in WW. With the excess of chlorine the combined chlorine is generated, which – in the typical conditions of the WW - is at 90% mono-chloroammine, a disinfection agent which does not produce organo-halogenated compounds and trihalomethanes (THMs); the experimental activity – laboratory as well on WWTP at real scale – confirm literature data (Ragazzo et al., 2011).

The abatement efficacy depends on the concentration as well as on the contact time according the following expression (Metcalf & Eddy, 2010):

$$\frac{N_t}{N_0} = (1 + 0.23 \cdot C_t \cdot t)^{-3}$$

Eq. 6: Coliform number

where: N_t = number of coliform bacteria at time t, N_0 = the initial numbre, t = contact time in minutes and C_t = the concentration of the residual Chlorine concentration at time t.

The gaseous Chlorine and Sodium Hypochlorite reacts with water producing hypochlorous acid:

$$HClO \rightarrow H^+ + ClO^-$$

The hypochloros acid is characterized with disinfection properties much stronger than hypochlorite ion. The disinfection efficiency is therefore strongly influenced by the pH. The use of solutions of sodium hypochlorite is preferred to the use of chlorine gas as it is corrosive and toxic. Sodium hypochlorite is normally supplied as aqueous solution; its stability decreases with increasing temperature while the disinfection efficacy dcreases with the time and with light exposition. The use of hypochlorite allows obtaining a prolonged disinfection with competitive costs.

Reagents dosing can be automatically controlled considering one or more of the following parameters: WW flow, residual chlorine, redox potential. The chlorine dinfection process leaves residual compounds among which the halogenated organic compounds, organic and inorganic chlorammines. These by-products are not desired as can make the final wastewater dangerous for the receiving ecosystem and for human health; this aspect is the main disadvantage of chloration. If residual chlorine overtakes the maximum concentration allowed by law a de-chloration process must be applied. Disinfection with chlorine and Hypochlorite must apply a contact times between 20 and 30 min; the disinfection tank usually are realized with a labyrinth form.

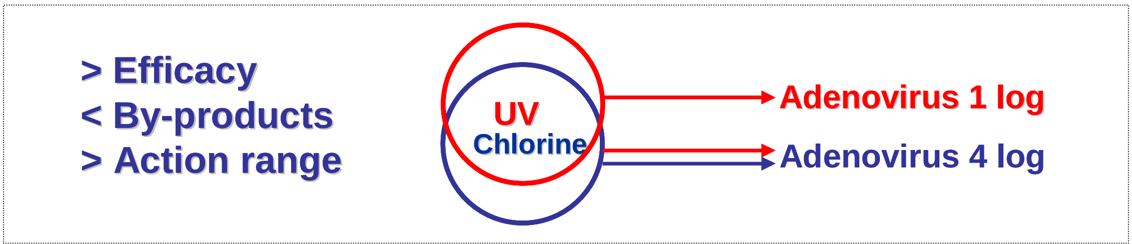
Chlorine dioxide

This gas is effective on bacteria, viruses but also on spores and cysts; according to some studies (Ragazzo, 2011) it is more effective at lower dosages and is largely applied in water potabilization. For its instability the product must be produced at the moment of its use from Sodium chlorite and chloridric acid. The ClO_2 does not react with N organic as well as N-NH_4 and produces less by-products than Chlorine.

The plant costs (realization of the plant) are higher than those of storage and dosing sodium hypochlorite (Ragazzo, 2011). Moreover mixed systems with UV and chlorine compounds can be used for advanced treatment: UV/ClO_2 for advanced oxidation of geosmin and 2-methylisoborneol. Specific applications aim at taste and odor improvement/control: the use of both systems can produce satisfactory results for virus abatement (see **fig. 4.1**).

Chlorine is a strong oxidant and reacts with all the reduced substances in the WW, organic substances included. First it rects with inorganic reduced N (NH_3), always present in the effluent. It forms combined chlorine, that typically is at 90% monochlorammine; this one is a long term disinfectant agent which does not produce THMs (Ragazzo & Falletti, 2013).

Figure 4.1 *– Combined disinfection systems with UV and Chlorine for virus abatement (Leong et al., 2008)*



CT

CT is the Concentration of Chlorine x Time of Contact. CT Disinfection demonstrates that the required disinfection is being achieved.

4.3.3 Disinfection with ozone

Ozone is one of the possible alternative solutions to chlorine, since it is a very powerful disinfectant against bacteria and viruses (Tyrrell et al., 1995; Liberti & Notarnicola, 1999; Xu et al., 2002; Sincero & Sincero, 2003); with some protozoa such as *Giardia* and *Cryptosporidium* it can have a lower effect (Lazarova et al., 1998, Paraskeva et al., 2002). The ATV Guide (1993) reports 3 log *Escherichia coli* reduction in secondary effluent with 10–15 mg/L Ozone and contact time of 30 min; Mezzanotte et al. (2007) have reported maximum reduction of 4 log *Escherichia coli* and 5.5 log *Total coliforms* with 3.5–5.5 mg/L Ozone and contact times of 6–12 min. Ozone production requires 10–20 kW/kg ozone (Sincero & Sincero, 2003), so it can be justified in large plants. Ozone by-products are mainly oxidised, organic compounds like aldehydes and ketones (Silva et al., 2010).

Ozone is a very strong oxidant agent which produces free radicals with high oxidizing potential and reacts readily with bacteria, algae, viruses and with organic substances with double carbon bonds (non ionic surfactants, dyes, etc.), odors and reducing substances. Moreover ozone can react with pesticides and herbicides with the formation of toxic compounds (but it can react and destroy them too – see Ragazzo et al., 2011). Ozone is not stable therefore it must be produced in the same place of use with a pretreated air flow or with pure Oxygen through an electric arch generqated with electrodes under high voltage (10-20 kV). Unless many advantages, its use is limited by the plant and management high costs (10-15 kg O_2/kg O_3; 8-15 kWh/kg O_3).

The addition of the mixture air/ozone or oxygen/ozone is performed in basins with a height of 5 m, in order to obtain a high degree of utilization. The remaining (residual) Ozone fraction in gaseous phase after the disinfection system must be destroyed according to its harmuful nature. For this reason disinfection unit must be covered.

Among the problems tied to the use of ozone must be mentioned the formation of indesired by-products like: aldeydes, potentially cancerogenic, forming at low pH values; bromates, suspected to be carcinogenic, whose production can be reducing operating at low pH values (only when Bromine is present in wastewater). Ozone reacts with pesticides and herbicides with the formation of toxic compounds (Paraskeva & Graham, 2002).

4.3.4 Disinfection with peracetic acid

Peracetic acid (PAA) is a germicidal agent, particularly used in the food industry and as disinfectant in hospitals. For wastewater treatment its use is recent. It is sold in different mixtures in solution with H_2O_2 and acetic acid (solutions at 15-20%) (Metcalf&Eddy, 2010):

$$CH_3CO_2H + H_2O_2 \leftrightarrow CH_3CO_3H + H_2O$$

Peracetic acid is a powerful disinfectant against bacteria, but less so against viruses; Mezzanotte et al. (2007) have reported maximum reduction of 3.8 log *Escherichia coli* and 4 log *Total coliform* reduction with a dosage of 15 mg/L and contact time of 36 min in secondary effluent. The main advantage of UV disinfection is the absence of chemicals, but it requires filtered water since its results are affected by turbidity; Nurizzo (2000) reports 3.8-4.2 log coliform reduction with a dosage of 30-50 mWs/cm^2 and contact time less than 1 min. The main disadvantage is the photo-reactivation of partly damaged bacterial cells.

PAA is easy to be used but it is corrosive for metals and for some plastic materials too; moreover it is a comburent. Costs are higher than for chlorintion systems. This type of disinfection does not loose efficiency due to the quality of the WW (this happens with all other types of disinfection substances); in particular there are no significant differences with variation of suspended solids.

This disinfection system allows a good abatment of bacteria indicated by the National law (Italian). PAA has a high germicidal effect with a large condition range: pH, temperature, sospende solids concentration; less reliable the indications about the behaviour with reference to virus. High disinfection efficiencies require contact time of about 30 min. Wastewaters treated with PAA appear to be of a better quality in comparison to those treated with ozone or chlorine; the PAA produces few by-products. The necessary PAA doses are higher than those of active chlorine for the same contact time. It must be observed that the use of PAA increases the COD level of some points in the final effluent; with the presence of chlorides, organic and inorganic compounds, PAA can allow the formation of organo-chlorinated compounds (unless in small quantity). For a chemical agent the factors influencing the disinfection capacity are: the contact time and the concentration of disinfectant.

The contact time can be determined according to the microorganisms bacteria from the Chick's law:

$$\frac{dN_t}{dt} = -kN_t$$

Eq. 7: Chick's law

where:

dN_t/dt = rate of change in the concentration of microorganisms with time;
k = inactivation rate constant, t^{-1};
Nt = number of organims at time t;
t = time

If t = 0, integrating the previous equation w obtain:

$$\frac{N_t}{N_0} = e^{-kt}$$

Eq. 8: Bacteria growth

For the calculation of the concentration of the disinfectant we ca use the Watson equation:

$k = k'C^n$

Eq. 9: Watson equation for inactivation rate constant

where:

k = inactivation rate constant;
k' = die-off constant;
C = concentration of disinfectant;
n = coefficient dilution.

To enhance the mixing of the added disinfectant a serpentine fashion channel is used as contact basin. The length-to-width ratios must be at least 20 to 1 (preferibly 40:1). To favour mixing, buffles are inserted along the contact basin (Metcalf&Eddy, 2010).

4.3.5 Disinfection with performic acid

Performic acid (PFA) is a wide-spectrum disinfectant, able to inactivate viruses, bacteria and bacterial spores, mycobacteria as well as microscopic fungi (Gehr et al., 2009). It is used as disinfectant in surgery, as oxidant agent for different substances in chemistry and medicine, and in food industry (Gehr et al., 2009); Heinonen-Tanski et al. (2010) refer an interesting potential application as disinfectant at low temperature in industrial processes as meat industry.

In wastewater disinfection treatment PFA use has been proposed only in recent years and the trials performed in Caorle in 2005-2006 (Ragazzo et al., 2007) represent one of the first full scale application. Since then different experimentations were performed in this application field, either at full scale level or in pilot and laboratory assays. Among the firsts it is worth mentioning the trials performed in Holland at Wervershoof WWTP (2006-2008, Kemira, 2008) and in France at Auch (2008), Cazaux and Biganos WWTPs (2010-2011) (Aubeuf, 2011).

Particularly interesting the tests effectuated on advanced primary effluent resistant to UV (Gehr et al., 2009) and the Molina de Segura WWTP application (Spain, 2011) where, to guarantee the reuse compliance, PFA was tested in combination with the existing UV system (Battle et al., 2011).

HYPROFORM– 1st PFA generation - pilot system

PFA solutions for disinfection are prepared by mixing Formic Acid (FA) 70-90 wt % and hydrogen peroxide (H_2O_2) 35-50 wt % (Mattila et al., 2000) with the presence of a catalyst. Due to its instability PFA can not be stored so it is produced in situ, immediately before its use. Because the production implies an exothermic reaction, the all process must be taken under controlled conditions.

The 1st PFA production prototype used in Caorle was basically constituted by: reagents storages and pumps, mixing unit equipped with cooling system, emergency water device and PLC control unit. From the two storage 1 m3 tanks the chemicals, in a controlled ratio, were pumped into the small open reactor (less than 6 litres volume) and the PFA solution (8 – 10 wt%) by gravity was dosed into the treatment. The PLC unit allowed to control dosages of chemicals and PFA and, through the cooling system, to maintain the proper temperature in the reactor. An alarm was specifically designed to activate the automatic emergency water, located above the reactor, if necessary.

DESINFIX (DEX 135) – New PFA generation - Commercial system

In the last generation the PFA system has been developed in order to improve effectiveness, reliability and manageability. So substantial changes have been made on reagents dosing system, reaction unit and safety aspect. In particular the development of dosing devices has improved dosages control, accuracy and stability.

In DESINFIX the mixing unit is a tubular reactor in thermostatic bath and the PFA concentration obtained ranges between 12-15 wt % (DEX 135). The system is equipped with UPS and leakages alarm; all the variables such as temperature, pressures, levels and flows rate are controlled and the system provides shutdown of production and emergency washing devices for any need. Operations and maintenance do not require particularly specialized operators but only a technical training is advised.

4.3.6 Wastewater filtration

Membrane systems present higher costs (from 1.7 to 10 times) in comparison to traditional methods for plants with more than 50,000 PE. Membrane filtration is necessary before UV systems.

Disc filtration

The filtration is obtained with semi-permeabile membranes working, according to needs, at more or less high pressures. The membranes are synthetic supporting materials, normally made of polymers which allow to separate the concentrate (retained suspended solids) from permeate (refined waste water).

Due to the dimensions of the particles, membranes can be conventionally subdivided into:

- **microfiltration** membranes (range 0.05-10 μm, max operative pressure 1 bar);
- **ultrafiltration** membranes (range 0.001-0.2 μm, max operative pressure 10 bar);
- **nanofiltration** membranes (at the boundary between ultrafiltration and inverse osmosis, allowing the separation of organic compounds with low molecular weight and bivalent ions).

Fixed the objective to be reached and known the characteristics of the WW to be treated, in the design phase material, porosity and configuration of the membranes must be identified. Membranes show a distribution of the pores of different dimensions which can influence the filtration efficiency. Examples of disc filtration equipment are reported in **figs. 4.2** and **4.3**.

Not all disc filters are created equal. The difference in woven filtration media and flow pattern makes each technology unique to each application. Both inside-out and outside-in configurations perform to expectations, considering that these devices have been marketed for the relatively clean waters of municipal tertiary applications.

4.3.7 Disinfection with UV rays

Among the disinfection technologies which apply physical means the most diffused is the UV rays. UV rays is an alternative to chemical systems; it requires a prefiltration and in any case a residual application of chemical reagents. The UV technique does not present by-products. In this case doses that can be considered effective for EC could be not effective for pathogens. It is possible the reactivation of the biological agents after disinfection. The energetic costs are higher than other chemical systems: from 15% to 40% of the total specific consumption (kWh/m^3).

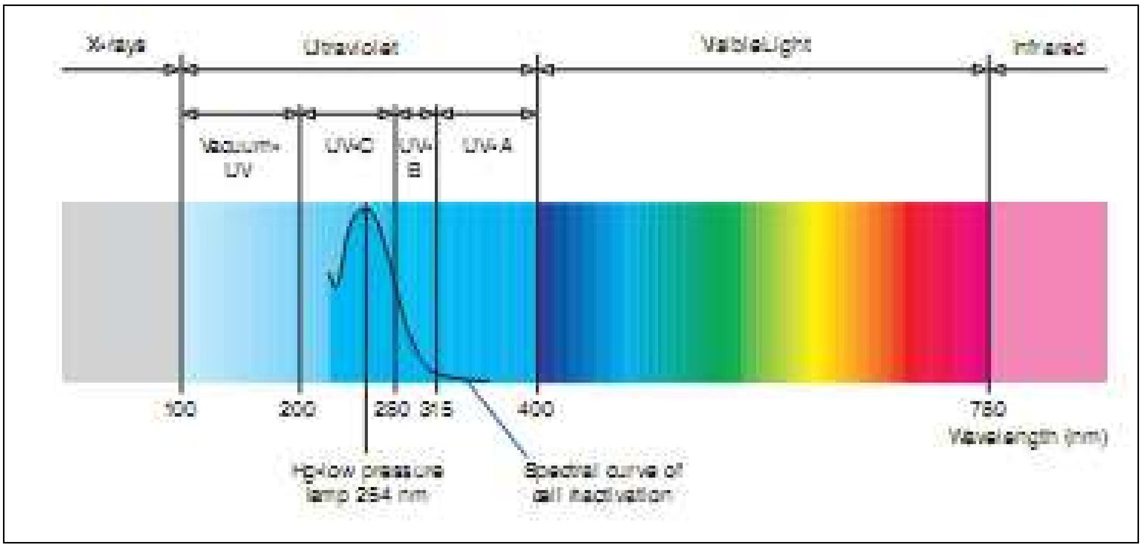
UV disinfection consists in inactivation of bacteria while sterilization is their total elimination. Ultraviolet (UV) light is a naturally occurring component of sunlight. It falls in the region between visible light and X-Rays in the electromagnetic spectrum (**fig. 4.4**).

Generally, UV light is considered as falling between 100 nm and 400 nm in wave-length, however UV light in itself can be categorized even further into separate regions. Although scientists hold varying opinions as to the exact boundaries of these regions, they are generally considered to be approximately as follows: Far UV (or "vacuum") 100 nm – 220 nm, UVC 220 nm – 290 nm, UVB 290 nm – 320 nm and UVA 320 nm – 400 nm. Of these UV regions, UVC is recognized as having significant germicidal properties. UVC light is however, almost entirely filtered out by the Earth's atmosphere. As such, if we are to utilize the germicidal properties of UVC light, we have to artificially generate it here on Earth using commercially produced UV lamps (see: http://www.wateronline.com/doc.mvc/Wastewater-Disinfection-with-the-TrojanUV3000-0001).

Figure 4.2 *– Disc filtration*

Figure 4.3 *– Disc filtration*

Figure 4.4 *– UV rays spectrum*



The bactericide action of UV rays depends on the induced photochemical modifications on DNA and RNA of the microorganism cells. UV rays can affect bacteria as well virus. Nucleic acids can adsorb the light at different wave length between the range 240÷400 nm; the max adsorption is obtained for a wave length of 265 nm. UV lamps contain a small amount of mercury, either in a free state within the lamp tube, or imbedded within the lamp tube's surface. When electricity is applied to the lamp electrode, electrons flow between them, these vaporize the Mercury, which when bombarded with electrons emit UV light. The exact wavelengths emitted depend on the vacuum pressure within the lamp tube itself. Practically Hg vapours lamps with different intensity and pressure are used. The UV lamps for WW disinfection can work in the wave length range range 240÷270 nm, with a peak of emission intensity at 254 nm, for which there is the highest disinfection effect. The low pressure Hg lamps are more used than those at mdium pressure as they realize a higher efficiency, limited consumptions up to 100 W/m of lamp and operative temperatures in the range 20÷40°C.

Low Pressure (LP) UV lamps are evacuated to relatively "low" pressures (between 1-10 Pa) and emit germicidal (I.E. UVC) light at a single UVC wavelength of approximately 254 nm. Medium Pressure (MP) lamps are evacuated to what is termed "medium" pressure and emit a broader spectrum of UV light with higher intensities between around 254 – 265 nm.

The standard duration of the UV disinfection lamps is around 8000 hours of activity; the mean life of the lamps is lowered by the increasing of the swithcing on number. Among the principal problems of this disinfection method there are: costs of installation, the Energy consumption; the requirement of wastewater with low sospende solids concentration (< 10 mg SS/L) in order to:

- reduce the fouling of the lamps;
- guarantee an effective exposition of the wastewater.

The main problem is tied to the presence of suspended solids which can absorb or reflect the UV radiations and which can behave as a protective shield for hidden microorganisms. UV disinfection is not able to guarantee a residual disinfection after treatment and therefore can favour a photo-reactivation and the dark repair (repair of the DNA molecules and successive bacteria reactivation after UV treatment); therefore a treatment with a residual disinfectant agent can be useful. UV rays are more effective on bacteria than on virus. The effectiveness of UV disinfction is based on the UV dose to which the micro-organism are exposed. The UV dose can be varied by changing either the intensity or the exposure time.

Disinfection is performed in three stages: with (1) **disc filtration**, (2) **UV rays equipment**, (3) **peractic acid disinfection** (labyrith). Disc filtration reduces the presence of suspended solids; these in fact can reduce significantly the effectiveness of the UV rays equipment. After disc filtration a **UV rays equipment** is applied; moreover a refining system with **peractic acid disinfection** (labyrith) is necessary to guarantee the respect of the limit value and a residual presence of disinfectant agent. The final discharge must respect for the indicator *Escherichia coli* the limit value of 5000 cfu/100 ml.

The UV dose D is defined as follows:

$$D = I * t$$

Eq. 10: UV dose

where:

D = UV dose (mJ/cm^2)

I = UV intensity (mW/cm^2).
T = exposure time (s).

A key factor in determining how effective UVC light will be in de-activating a given pathogen, is the length of exposure time that pathogen has to the UVC light for a given UV intensity. The longer the exposure time, the more UVC radiation will penetrate the pathogen's cells and therefore the more effective the inactivation process will be. The slower the flow rate of the water through the UV system, the longer the UV exposure time and viceversa, and so the maximum and minimum flow rate of the water should be considered. This is because many UV systems have the ability to adjust the power output of the lamps in relation to changes in water flow rate. By doing so, energy may be conserved when water flow rates are lower than peak flows. When determining maximum and minimum flow rates, it is important to establish the instantaneous flow rates as it is this that that will determine the instantaneous minimum and maximum UV exposure times. Daily and hourly flow rates are usually misleading in this respect, as they can mask important "peaks and troughs" in the instantaneous flow rate, thereby resulting in spurious calculations of the *true* UV exposure time during these peaks and troughs.

Different pathogens have differing resistance to UV; some are more susceptible than others and so require different amounts of UVC exposure in order that they are inactivated. In order to correctly size and select a UV system, it must be established which pathogen(s) are to be inactivated. In fact with disinfection the pathogen is reduced by a predictable amount. This predictable amount is referred to as a "log" reduction (as in "Logarithmic" reduction). A "one log" (most commonly referred to as 1 log) reduction will see the pathogen of interest reduced by 90% from the influent level. A 2 log reduction will see a 99% reduction, 3 log by 99.9%, and so on. Scientists have calculated the amount of UV exposure required to inactivate a whole range of different pathogens by various log reductions.

The UV dose required to inactivate a given pathogen to a given log reduction level is rarely linear. A common mistake often made is to take the UV dose required to achieve a 1 log inactivation and simply multiply it in order to calculate a higher log reduction. Although one very common pathogen, *Escherichia coli*, has a dose response curve that is almost linear, most are not, and so this means of calculating log reduction versus UV dose is not correct. UV dose is measured in millijoules seconds per cm^2 (mJ/cm^2) and is calculated using the following parameters:

- UV Intensity (I) measured in milliwatts per cm^2 (mW/cm^2);
- Exposure time (t) (seconds).

In addition, the UV intensity at any point in the reactor is influenced by the UVT. It is important to understand that actual equations used by UV systems are more complex than this and vary from UV system to UV system to account for UV reactor design differences. The relationship between these parameters can be described in general by the following equation:
(I/UVT) * t = UV dose or UV Fluence
Eq. 11: UV dose or fluence

From this relationship it must be stresse that **UV Intensity** (UVI) and **UV dose/fluence** are two different concepts. These two parameters are often (incorrectly) used interchangeably, or one is confused with the other. UVI (Intensity) measures the “amount” of UV energy in the water and varies throughout the reactor. UV dose/Fluence is the amount of UV energy penetrating the water, multiplied by the amount of time the water is exposed to this energy, and it is this that determines the log reduction of the pathogen. UV Intensity is measured by a UV intensity monitor mounted in the reactor. Both of these should not be confused with UVT (Transmissivity) which is the amount of UVI that is adsorbed by the water when UV light travels from the Lamp to the end point (wall) in the reactor.

With all reactors, the delivered dose will cover a range of doses (the Dose Distribution). The narrower the dose distribution, the more efficient the reactor. For any stated dose, there is always some water that will receive less dose and some more. Average dose, as the name implies, is simply the average throughout the reactor. It takes no account of dose distribution, and so can give a false view of reactor performance. The average dose value will always be higher than an equivalent CFD or RED dose, often by as much as 70%.

Example of a UV lamp is reproted in **fig. 4.5**.

Figure 4.5 *– UV rays Siemens lamp*

4.4 Chemical by-products from disinfection

Organic matters normally presents in natural waters not only cause colour, taste and odor in drinking water but are also the precursors of DBPs such as trihalomethanes (THMs), haloacetic acids (HAAs) (Zhang et al., 2011). Moreover as water contains Bromide, the Bromine substitution occours during chlorine disinfection as the bromide is oxydized by chlorine to hypobromous acid (HOBr) (Pourmoghaddas & Stevens, 1995). HOBr is more efficient as halogenatig agent than hypochlorous acid (HOCl). Disinfection with chlorine and its compounds can generate THMs, chlorinated solvnts and othe DBPs (Sorlini S. & Collivignarelli C., 2005). Not only chlorine/chlorine compounds disinfection procduces by-products but at different degrees also the other chemivcal agents used for this function.

According to literature data we can sinthetyze the main by-products classes for each disinfection techniques as in **tab. 4.2**.

Table 4.2 *– By-products and disinfection techniques*

Technique	By-products	Reference
Disinfection with Chlorine and Chlorine compounds	Trihalomethanes, Chlorophorm, Dichlorobromomethane, Dibromochloromethane Halonitromethanes	Metcalf & Eddy, 2010, Ragazzo et al. 2011 Song et al., 2010.
Disinfection with Peracetic acid	Aldehydes, organohalogenated compounds, bromophorm, bromophenol, acetic brominated acids	Nurizzo et al., 2005; Veijalainen et al. 2009
Disinfection with Performic acid	Bromophenol and acetic brominated acids	Ragazzo et al., 2011; Veijalainen et al. 2009
Disinfection with Ozone	Aldehydes, ketones, fatty acids, bromides and monobromoammine. Halonitromethane.	Paraskeva et al., 2002, Liberti et al. 1999. Song et al., 2010.
Disinfection with UV rays	Nitrosoamine, nitrophenols	Nurizzo et al., 2005

There are no doubts that the DBPs of chlorination are the most studied and the experience is large all over the world; therefore if from one side it is known that DBPs are produced, from the other less knowledge is available for other techniques. For example for the use of PFA a very satisfactory results of experimentation (Ragazzo et al, 2013) have been gathered but the production of DBPs on the long period is still not known (Ragapromising perspective is evident
To have a large and authoritative review of the state of the art on chlorination disinfection DBPs the study of Hrudey (2009) must be considered; he details the classes of DBPs as in **tab. 4.3**. In **tab. 4.4** the emerging DBPs are detailed.

Table 4.3 *– Established chlorination disinfection by-products (Hrudey, 2009)*

Class od DBPs	Number of substances identified
Trihalomethanes (THMs)	4
Haloacetic acids (HAAs)	9
Haloacetonitriles (HANs)	4
Haloketones (HKs)	2
Miscellaneous chlorinated organics	2
Cyanogen halides	2
Oxyhalides	3
Aldehydes	8
Aldoketoacids	2
Carboxylic acids	3
Maleic acids	1
Chlorophenols (CPs)	3
Chloroanisoles	1

***Table 4.4** – Emerging DBPs (Hrudey, 2009)*

Class od DBPs	Number of substances identified
Halo-acids (HAs)	18
Halo-acetates	1
Halo-nitromethanes (HNMs)	9
Iodo-acids	5
Iodo-trihalomethanes	6
Other halomethanes	6
Halo-acetonitriles	6
Halo-ketones	11
Halo-aldehydes	4
Halo-amides	5
Carbonyls	6
VOCs & m DBPs	4
Halo-pyrrole	1
Nitrosoamines	5
Halogenated furanones	12

4.5 Considerations on disinfection systems

The functional parameters to be adopted in the disinfection units after secondary treatment are reported In **tab 4.5**; the technical and economical characteristics of disinfection systems are compared in **tab. 4.6**.

***Table 4.5** – Dimensional parameters for disinfection (dose/contact time, etc.)*

Dis. System	Objective < 10^4 TC/100ml <2 x10^3 FC/100ml	Objective < 10^2 FC/100 ml no Enterovirus
Chloration	4 (3-8)mg/L; 30 min.	10 (8-15) mg/L; 30-60 min
Ozone	5 (3-10) mg/L; 10 min	7 (5-10) mg/L; 10 min
UV	35 (25-40) mW s/cm^2	65 (50-100) mW s/cm^2
Microfiltration	50 (40-80) L/(h· m^2); n°2 contr./h	non possibile per rimoz. virus
Ultrafiltration	50 (40-80) L/(h· m^2); n°2 contr./h	50 (40-80) L/(h· m^2); 2 contr./h

***Table 4.6** – Technical and economical characteristics comparison*

Characteristics	Chlorine	Ozone	UV	Microfiltr.	Ultrafiltr.
Safety	+	++	+++	+++	+++
Bacteria removal	++	++	++	+++	+++
Virus removal	+	+	+	++	+++
Protozoa removal	-	++	-	+++	+++
Bacteria re-growth	+	+	+	-	-
Residual toxicity	+++	+	-	-	-
By-products	+++	+	-	-	-
Managem,ent costs	+	++	+	+++	+++
Investment	++	+++	++	+++	+++

(-) none; (+) low, (++) mean, (+++) high

According to literature information in **tab. 4.7** the main and consolidated disinfection alternatives are compared according to the reported specific scale. In **tab. 4.8** the efficacy pf each disinfection technique aginst specific pathogens is reported.

We can synthetize the advantages and disadvantages of the disinfection technologies according to literature information and data as in **tab. 4.9**.

Table 4.7 *– Comparison of disinfection systems (Leong et al., 2008)*

0,5	NEGLIGIBLE
1	LOW
1,5	MEDIUM-LOW
2	MEDIUM
2,5	MEDIUM-HIGH
3	HIGH
3,5	VERY HIGH

ALTERNATIVES and EVALUATION VARIABLES

	OZONE	UV	PAA	CHLORINE
DISINFECTION EFFICIENCY	3,5	3	2,5	3
SENSITIVITY to WATER QUALITY	3,5	3	2	2,5
TECHNOLOGICAL COMPLEXITY	3,5	3	1,5	1
BY - PRODUCTS	3,5	0,5	1,5	3
POTENTIAL TOXICITY OF EFFLUENT	2	0,5 (*)	1	3
POTENTIAL REGROWTH after DISINFECTION	0,5	3	0,5	0,5
REMOVAL of COMPOUNDS of CONCERN (hormones, pharmaceuticals and personal care products, endocrine disrupting compounds)	3-3,5	0,5	0,5	2-2,5

Table 4.8 *– Comparison of disinection systems against pathogens (Leong et al., 2008)*

	OZONE	UV	PAA	CHLORINE
ADENOVIRUS	Good	Poor	---	Good
MS2 COLIPHAGE	Good	Fair	Fair	Good
ENTEROVIRUS. POLIOVIRUS	Good	Good	Poor	Good
CRYPTOSPORIDIUM	Fair	Good	Poor	Fair
GIARDIA LAMBLIA	Fair	Good	Poor	Fair

***Table 4.9** – Advantages and disadvantages of common use disinfection technologies*

Technology	Advantages	Disadvantages
Hypochlorite and gaseous chlorine	- good/high efficiency; - low costs; - well known technology; - technology largely used in potabilization.	- efficiency is function of the final WW quality; - hazard of the secondary products (by-products) for ecosystems and human health; - hazard in chlorine gas management.
Chlorine dioxide	- the efficiency does not vary with the pH varying; - it destroys spores and cysts more easily than other technologies; - produces less dangerous by-products; - the germicidal effect is not influenced by the N content in the treated WW.	- high costs; - produces the formation of dangerous by-products (chlorites).
Ozone	- it destroys organisms like spores, cysts wuth higher facility with reference to other treatments; - low production of dangerous residuals (not negligible).	- high costs; - efficiency is conditioned with effluent quality.
UV rays	- by-products are not generated in the final effluent (in case present in negligible quantity).	- very high costs; - efficiency is highly conditioned with the effluent quality; - microorganisms with strong membrane/cell walls or DNA repairing systems can resist to the treatment.
Peracetic acid	- by-products are negligible; - treatment efficiency is influenced with the effluent quality.	- possibility to enhance COD and BOD_5 value in the final discharge; - high costs (chemicals); - management difficulty (Seveso durective).

5. The chosen set of WWTPs in the province of Venice

5.1 The set of WWTPs

The study has analysed the coastal impacts of microbiologic parameters in the province of Venice. The whole list of WWTPs (without Imhoff tanks) and the applied disinfection systems all over the province of Venice are reported in **Annex II**. Among the plants of the province a specific set has been chosen according to the different disinfection systems applied and the effective significance of the plant, the potentiality (≥ 10,000 PE) and/or the potential impact on the coastal waters' quality. Moreover a plant of the province of Treviso (Paese WWTP) has been considered according to the disinfection system adopted (ozone) and its specific characteristics; it must be said that a plant with ozone disinfection system is present in the province of Venice but it is particular as it serves a food & beverages industrial settlement (San Benedetto industry in Scorzè).

The set of WWTPs with different disinfection systems considered in this study is detailed according to the area and plant manager in **tab. 5.1**. It must be observed that for ASI, according to the new obligation of chlorine substitution in the authorization acts, chlorine has been substituted with PFA since beginning of 2013; except for Jesolo and Eraclea mare in this study for ASI plants data are referred to chlorine disinfection systems, that is to the situation before the new obligation since December 2012 established in Veneto region with the Water Protection Plan (Veneto Region, 2009).

Table 5.1 *– Set of WWTPs analysed in the study with localization and plants' managers*

WWT Plant	SIRAV Code*	Management society	Location	PE max (actual)^	Final discharge	Disinfection system	Period of activation
Caorle	4148	ASI	Via Traghete	120,000	Traghete/Saetta channels	NaClO/PFA**	15/03-30/09
Eraclea Mare	4869	ASI	Via dei Pioppi	32,000	Primo channel	NaClO/PFA**	15/03-30/09
Jesolo	4155	ASI	Via Aleardi	185,000	Sile river	PAA/PFA**	15/03-30/09
San Donà di Piave	4165	ASI	Via Tronco	45,000	Tabina channel	NaClO/PFA**	15/03-30/09
Musile di Piave	4157	ASI	Via Rovigo	10,000	Piave river	NaClO/PFA**	15/03-30/09
Fusina-Venezia	4140	Veritas	Fusina, via dei Cantieri	330,000	Venice lagoon	UV	whole year
Paese	3733	AVS-SIBA	Via Brondi	45,000	Irrigation channel	Ozone	whole year

*Code of the Veneto Regional Environmental Informative System (regional cadasters).

^ Source: Province of Venice.

** PFA since 8th March 2013 (date of effective chlorine and products' prohibition according to the WPP of Veneto region).

With reference to **tab. 3.5** and **fig. 3.12**, the reported WWTPs refers to the plants that historically are controlled due to the effective impact alonmg the costal belt of the province; these WWTPs have been considered in the project BIOPRO and in the integrated analysis on the coast for microbiological pollution; moreover tehse plants encompass HYPO, PAA, O_3 and

UV disinfection systems. For the present study these set has been enlarged considering plants which do not have a direct impact on the coast (as Fusina, Campalto, San Donà di Piave, Musile di Piave).

The other WWTPs considered in the province of Venice in this study to have the general framework of the microbiological sources of impact to be considered together with monitoring data of water bodies are reported in **tab. 5.2**. These plants have been chosen as they are higher than 10,000 PE and from the historical knowledge of the environmental condition they can have an impact/influence on the bathing waters' quality and therefore are monitered more frequently during the bathing season. For this set of plants no data from their managers were supplied or were available.

Table 5.2 *– Set of WWTPs in the province of Venice considered in the study*

WWT Plant	SIRAV Code*	Management society	Location	PE max (actual)^	Final discharge	Disinfection system	Period of activatio n
Chioggia	4139	Veritas	Val da Rio	160,000	Brenta river	UV	15/03-30/09
Campalto	4141	Veritas	Via Brigadiere Scantamburlo	130,000	Osellino Channel/Lagoon	UV	whole year
Lido di Venezia	4143	Veritas	Via Galba	60,000	Adriatic sea 4 km far from the beach	NaClO/PAA**	15/03-30/09
Cavallino	4167	Veritas	Via Fausta	105,000	Adriatic sea 4 km far from the beach	NaClO/PAA**	15/03-30/09
Quarto d'Altino	4164	ASP Sile-Piave SpA	Via Marconi	30,000	Sile river	PAA	15/03-30/09
S. Stino di Livenza	4158	Acque Basso Livenza SpA	Via Canaletta	10,000	Malgher channel/Lemene river	PAA	15/03-30/09
Portogruaro	4162	Acque basso Livenza SpA	Destra Reghena	8,400	Reghena river	PAA	whole year
Bibione	4161	CAIBIT SpA	Via Parenzo	150,000	Maestro ch./Tagliamento river	NaClO/PFA**	15/03-30/09

*Code of the Veneto Regional Environmental Informative System (regional cadasters)

^ Source: Proibce of Venice

** PAA/PFA since 8th March 2013 (date of effective chlorine and products' prohibition according to the WPP of Veneto region).

<u>It must be observed that the considered WWTPs present different disinfection systems but they are different plant operating with different wastewtaers, in different conditions</u>. Therefore all the considerations that will be done in this study take care of this limitation. In the following §§ details and descriptions of the chosen WWTPs are reported.

5.2 ASI WWTPs

5.2.1 Caorle WWTP

The treatment phases can be synthesized as follows:

<u>Water line</u>:

- coarse screening;

- WW uprising;
- equalization;
- fine screening;
- degritting;
- pimary sedimentation;
- denitrification;
- oxydation/nitrification;
- secondary sedimentation;
- disinfection

Waste treatment line (sewer maintenance): screening (coarse), then biological treatment (30-40 m^3/d up to max 50).

Sludge line:
- thickening;
- dewatering;
- drying.

The Caorle WWTP has a potentiality of 120,000 PE and treats the domestic WWs from urban settlements with very high difference between winter and summer loads according to touristic presences. Moreover the plant can treat wastes from sewer maintenance. The plant discharges the final effluent into the Saetta channel connected with secondary branches to the sea. Before the plant a combined overflow system is present and is activated only in cases of heavy rain events. The final disinfection is performed with NaClO for the period 15/03-30/09. Since March 2013 the PFA has been adopted. It must be observed that in this plant a sperimentation of the PFA has already been performed by ASI in 2005.

Wastes from sewer maintenance undergo screening (6 mm); the separated material is sent to landfill; the separated WW is poured into the equalization tank. The excess sludge is sent to two thickening tanks. The sludge is conditioned with cationic polyelectrolyte and then is sent to a belt-press. The existing draying present are used for sludges only in case of emergency; instead they are commonly used to dry sands from the sewer maintenance.

5.2.2 Eraclea mare WWTP

The WWTP of Eraclea mare receive mixed domestic wastewaters coming from the fractions of of Eraclea, Eraclea mare and Torre di Fine; it is a biological plant with suspended biomass. During the max touristic presences, for two months every year, the plant works at its max potentiality; for the rest of the year significant contributions derive only from Eraclea paese and Torre di Fine.
The treatment stations at the moment are the following:
Water line:

- uprising (n. 3 submerged centrifughe pumps);
- fine screening (5 mm);
- degritter
- Pre-denitrification;

- Biological oxidation and nitrification;
- secondary sedimentation (n. 2 settlers of 286 m^3, and n. 1 settler of 904 m^3 active only in the crode season);
- disinfection ith NaClO dosing.

Sludge line:
- prethickening;
- anaerobic digestion
- post-thickening
- dewatering with beltpress (16% dry matter)
- drying beds

The drying beds are used for sludges only in case of emergency; normally they are used for drying sands from the sewer network maintenance (EWC 200306). The plant has a project potentiality of 32,000 PE, but from the functionality verification at mean lods it appears that the plant treats 12,000 PE (organic load) in high season and 4,000 PE in the low season.

5.2.3 Jesolo WWTP

This plant treats not separated wastewaters (black and white WW). In cases of excessive rain two overflow points are designed: one after pre-treatments (screening and degritting) and one after the primary sedimentation. During touristic season n. 3 depuration lines are active, 2 of which fed with Archimede screw (cocleas).
The treatment pahses are:

- uprising with cocleas;
- screening
- degritting
- primary sedimentation
- biological oxidation (about the 80% of the WW coming from primary sedimentation), denitrification (about 20% of the WW from primary sedimentation) and feeding of the third line (the effluent of primary sedimentation is divided in 3 flows). The WW of denitrification tank is sent to biological oxidation.
- Secondary sedimentation;
- disinfection with PAA (PFA since 2013).

Sludges from sedimentation are sent to a thickening tank and than to primary and secondary digestion and to a bel-press. The produced water from sludge dewatering is send to the head of the plant and the sludges go to the recovery.

5.2.4 San Donà di Piave WWTP

The San Donà di Piave plant is 45,000 PE and treats WW from San Donà settlement and some neighbouring fractions. The territory is served with non separated sewer with final discharge

into the Tabina channel. The plant is authorized to treat liquid special not hazardous wastes from maintenance of sewers up to 40 m^3/d.
The treatment pahses are:
Water line:

- coarse screening;
- uprising;
- degritting;
- primary sedimentation;
- denitrification;
- oxidation and nitrification;
- secondary sedimentation;
- disinfection.

Sludge line:

- anaerobic digestion;
- post-thickening;
- de-watering.

In the restyling project recently approved by Veneto Region for the water line an improvement with fine screening, biologic selector and filtration before disinfection is designed, while for the sludge line a pre-thickening phase is designed. For up-rising a 4th coclea will be realized in addition to the 3 existing ones. In **fig. 5.1** the final discharge channel after the disinfection station with the flow measure is reported.

Figure 5.1 *– San Donà di Piave WWTP final discharge channel after the contact tank*

5.2.5 Musile WWTP

The WWTP has a design potentiality of 10,000 PE. The depuration process is biologic with suspended biomass and treats mostly domestic WW. The existing treatment stations are:

Water line:

- uprising (3 submersible centrifugal pumps);
- fine screening (5 mm);
- degritting;
- by-pass after primary treatments;
- pre-denitrification;
- biologic oxidation (suspended biomass; n. 3 basin in serie);
- secondary sedimentation;
- disinfection with NaClO (PFA since March 2013).

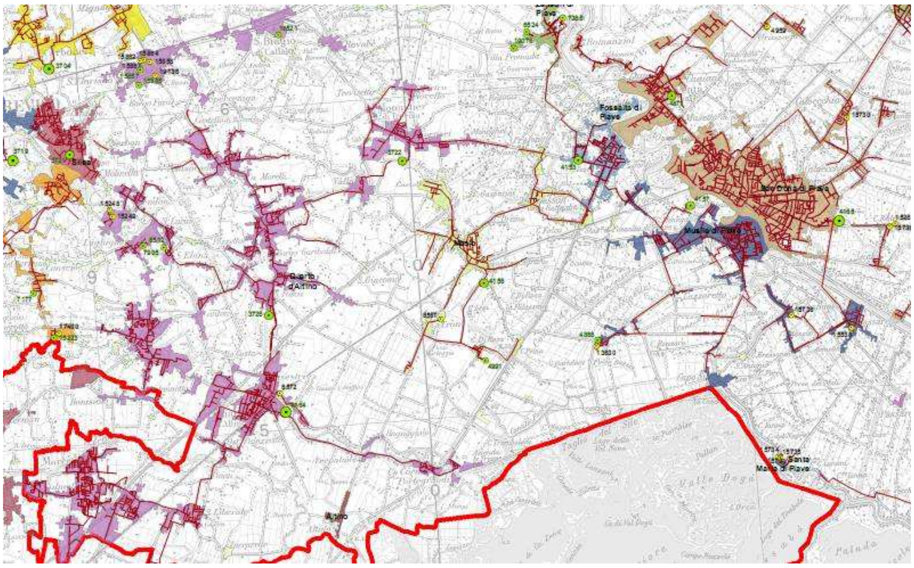
Sludge line:

- anaerobic digestion;
- drying bed (n. 3 beds, 2 of which are used for sludges and 1 for drying of materials recovered from the maintenance of sewer pipes).

5.2.6 The corresponding agglomerations

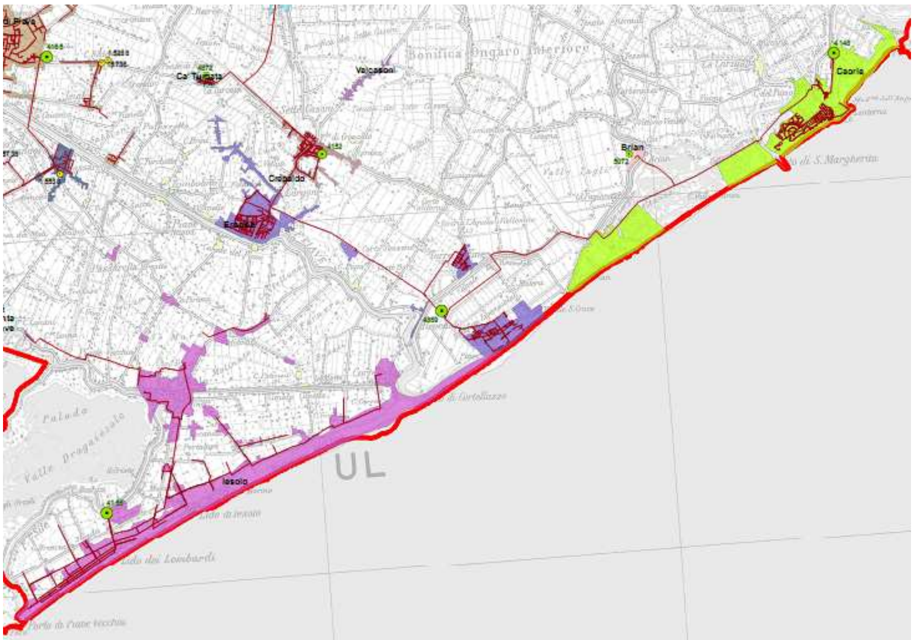
According to DGRV n. 3856/2009 (Veneto Region, 2010) the agglomerations to which the plants of Musile di Piave and San Donà di Piave belong are reported in **fig. 5.2**. The same for the plants of Jesolo, Eraclea Mare and Caorle (**fig. 5.3**).

***Figure 5.2** – Musile di Piave and San Donà di Piave agglomerations*



(Source: Veneto Region, 2010)

Figure 5.3 *– Jesolo, Eraclea Mare and Caorle agglomerations*



(Source: Veneto Region, 2010)

5.3 The Veritas WWTP of Fusina in Venice

The WWTP of Fusina, started in 1985, treats the domestic and inudtrial wastewaters from the S-W territory of Mestre, from the territory of 17 communes of the Mirese Consortium and from the industrial agglomeration of Porto Marghera. In **fig. 5.4** a general view of the plant is presented.

The original design scheme has been though to abate nutrient compounds according to the limits of the old Decree n. 962/1973 (now repealed and substituted with Moinisterial Decree 30/07/1999) for the discharges into the Venice Lagoon. At present state the unit phases are (source: Veritas, 2013):

<u>1) WW line</u>**:**

- Screening.
- Degritting (grit and oil removal).
- Equalization.
- Intermediate WW uprising.
- Integrated biological treatment in two stages (denitrification and oxidation-nitrification).
- Chemical dephosphatation.
- Final sedimentation.
- Disinfection.
- Return wastewater.
- Return sludge.

<u>2) Sludge line</u>:

- pre-thickening;

- anaerobic digestion and biogas recovery for Energy production;
- post-thickening;
- de-watering/drying.

Figure 5.4 *– The Fusina WWTP in Porto Marghera-Venice*

The design potentiality is 400,000 PE. The process scheme is developed on 4 lines of dnitrification with 6,000 m^3 each and 4 lines of nitrification, of which the 3 original lines have a oxygenation system with surface aerators, while the 4^{th} line, started the 13^{th} April 2010, presents a insufflation system with compressors with diffusers of Flyght type. Since the 1st May 2011 the final WW of the plant are not treated with peracetic acid for the disinfection but are sent to the new refining unit, which performs fabric filtration and UV disinfection. Filtration is performed with 7 couples of disc filters Hydrotech. WW flows by gravity into the filter stretches from a central pipe; solids are separated on the fabric tissue; when these are clogged the couter-washing process starts, using WW just filterd with a jet under pressure.

WW from filtration is divided in two parallel flows of the same dimension (width 1,524 mm, depth 2,146 mm) where 480 UV lamps of the Trojan UV 3000 Plus are installed (**fig. 5.5**). The Hg vapours lamps, which emit monochromatic electromagnetic radiations able to abate the microbiological charge, have the technical characteristics reported in **tab. 5.3**.

Each disinfection unit has an intensity detector which allows selfregulation of the light dosage proportionally to the WW flow. A level sensor measures the fluid level in the channel and controls and automatic sluice gat in order to maintain lamps always submerged. Each UV lamp has the ActiClean™ self polishing system; this system functions mechanically with a bottom scraper as well as chemically with a dosing system of citric acid to avoid algae growth and $CaCO_3$ deposition. At the moment 50% of the treated WW are pumped to a phytodepuration dedicated area, the remaining 50% is discharged directly into the Venice Lagoon; this will happen till the structures of the PIF Progetto Integrato Fusina will be completed with thefinal discharge point 10 km out of the Lido island with a submarine outfall (with 10 km submarine pipe).

***Figure 5.5** – Trojan UV 3000 Plus disinfection unit*

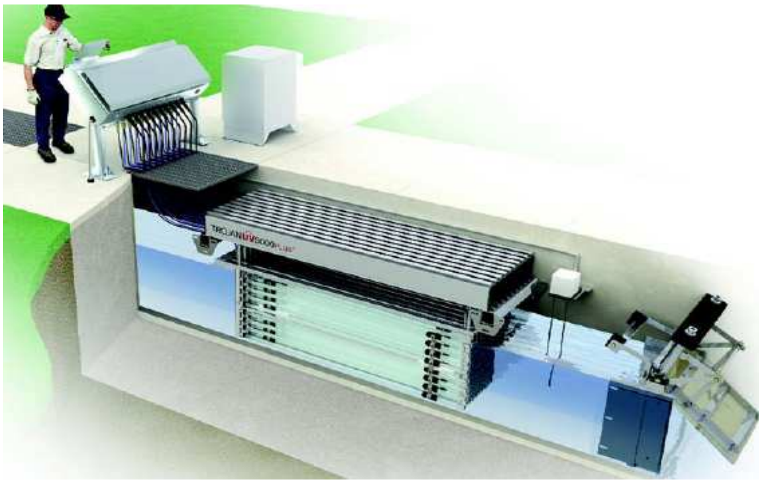


***Table 5.3** – Technical characteristics of the UV disinfection system in Fusina WWTP*

Lenght	1.58	Peak flow	2160 l/s
Range	UVC	Suspended solids	≤ 15 mg/l
Power	240 W	UV tramittance at 253.7 nm	> 60 %
Potential	220 V		
Endurance	12,000 hrs	Dose	≥ 40 mWs/cm^2

5.4 The Paese Alto Trevigiano Servizi-SIBA WWTP

5.4.1 Paese WWTP

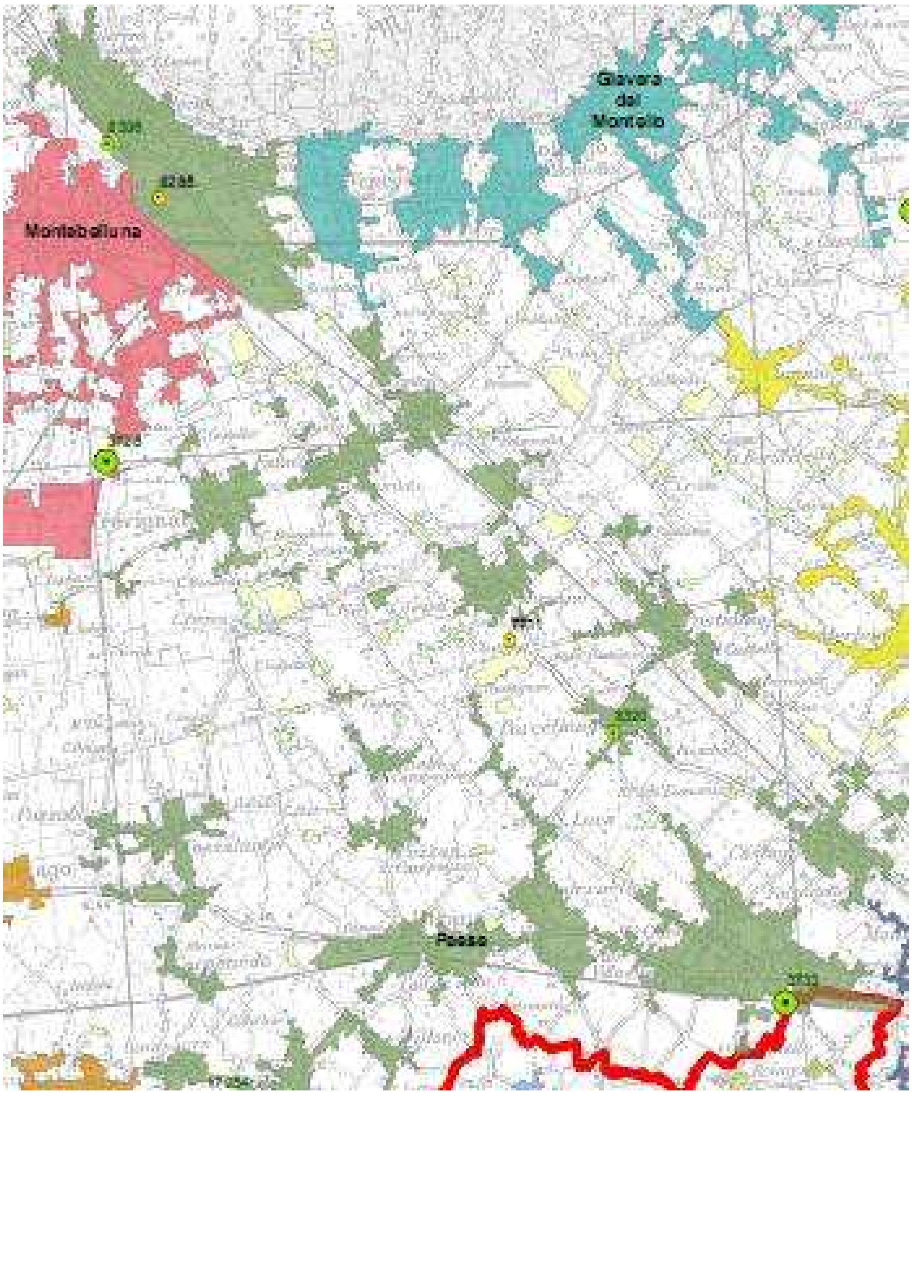
The Paese treatment plant, managed by SIBA-Veolia Italia spa under the supervicion of Alto Trevigiano Servizi consortium, is one of the most important in the province of Treviso (45,000 PE) with regard to the treatment of liquid wastes with a chemo-physical pre-treatment section and biological oxidation. A second line of 15,000 PE has been realized and will be dedicated exclusively to the treatment of liquid wastes; it coincides with the old depuration plant (before upgrade). This line is divided into two parts according to the quality of wastes received: 1. landfill leachate and wastes from the maintenance activity of septic tanks/Imhoff boxes; 2. wastes with low biodegradability.

When received into the plant, after mid to fine screening, wastewaters are risen to an equalization tank to homogenize the received load of pollutants and at the same time to perform pre-aeration with oxygen. The equalization tank collects the settler's outflow from the waste treatment line and, partially, the recirculation sludge from the secondary settler of the wastewater treatment line. The pre-denitrification tank with a volume of 1,125 m^3 is applied for the abatement of nitrates and partially of the organic biodegradable polluted load. Nitrates are supplied with the recirculation of the activated sludge with a variable recirculation ratio of about 2/1 (2010; source: plant manager); on the basis of the nitrates load received by the plant for external waste treatment the plant manager performs mixed-liquor recirculation as needed (recirculation ratio of 1/3). This is followed by the oxidation-nitrification phase where biodegradable and nitrogen substances are oxidized by heterotrophic and autotrophic bacteria. Clarified waters from the secondary settlers undergo flocculation treatment; the raw wastewater received in the plant is 8.8% of industrial origin (n. 1 textile industry connected to the sewer), and consequently presents problems linked to the presence of chemical dyes in the textile processing cycles. After flocculation, the wastewater is pumped to a tertiary settler, where the sludge is separated from the clarified mixture and is sent to the well for the collection of tertiary sludge. The treated wastewater then undergoes filtration with sand filters and finally a disinfection treatment with ozone for the reduction of microbiological organisms.

5.4.2 The corresponding agglomerations

According to DGRV n. 3856/2009 (Veneto Region, 2010) the agglomerations to which the plant of Paese belongs is reported in **fig. 5.6**.

Figure 5.6 *– Paese agglomeration with the plant of Paese*



PART II: MATERIALS & METHODS

6. Water bodies monitoring, discharge controls and classification criteria

6.1. ARPAV analytical methods for surface waters and discharges

6.1.1 Monitoring and control data management system in the Veneto region

Data from institutional monitoring and control performed by the regional Environmental Agency on WWTP discharges have been extracted from the Veneto's Regional Environmental Informative System (SIRAV).

ARPAV (Veneto Regional Prevention and Protection Agency) is the institutional body responsible for environmental monitoring and controls. Data produced from these activities are available from the SIRAV. The chemo-physical, chemical and biological data produced by the laboratories of the regional Environmental Agency are stored on local database systems (LIMS - *Laboratory Information Management System*) after a double phase control process and eventually converge into the SIRAV system.

6.1.2 Sampling and analytical methods for microbiologic parameters

For the research of *Faecal streptococci*, *Escherichia coli* and *Salmonella* ARPAV Laboratories (Venice and Treviso) followed the Italian Official methods (ISTISAN, 1997; APAT, 2003) with instantaneous sampling and results have been expressed as colonies forming unit (cfu)/100 ml. In **tab. 6.1** the meaning of investigated biological quantitative and qualitative (*Salmonella*) parameters and the followed reference official methods are described. In the table TC and FC are reported too asd they were monitored in the discharges and rivers tll 2005 and till 2009 in bathing waters; the BIOPRO project on disinfection systems and the integrated area analysis (see Chapter 10) consider these faecal indicators too.

Table 6.1 *– Microbiological parameters and reference methods*

PARAMETER	MEANING	REFERENCE METHOD
ESCHERICHIA COLI (EC)	Indicator of faecal contamination of human and animal origin	Analytical methods for water Vol.3, 29/2003, APAT CNR 7030 (APAT, 2003)
FAECAL STREPTOCOCCI (FS)	Indicator of faecal contamination of human and animal origin. Indicator of the water treatment systems for drinking water	Report ISTISAN 97/8 (ISTISAN, 1997) and ISO 7899-2-2003
TOTAL COLIFORMS (TC)	Eterogeneous groups of the Enterobacteriacae group of faecal and/or environmental derivation. Useful as indicators of the efficiency of water depuration systems and of integrity of the water pipes	Report: ISTISAN 97/8 (ISTISAN, 1997) and APAT CNR 7010 (APAT, 2003)
FAECAL COLIFORMS (FC)	Indicator of faecal contamination of human and animal origin. Indicator of the water treatment systems for drinking water	Report: ISTISAN 97/8 (ISTISAN, 1997) and APAT CNR 7020 (APAT, 2003)
SALMONELLA	Pathogen of human and animal faecal origin, adapted to a specific host or ubiquitous	APAT, 2003

The samples of microbiological parameters were taken with the following official procedures:

- WWTPs' effluents: mean-composite sampling every 24 hours (instantaneous withdrawal at a fixed time over a period of 24 hours according to Directive 271/91/EEC for a sample representative of the real WWTP behaviour) according to the official Italian method (APAT, 2003), which follows the International procedures (APHA et al., 1998);
- surface waters (rivers, bathing waters, marine-coastal waters): instantaneous sampling for all the parameters, according to the official Italian method (APAT, 2003), which follows the International procedures (APHA et al., 1998).

For the research of FS and EC samples of 500 mL of surface waters or wastewaters were collected; the analytical methods applied are:

- *Escherichia coli (EC)*: determined with the APAT method (2003) n. 7030 F membrane filtration according to APHA et al. (1998) and AOAC (1995) and expressed as cfu/100 mL, with culture terrain TBX (Tryptone Bile X Glucuronide Agar); EC is expressed since 2010 in MPN/100 ml.
- *Faecal streptococci (FS)*: determined according to the APAT method (2003) n. 7040 C which follows the International standard procedures (APHA et al., 1998 and EN ISO, 2000) and expressed as cfu/100 mL, with culture terrain of "Slanetz & Bartley".
- *Salmonella*: 1 liter of surface water or wastewater sample; the analytical procedure made it possible to evaluate the presence/absence of the pathogen through successive phases: pre-enrichment, enrichment, isolation, biochemical and serological confirmation method (APAT, 2003 method 7080) according to the APHA et al. (1998) standard procedure.

The Venice ARPAV microbiology laboratory also satisfies periodical inter-calibrations (Schmidt, 2003) and is certified ISO 17045. For the objectives of the study, each surface water or wastewater sample was analyzed for the quali-quantitative determination (identification of the bacterium and quantification expressed as colonies forming units cfu/100 mL) of EC, FS and *Salmonella* (only qualitative assessment: absence/presence).

6.1.3 Sampling and analytical methods for chemical parameters

Official sampling and analytical methods adopted in Italy were applied during this study: *Analytical methods* (APAT, 2003) used since 2004. Where analytical methods were lacking in the Italian national legal framework International official methods were also used (i.e. APHA & AWWA 1998). The sampling techniques were the following: instantaneous sampling for surface waters and mean-composite sampling on a 24 hours basis for WWTP effluents (in accordance with Directive 91/271/EEC on wastewater treatment).

6.1.4 Dangerous, priority and priority hazardous substances monitoring and control

With decree n. 367 of 6/11/2003 the Italian national list of dangerous substances for water bodies was introduced; the list has been amended by Decree n. 152/2006 and now its is inserted in the Annex 1 Part III tabs 1/A (parameters with EQS and analytical method established) and 1/B (additional parameters without EQS value) of the Decree.

Tab. 6.2 shows a comparison between the water quality standards established by the Italian regulations (the Italian national and local lists) and the entire list of the European P and PH substances, the limit values for discharges and the limits of detection (the LOD was in accordance with Hubaux & Vos, 1970 and with Vanatta & Colemann, 1997). These limits have already been established in the Venice lagoon and illustrate the main issues associated with the control of priority substances. In addition, table 3 presents the analytical techniques adopted and the LODs.

The EQSs and discharge limit values for the Venice Lagoon and its catchment area, as well as the acceptable loads for the lagoon, were defined by the National Institute for Health (ISS, 1996) and by the National Research Council Water Institute (IRSA-CNR, 1996). When these studies were carried out, the previously established data concerning the characterisation of the existing discharges into the Venice lagoon catchment area, the water quality data characterisation, the estimated loads and the defined water quality objectives were taken into consideration, in order to guarantee the maintenance of the capacity of the auto-depuration system and the existing biological community (political objectives).

Table 6.2 *– Environmental Quality Standards (EQSs) in the Italian (decrees n. 367/2003, n. 152/2006) and Venice lagoon (decree dated 23/04/1998) regulations for European P and PH pollutants in surface waters; Limit of Detection (LOD) for industrial discharges and surface waters and the analytical techniques used in achieving the LOD*.

Pollutant	2008 EQS Italian Regulations (µg/L)	2015 EQS Italian Regulations (µg/L)	EQS for the Venice lagoon and its catchment area (µg/L)	EQS Directive 2008/105/EC Inland surface waters Average annual value (µg/L)	Limit values for discharges in the catchment area of the Venice lagoon (µg/L)	LOD obtained by the Venice ARPAV for *Discharges* (µg/L)	LOD obtained by the Venice ARPAV *Surface waters* (µg/L)	Analytical technique used to achieve the reported LOD
Cadmium PH	1^	0.1 D 0.03 M-L	0.01	0.08	5§ (1§§)	0.5	0.2	ICP-MS
Mercury PH	1^	0.02 D 0.003 M-L	0.005	0.01	3§ (0,5§§)	1	0.2	ICP-MS/CVAAS
Nickel P	20^	1.3 D 0.6 M-L	0.5	20	100°	5	1	ICP-MS/GFAAS
Lead P	10^	0.4 D 0.06 M-L	0.03	7.2	50§ (10§§)	0.5	0.5	ICP-MS
Tributyltin (compounds) PH	0.001*	0.0001	0.01	0.0002		0.03	0.03	GC/MS
Tributyltin cation PH	0.001*							
Total Policyclic Aromatics Hydrocarbons PH	0.2^	0.005	0.06 (Lagoon)			0.01	0.01	HPLC/FL
Benzo(a)pirene PH	0.004 D* 0.003 M-L	0.001	0.003 (Lagoon)	0.05		0.01	0.01	HPLC/FL
Benzo(b)fluoranthene PH	0.004 D* 0.003 M-L	0.001	0.003 (Lagoon)			0.01	0.01	HPLC/FL
				Σ 0.03				
Benzo(k)fluoranthene PH	0.004 D* 0.003 M-L	0.001	0.003 (Lagoon)			0.01	0.01	HPLC/FL
Benzo(g,h,i)perylene PH	0.004 D* 0.003 M-L	0.001	0.003 (Lagoon)			0.01	0.01	HPLC/FL
				Σ 0.002				
Indeno(1,2,3-cd)pyrene	0.004 D* 0.003 M-L	0.001						HPLC/FL
Anthracene P	0.1 D* 0.01 M-L	0.01 D 0.006 M-L		0.1				
Fluoranthene P	0.1*	0.01		0.1				
Naphtalene P	0.1*	0.01		2.4				

Pollutant	2008 EQS Italian Regulations (µg/L)	2015 EQS Italian Regulations (µg/L)	EQS for the Venice lagoon and its catchment area (µg/L)	EQS Directive 2008/105/EC Inland surface waters Average annual value (µg/L)	Limit values for discharges in the catchment area of the Venice lagoon (µg/L)	LOD obtained by the Venice ARPAV for *Discharges* (µg/L)	LOD obtained by the Venice ARPAV *Surface waters* (µg/L)	Analytical technique used to achieve the reported LOD
Benzene P	1^	0.2 D 0.1 M-L	0.1	10		1	1	GC/MS P&T
1,2,4 Trichlorobenzene P	0.4^	0.01 D 0.005 M-L				0.1	0.1	GC/ECD
1,2 Dichloroethane P	10^	0.3 D 0.1 M-L	0.4	10		1	1.0	GC/MS P&T
Hexachlorbutadiene PH	0.1^	0.001	0.1 (Lagoon)	0.1		0.1	0.1	GC/ECD
Trichloromethane (Chloroform) P	**12^**	**1 D 0.01 M-L**	**5.7 (Lagoon)**	**2.5**	**400°^^**	**1 (0,1)**	**0.4**	**GC/ECD/HS**
Di(2-ethylhexyl)phtalate P	1 D* 0.1 M-L	0.3D 0.03 M-L		1.3				
Pentachlorophenol P	0.4^	0.01	0.03	0.4				
Endosulfan P	0.1^	0.00001	0.009 (Lagoon)	0.005		0.01	0.01	GC/ECD
Alpha endosulfan P	0.1^	0.00001						
Lindan (γ isomer of hexachlorcyclohexane) PH	0.1^	0.001 D 0.0005 M-L				0.01	0.01	GC/ECD
α-hexachlorocyclohexane PH	0.1^	0.0002				0.01	0.01	GC/ECD
β-hexachlorocyclohexane PH	0.1^	0.0002		0.02		0.01	0.01	GC/ECD
Hexachlorobenzene PH	0.1^		0.0008 (Lagoon)	0.01		0.01	0.01	GC/ECD
Diuron P	0.1^	0.02 D 0.01 M-L		0.2				
Isoproturon P	0.1^	0.02 D 0.01 M-L		0.3				
Atrazine P	0.1^	0.01	0.01 (Lagoon)	0.6		0.01	0.01	GC/MS
Simazine P	0.1^	0.02 D 0.01 M-L	0.01 (Lagoon)	1				
Clorfenvinphos P	0.1^	0.0002		0.1				
Clorphyrifos P	0.1^	0.0001	0.006 (Lagoon)	0.03		0.01	0.01	G./ECD
Alachlor P	0.1^	0.03 D 0.01 M-L		0.3		0.01	0.01	GC/MS
Trifluralin P	0.1^	0.003 D 0.0006 M-L		0.03				
Pentachlorobenzene PH	0.03*	0.003	0.03 (Lagoon)	0.007		0.1	0.1	GC/ECD
C_{10}-C_{13}-Chloroalkanes PH	0.5 D* 0.1 M-L Temporary			0.4				
Total brominated diphenylethers PH	0.001*	0.0005		0.0005				
Nonylphenols PH	0.3 D* 0.03 M	0.03 D 0.003 M		0.3				
4(para)-nonylphenol PH	0.01 D* 0.006 M-L	0.001 D 0.0006 M-L						
Octylphenols P	0.1 D* 0.005 M-L	0.01 D 0.001 M-L		0.1				
Para-terz-octylphenol P	0.1 D* 0.005 M-L	0.01 D 0.001 M-L						

LEGEND: D: surface waters; L: lagoons; M: marine waters; LOD: limit of detection; ICP/MS: Inductively Coupled Plasma Mass Spectrometry; HPLC: High Pressure Liquid Chromatography; GC: Gas Cromatography; ECD: Electron Capture Detector; GC/ECD: Gas Cromatography with ECD detector; GC/NPD: Gas Cromatography with NPD detector; AAS: Atomic Absorption Spectroscopy; GC/MS: gascromatography/mass spectrometry; GC/MS P&T: gascromatography/mass spectrometry purge & trap; HPLC/FL: high pressure liquid cromatography/fluorescence detection; P: priority substances according to Decision n. 2455/2001/EC; PH: priority hazardous substances according to Decision n. 2455/2001/EC.

* Decree n. 367/2003.

^ Decree n. 152/2006.

^^ As the sum of tetrachlorometane, chloroform, 1,2-dichloroethane, trichloroethilene, tetrachloroethilene, trichlorobenzene, easchlorobutadiene, tetrachlorobenzene.

° Section 1 Tab. A Decree 30/07/1999.

§ Section 3 Tab. A Decree 30/07/1999 if the final wastewaters flow into a treatment plant.

§§ Section 4 Tab. A Decree 30/07/1999 if the final wastewaters flow directly into water bodies (more restricted table).

The local list of parameters, together with the EQSs for the Venice lagoon catchment basin were developed on the basis of a conservative risk analysis model concerning the protection of the entire ecosystem. A comprehensive approach was taken regarding the lagoon, based on the mass balance for each pollutant, estimated by taking into account the inflow and elimination processes, and by studying a complete mixing model and the pollutant loads discharged over the past decades. Two limits for the quality objectives were defined: a lower limit, corresponding to the background level and an upper limit, defined on the basis of a toxicity and eco-toxicity assessment and the use of the matrix (i.e. water quality, sediments and fish/mussels for human consumption).

To give a useful picture of Italian regulation constraints for WWTPs discharges for dangerous susbatances management and in particular with reference to DBPs substances in **annex III** the limit values according to Legislative Decree n. 152/2006 tab. 3 Annex V Part III, Venice Lagoon Limit values according to Ministerial Decree 30/07/1999, the reuse regulation (Ministerial Decree n. 185/2003) and drinking water quality standards (Legislative Decree n. 31/2001) are detailed and compared. From **annex III** we can observe that the Italian regulation gives limit values for the DBPs: Esachlorobutadiene, 1,2-dichloroethane, Trichloroethylene, Trichlorobenzene, Chloroform, Carbon tetrachloride, Perchloroethylene, Pentachlorophenol. Of these DBPs Chloroform and 1,2 Dichloroethane are P (priority) substances; Esachlorobutadiene and Pentachlorophenols are PH (priority hazardous) substances according to the European list (Decision n. 2455/2001/EC).

By-products of chlorine disinfection in discharges can be monitored with the following tracers:

- Chlorophorm ($CHCl_3$);
- Bromophorm ($CHBr_3$);
- Bromo-di-chloro-methane ($CHBrCl_2$);orator
- Di-chloro-bromo-metthane $CHCl_2Br$).

For each plant the analytical panel/list of tab. 3 Annex V Part III Decree n. 152/2006 is performed by ARPAV laboratory. In **annex III** the test lists for WWTPs performed by the Venice laboratory are reported.

For many of the indicated DBPs substances of chapter 4 no routinary analytical methods are available. In **annex IV** the ARPAV test lists for WWTPs discharges according to Decree n. 152/2006, Annex V Part III, Ministerial Decree 30/07/1999, Decree 30/09/1999 and the plants' authorizations are reported. The reported parameters are only the ones of interest for this study (macrodescriptors, microbiological parameters, dangerous substances/DBPs). It is pointed out that ARPAV test lists are different for BSL WWTPs (discharging into Venice lagoon and into its watershed) and no BSL WWTPs.

6.2 Analyical methods used by WWTPs' managers for discharges

6.2.1 Sampling and analytical methods for microbiologic parameters

In addition to the information already reported for ARPAV laboratory analytical methods it must be observed that:

SIBA (Paese WWTP) as well as Veritas (Fusina WWTP) and ASI (San Donà di P., Musile di P., Eraclea mare, Jezolo, Caorle WWTPs) applied, as sampling and analytical reference method for *E. coli*, used as indicator of faecal contamination of human and animal origin, the Analytical methods for water Vol. 3, 29/2003, APAT IRSA-CNR (APAT 2003); the methods also satisfies periodical intercalibrations (Schmidt, 2003).

6.2.2 PFA experimentation performed by ASI

The PFA disinfection was performed by ASI laboratory; the first experimentation in 2005-2006 was made on Caorle WWTP (first full scale experimentation) and in 2011 on Eraclea Mare WWTP (second full-scale experimentation); ARPAV participated with 3 integrative samplings only in the third full-scale experimentation activity on Jesolo WWTP during 2012. I had the opportunity of a constant discussion and assessment of the new techniwue with ASI experts.

In all the full scale phases with PFA the disinfection inlet and outlet were always monitored using automatic refrigerated sampling devices. The samples, obtained by three hours of time collection, were taken three times per week in sterile bottles containing sodium thiosulphate (10% solution) for PFA quenching. During the Phase C manual composite samples were also collected at dosing point ("T0 samples"). Immediately after collection the samples were taken to the laboratory for the analysis.

<u>Chemical characterization</u>: Unless otherwise stated, the APHA (2005) methods were used. Temperature and redox were measured during sample collection, while pH, conductivity and turbidity (APAT 2110, 2003) were analysed in laboratory. Total Organic Carbon (TOC) was determined by OI Analytical TOC-meter, whereas Total Suspended Solids were measured according to APAT 2090 (2003). Biochemical oxygen demand in 5 days was investigated using seeding-dilution method and measuring dissolved oxygen with membrane electrode.

<u>PFA Control</u>: The PFA concentration was measured on site in the unit production. Hydrogen peroxide was titrated with 0,1N ammonium cerium sulphate in 5% H_2SO_4 solution (temperature <10°C), using ferroin indicator; than in the same reaction vessel 10% potassium iodide and 3% ammonium molybdate solutions were added and the PFA title was determined by 0,1 N sodium thiosulphate solution using 1% starch solution (Greenspan at al., 1948).

The <u>formic ion</u> concentration in unit production and T_0 - outlet points was analysed by ionic chromatography (Dionex ICS 3000 with AG19 4 mm and AS19 4mm), using as mobile phase KOH gradient elution 10-45 mM.

<u>By-products</u>: The by-products in Phase C were analysed at inlet or T_0 point and at outlet. Bromate formation was investigated by Ionic chromatography (EPA 300.1 1999) and a headspace - GC-MS screening was obtained according to EPA 5021A 2003 + 8260C 2006. The

aldehydes were determined according to APAT 5010B1 2003. In the THMFP investigation initial and final THMs concentrations were measured with headspace-GC-MS (APHA 5710B 2005+EPA5021A 2003+8260C 2006). Formate and chlorate were also analysed before and after 2 days reaction.

Microbiological analysis: The microbiological analysis were performed by membrane filter technique (APAT 7020B, 7030D, 7040C 2003); each result was obtained from at least 4 independent quantifications.

6.3 Representativeness of biological data: considerations

It must be observed that the disinfection systems are not activated in all the WWTPs during all the year: usually they are activated during the bathing season according Italian law (1/04-30/09); in some cases all over the year. To supply an extensive and systematic information on the importance of the biologic pollution, that rests on the area under study, the following parameters have been assessed:

- quantitative parameters: indicators of faecal contamination (Total and Faecal Coliforms, Faecal Streptococci, Escherichia coli and Cytopathogenic virus), which do not represent human pathogenic microorganisms, but whose finding at specific concentrations points out the probability of a concomitant presence of pathogenic bacteria and virus of the gastroenteric stretch (these last two present a more difficult finding, but are able to produce gastroenteric infections of different seriuosness also at low concentrations); for this type of parameters the mean value and the log10 value of the mean have been calculated; it must be observed that the high variability of the microbiological data do not allow to apply rigorous statistical criteria.
- qualitative parameters: bacteriological gastroenteric pathogens (genus *Salmonella*), viral pathogens (genus *Enterovirus*), for which the isolation frequency percentage has been registered in the years.

6.3.1 Statistical analysis of microbiological data

The topic of environmental microbiological pollution, which has in its original derivation tight relationships with infectivology, is affected by its intrinsic characteristics of an approach rigorously on the number, necessarily different from the one used for chemo-physical data treatment. In fact, in this case the object of the study is represented by “alive pollutants”, whose concentrations can vary in the time in relation with the growth and the mortality of the same micro-organisms, following an exponential function and dependently from many environmental functions too.

As confirmed by many ISTISAN’s (Italian National Chief Health Institute) reports on the general data analysis, it must therefore be considered that the high variability of the microbiologic pollutants’ distribution in the environment, conditioned by many external factors, do not allow the application of some statistical methods of common use, like the standard deviation. To represent the microbiologic data, instead, it is used the mean value of cfu (colonies forming units) for a fixed volume sample analyzed, reported to its decimal logarithmic dimension. Conventionally, the measured environmental data representativeness is of the order of an interval of logarithmic scale (one order of size).

This data treatment system, even though it presents many limits, at the moment has the advantage to make comparable the time series produced by public institutions that have been interested on the topic in the last years (ISTISAN, public health laboratories, etc.) and represents, besides, the only possible way to translate into exploitable information the enormous amount of microbic environmental data at present measured.

6.3.2 Sampling rapresentativeness and analyzed data reproducibility

The detection frequency of a monitoring network is built on the basis of the sampling representativeness criterion. In this sense, the frequency during the years considered in the study for the monitoring stations of rivers, bathing waters and marine-coastal waters must be undertaken as significant.

The analysis carried out on WWTPs' effluents, in the considered years, instead, reflects a lower regularity in the sampling frequency, which is however compensated for the execution of mean composite samples on the three hours (since year 2005 mean weighted samples are executed on 24 hours also for the microbiological parameters; for the other parameters since 1999). Therefore the frequency of data production and homogeneity in its distribution can be considered representative, allowing a whole analysis

The high variability of microbiological data and the impossibility of defining precision and accuracy, as it happens for the chemo-physical data, make extremely difficult the standardization of the microbiological method. To guarantee the maximum data comparability it must be pointed out that the used data in this study were produced by ARPAV Provincial Department of Venice, which follows quality assurance procedures and is controlled by SINAL (Italian National Quality Certification Organism for laboratories) and therefore subjected to the application of a rigorous quality system.

6.4 Water monitoring and classification data in the period 2005-2010

6.4.1 Rivers

In the period 2005-2010 the technical criteria of Italian Decree n. 152/1999 have been applied for monitoring and classifications of rivers. According to Decree 152/2006 and Directive 2000/60/EC some integrations have already been done (dangerous, priority and priority hazardous substance monitoring). In any case till 2010 the river classification have been made according this thecnical approach. The monitoring of PLM parameters still goes on to guarantee continuity with previous monitorings, although gradually the new classification system is going to be completed; the EBI (Extended Biotic Index) monitoring is closed.

According to Decree n. 152/1999, water bodies are ranked into five classes which define the environmental quality status (final status comparable to the "Status" of the WFD deriving from Ecological Status and Chemical Status): **high; good; sufficient; poor; bad**. The *Ecological Status* is performed combining the Pollution level defined by chemical and microbiological parameters (PLM - so called "macro-descriptors") with the results of a macro-benthos index (as for example the EBI), a synthetic index of the biological quality based on benthonic macro-invertebrates. The Ecological status is expressed in 5 classes from 1 (the best class) to the 5 (the worst class) and is determined with the crossing of the mean result of biotic index and the macro-descriptor parameters: **N-NH_4; N-NO_3; P_{tot}; Dissolved O_2 as saturation percentage; BOD_5; COD; *Escherichia coli*.**

With macrodescriptors the organic pollutants the eutrophisizing substances and the microbioogical pollution can be monitored. It is highlighted that is attributed to the river section or to the stretch represented by the same section the worst result between the ones obtained from the Biotic Index and Macrodescrptor parameters. The **Pollution Level with Macrodescriptors** (PLM) is the sum of the scores defined by the table below defined with the 75° percentile of each macrodescriptors in the considered period. The possible scores are the following: 80 (the best condition), 40, 20, 10 e 5 (the worse condition). PLM are reported in **tab. 6.3**.

Table 6.3 *– Concentrations corresponding to the different Pollution Levels expressed by Macro-descriptors (PLM) – Reference: Italian Decree n. 152/1999*

Parameter	Level 1	Level 2	Level 3	Level 4	Level 5
100-Dissolved Oxigen (% sat.)	≤ 10	≤ 20	≤ 30	≤ 50	> 50
BOD_5 (O_2 mg/L)	< 2,5	≤ 4	≤ 8	≤ 15	> 15
COD (O_2 mg/L)	< 5	≤ 10	≤ 15	≤ 25	> 25
NH_4 (N mg/L)	< 0,03	≤ 0,10	≤ 0,50	≤ 1,50	> 1,50
NO_3 (N mg/L)	< 0,3	≤ 1,5	≤ 5,0	≤ 10,0	> 10,0
Total Phosphorous (P mg/L)	< 0,07	≤ 0,15	≤ 0,30	≤ 0,60	> 0,60
Escherichia coli (UFC/100/ml)	<100	≤ 1.000	≤ 5.000	≤ 20.000	> 20.000
Scores to be assigned for each analyzed parameter (75° percentile in the monitoring period)	80	40	20	10	5
POLLUTION LEVEL WITH MACRODESCRIPTORS (PLM)	*480-560*	*240-475*	*120-235*	*60-115*	*<60*

The *Ecological Status* determination process is reported in **tab. 6.4**. The *Environmental status* of the surface waters is derived from the assessment of the *Ecological status* and the *Chemical Status* of the water body.

Table 6.4 *– Ecological Status of water bodies (the worst result between Biotic Index and Pollultion Level with Macrodescriptors (PLM) – Reference: Italian Decree n. 152/1999*

	Class 1	Class 2	Class 3	Class 4	Class 5
Extended Botic Index (EBI)	≥ 10	8 – 9	6 – 7	4 – 5	1, 2, 3
Pollution Level with Macrodescriptoprs (PLM) – Scores	480 – 560	240 – 475	120 – 235	60 – 115	< 60

The *Chemical Status* is defined with the comparison of the measured values of the parameters in the "list of pollutants" (see some specific indications of Decree n. 152/1999 in **tab. 6.5**; this list can be useful as a preliminary approach, but it must be remembered that the list to be applied is in the end the list of Directive 2008/105/EC). For a complete general list see annex VIII of WFD; the list of chemical pollutants for Veneto regional surface water monitoring has been revised since 2011.

Table 6.5 *– Suggested main pollutants' list – Preliminary monitoring*
Reference: Italian Decree n. 152/1999

INORGANIC COMPOUNDS (dissolved)[(1)]	ORGANIC (on the raw sample)
Cd	Aldrin
Total Cr	Dieldrin
Hg	Endrin
Ni	Isodrin
Pb	DDT
Cu	Esachlorobenzene
Zn	Esachlorocyclohexane
	Esachlorobutadiene
	1,2 dichloroethane
	Trichloroethylene
	Trichlorobenzene
	Chloroform
	Carbon tetrachloride
	Perchloroethylene
	Pentachlorophenol

The *Environmental Status* is attributed (**tab. 6.6**) with the comparison of *Ecological Status* data with data relative to the **main chemical micro-pollutants** (it means the ones that is possible to find in the water bodies according to existing discharges and industrial cycles in the area of analysis, phyto-pharmaceuticals products for agriculture, etc.), that is heavy metals, halogenated compounds, phyto-pharmaceuticals compounds. If all additional parameters present values (expressed as 75° percentile on the monitoring period) below the established threshold values (environmental quality standards-EQS), the *Ecological Status* corresponds to *Environmental Status*; if almost one of the additional parameters takes over the established threshold value parameters, the *Environmental Status* becomes automatically Poor.

Table 6.6 *– Determination of the Environmental Status from Ecological Status and Chemical Status – Reference: Italian Decree n. 152/1999*

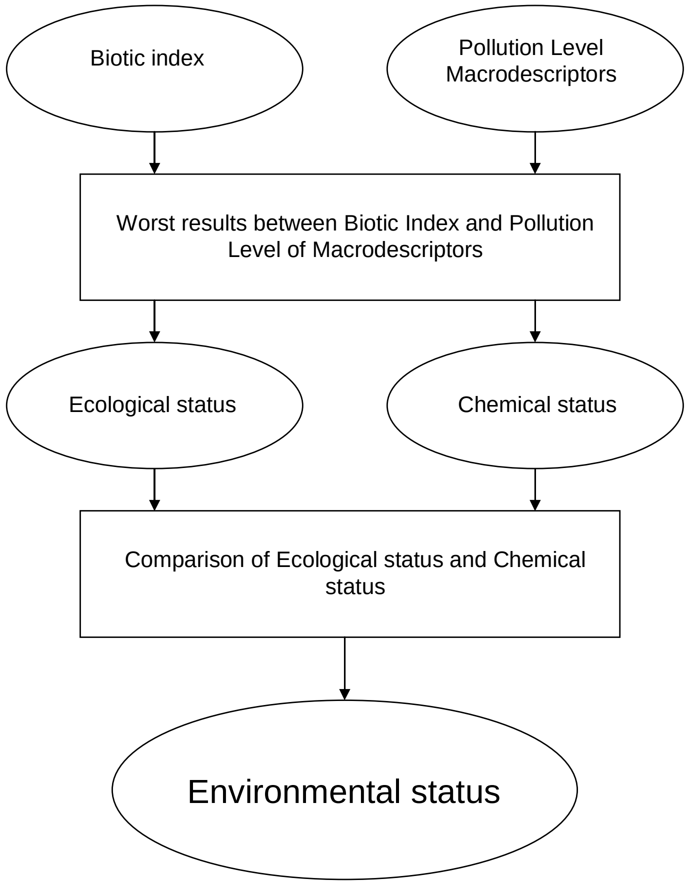
Ecological Status ⇒	Class 1	Class 2	Class 3	Class 4	Class 5
Conncentration of chimica pollutants from the "list of pollutants ⇓					
≤ Threshold value (EQS)	High	Good	Poor	Poor	Bad
> Threshold value (EQS)	Poor	Poor	Poor	Poor	Bad

The whole classification process (definition of: *Ecological Status* + *Chemical Status* = *Environmental Status*) is reported in **fig. 6.1**.

6.4.2 Bathing waters

Bathing water classification and monitoring approach was based on Italian Decree n. 470/1982 (which had transposed Directive 76/160/EEC) till year 2009, while since Aprile 2010 (beginning of the bathing season) it was changed according the Legislative Decree n. 116/2008 which transposed the Directive 2006/7/EC on bathing waters.

Figure 6.1 *– Determination of the Environmental Status from Ecological Status and Chemical Status – Reference: Italian Decree n. 152/1999*



The most important change with the new regulation is the use of two indicators: EC and IE. The regulation requires 1 sample every 31 gg for each monitoring station with:

- obligation to sample in a time indow of 4 days with reference to an official agenda transmitted to the Health ministry at the beginning of the year;
- determination in situ only of the parameter temperature, oceanographical and leteorological data and data on the presence of wastes, etc.;
- determination in laboratory of the microbiological parameters IE (limit value 200 cfu/100 ml) and EC (limit value 500 cfu/100 ml).

In case of overtraking of the limit values the major of the commune is oblie to adopt the prohibition of bathing for the interested point and its influnce area; the prohibition is repealed after the respect of the limit values in one of the successive samplings.

7. Wastewater treatment plants (WWTPs) control approach and microbiological impact reduction

7.1. The control approach on WWTPs: integrated and functionality approach

7.1.1 Introduction

The European Recommendation 2001/331/EC (EC, 2001) bases the environmental controls of industrial sites and WWTPs on an integrated approach surpassing the simple analytic control at the discharge point in the receiving water body. This integrated approach requires documentary, technical, management and analytic controls. In the last few years the Veneto Regional Environmental Prevention and Protection Agency (ARPAV-Italy) has developed and applied a protocol and check-list for the implementation of the European Recommendation for WWTPs (Ostoich et al., 2010). The check-list includes the functionality assessment of the WWTP in the cases of discharge control delegation to the plant management as consented in Annex 5, the third part of Italian Decree 3/04/2006 n. 152.

For microbiological impact, according to ASI experimentation on influent and effluent quality data for plants with secondary treatment, the biological depuration process is normally able to guarantee 2 log of abatement (Ragazzo et al 2007; 2011). For this reason the reliability of a plant for this benchmark can be verified through the functionality analyses here proposed.

7.1.2 The hierarchical approach for environmental control planning

For WWTPs plants' discharge control a hierarchical approach is necessary. The reasons behind the need to rationalize, plan and reorganize environmental control activities can be synthetised into the following points:

- unsatisfactory efficacy of controls;
- while increasing the control "demand", the system is pushed to increase the quantitative levels of response;
- un-sustainability of the response model due to scarce available resources;
- the prevalence of repressive aspects of control and defensive behaviour of companies as a consequence.

These aspects, typical of the traditional control system at a regional level in Italy lead to:

- inconsistent controls on the regional territory, according to the different priorities decided by Provincial Administration (responsible of environmental controls) and the availability of resources;
- strong incidences of unplanned controls (emergencies, point requests, etc.);
- sharp prevalence of analytical controls on environmental outputs of productive plants in comparison with integrated controls of productive processes.

Therefore, with the aim to rationalize controls, the following requirements in the organization of controls on pressure sources must be stipulated:

- to standardize the approach in the control procedures at the regional level (standard protocols);

- to promote integrated controls to verify the comprehensive impact of a plant or industrial process on the environment;
- to promote controls which are much more orientated to all of the plant procedures, i.e., the plant characteristics, behaviour and management, rather than just on the emissions of pollutants;
- to function following planned activities which take account of the environmental significance (hierarchy) of pressure sources and of the availability of resources for controls.

7.1.3 WWTPs' integrated controls

The control of a firm has multiple aims: it is useful for the verification of the conformity with emission limits, for the quantification of technical performances and for the verification of environmental auditing performed by the plant manager. This control must consider not only emissions, but also the consumption of resources (matter, energy); the exceptional contributions of emissions, while the transitional phases (start up, stopping, etc.) and fugitive emissions must also be assessed.

The approach to environmental controls proposed and built according to the hierarchical system, is a preventive integrated control, or more specifically, a control where the aim is not to verify just one environmental aspect (for example the analytical control), but which could be useful in gathering all data and information which are "diagnostic" for the assessment of the functioning of the plant (point pressure source). This is useful in establishing the situations which can, more or less, guarantee the functioning of the plant in respecting regulations and thus, reducing the reactive behaviour and promoting a preventive one. To set up integrated controls, specific *Protocols for Control of Pressure Sources* (PCFP) have been prepared and experimented. These protocols allow the following types of control:

- *Documentary*: textual verification without measures, sampling and/or analysis made by the plant manager;
- *Technical*: verification of structural characteristics of the plant and its accessories with respect to the environmental quality standards;
- *Management*: verification of management requirements of the plant, verification of self-certifications, audit of the environmental management system;
- *Analytical*: (direct) monitoring of the environmental impact aiming to guarantee the compliance to pertinent environmental limits.

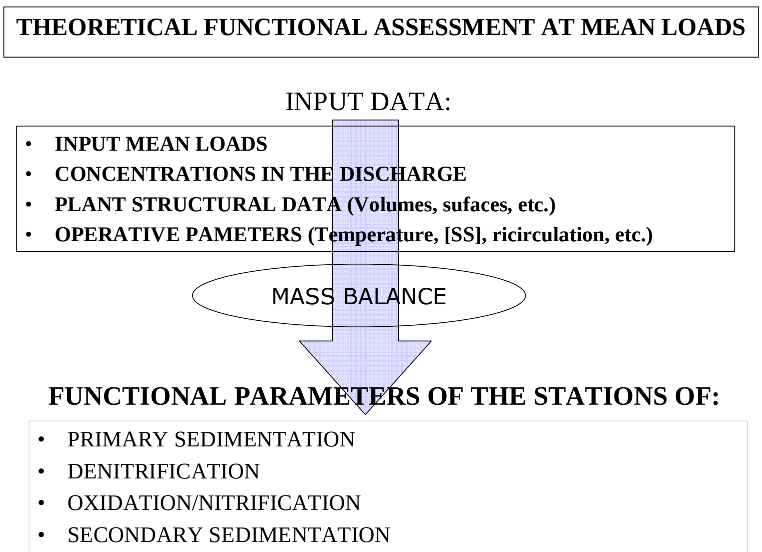
The protocols are based on the following questions: what should be controlled? In which conditions should the control be conducted? With what frequency it is necessary to make the control? ARPAV has already prepared protocols for control activities on: Wastewater Treatment Plants (WWTPs), on landfills, on physical agents, on process industries (industrial settlements), on waste incinerators and large combustion plants; other protocols are currently under experimentation.

7.1.4 WWTPs' functionality assessment

Within the control activities, the *manager's report* must be used to gather basic information so far unknown by the control Authority, the manager must provide this under his personal responsibility as self-certification; moreover an *operative check-list* must be used. The *manager's report* is subdivided into the following 3 sections: "Anagraphic" Section (local unit, legal head); "Plant" Section (water line, waste line, sludge line, phytodepuration line, etc.); "Technical Data" Section (dimension and potentiality, operative parameters, wastewater characterization, sludge production, liquid waste production, reuse of treated wastewater, resource consumption).

The operative check-list is realized according to the integrated control and includes the documentary, technical, management and analytic controls. In **fig. 7.1** the elements of the functionality verification are reported: the assessment refers to the theoretical verification at mean loads and is carried out with a precompiled electronic spreadsheet. The functionality verification, using data obtained during the inspection visit – including self-certification, analytical determinations, structural and management data – provides information regarding plant behaviour and information on each of the single sections in extreme conditions.

Figure 7.1 *– WWTPs' theoretical verification at mean loads (Ostoich et al, 2010)*



In the experimental control activities for the application of the protocol and the operative check-list, the following activities were carried out:

- visit to WWTPs considered eligible for delegation (on the basis of the past information);
- compilation of the "manager's report";
- compilation of the "operative check-list";
- functional theoretical verification at mean loads;
- study of time series of discharge control analysis (at least two years).

From these activities judgement of the effective possibility to delegate the controls to the WWTPs' manager can be determined.

In **Annex V** the depuration biological processes are described with the laws used in the functionality verification. Integrted controls and functionality verification have been developed by ARPAV with my personel contribution in recent years to support the institutional WWTPs' control activity but also – in accordance with the Provinces – the possibility of controls' delegation to the plant managers for parameters BOD_5, COD, TSS, N, P as stated in Annex V Part III Leg. Decree n. 152/2006. **Parameters of tab. 3 Annex V Part III of the Deccree – among which also Escherichia coli – cannot be delegated**.

A specific procedure was proposed to Veneto Regiona by ARPAV and approved by with Delibertion n. 578/2011 (Veneto Region, 2011). In **Annex VI** details on the control delegation criteria are supplied.

7.2 Approach for microbiological impact control and reduction

The importance of the control and monitoring of the coastal marine waters (Bartram & Rees, 2000) is particularly evident in the Venice province, where many and important tourist sites are localized. Furthermore, the economic and urban development of the province is responsible of significant discharges both into the rivers and into the marine waters, with the need of efficient WWTPs. Therefore, the sanitary and environmental "quality" of the coastal belt of the Province, is very important both from the environmental and from the economical point of view (tourism). As already said the use of disinfection for WW has the following consequences:

- higher costs;
- the need of a plant up-grading if not already realized;
- production of by-products (at higher or lower level).

Thereforethe decision to impose disinfection must be taken by the responsible Authority (Province) considering:

- use of the receiving water body (drinking water production, bathing waters, shellfish waters, irrigation, etc.);
- existing pressure sources;
- microbiological quality of receiving water bodies
- specific risk factors.

This § develops the approach on water monitoring (rivers and marine-coastal waters), application of the DPSIR scheme for the achievement of water quality objectives according to Directives 2000/60/EC, 2006/7/EC and other specific uses of the water resources; finally the integrated approach for integrated microbiologic assessment is discussed.

7.2.1 The DPSIR scheme

The proposed approach, due to indication of the WFD 2000/60/EC and the directive 2006/7/EC, is based on the Driving forces-Pressure-State-Impact-Response (DPSIR) scheme and on the integrated analysis (consideration of the different matrices together). The DPSIR scheme is here proposed in order to achieve the environmental objectives of the water bodies: for this purpose the planning tool is the Water Protection Plan (WMP) and it can be performed starting from driving forces (population, economic activities, etc.) realizing infrastructures like sewers and WWTPs, than monitoring water bodies and controllinf pressure sources, while guaranteeing a good functioning of the plants and then suggesting a rationale application of disinfection moinimizing negative effects from by-products.

The conceptual schemes, which have already been consolidated in the literature and realized in the European context, and which are a great aid in terms of the structuring of environmental information so as to render it more accessible and intelligible for decisional and informative purposes, are those elaborated by the OECD (1994) and by the European Environmental Agency (EEA, 1995). The model proposed by the OECD clearly outlines the fundamental connection between the environmental and anthropogenic systems and effectively clarifies the deeply-rooted relationship between society and its ecosystems. In keeping with the above-mentioned schemes three categories of indicators were outlined using a PSR model (OECD, 1994) 1) pressure indicators; 2) state indicators; 3) response indicators. On the basis of this model, it is possible to organize the environmental indicators according to different themes; they can be considered individually or on a more aggregative level. The DPSIR model, created by the European Environmental Agency, was created to improve the PSR model and to take account of those factors which are not easily verifiable but have a relevant impact on environmental conditions, and are the *driving forces* behind these problems (e.g, populations, industries, etc.). Moreover the *Impacts* are considered. The DPSIR model illustrates the complexity of socio-environmental interactions. It also allows for the calculation of the relative possibility of reaching the objectives of an intervention program.

The application of the DPSIR scheme requires the definition of the interest area; in this area the driving forces must be identified and quantified (population, tourists, agriculture, cattle, industry, etc.); point pollution sources must be searched and localized; the water monitoring status has to be measured and assessed and consequently improving actions to achieve the environmental and sanitary objectives must be implemented.

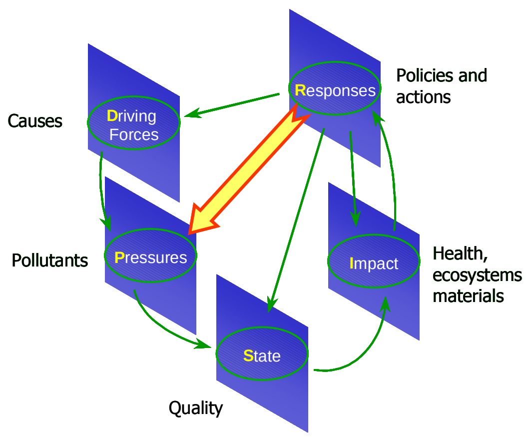
The DPSIR framework, proposed by the European Environmental Agency (EEA 1995, 1998), illustrates the complexity of socio-environmental interactions, lacking in the previous PSR model, but which present an integrated approach for reporting purposes (Kristensen 2004). Criticisms of the DPSIR framework are present in literature. Svarstad et al. (2008) outline that the framework is unable to take into account the dynamics of the system it models; this is evident if we consider the different intervals at which data are monitored and registered with regard to *Driving Forces* and *State*. With regard to water management it can be argued that the *Driving Forces* must define the long-term scenario, while *Pressure* and *State* should be assessed in the short and middle terms according to WFD requirements.

Despite the above mentioned criticisms, the DPSIR framework is widely used for water resources management and reporting (APAT 2001; Bowen & Riley 2003; Kristensen 2004; Skoulikidis 2009) and particularly in the development of integrated management strategies (Hughey et al., 2004). The DPSIR has been widely applied at basin level and is recognized as an effective environmental management tool (Cave et al. 2003); scientific literature and technical reports accept that the DPSIR framework provides useful support in water management at both local and basin levels (APAT 2001; Cave et al., 2003; Skoulikidis 2009). The DPSIR framework is the common analysis scheme for all regional catchments in Eurozone studies, with a view to evaluating environmental and socio-economic systems in European river basins; an example is the Humber catchment which was analysed at European level in a project carried out by EU officials (Cave et al. 2003; Salomons 2004). Bellos and Sawidis (2005) propose the DPSIR as a framework for environmental reporting and as an environmental support system (ESS) for decision–makers.

In the current study on the Fratta-Gorzone river the DPSIR framework was applied to evaluate the situation and help reach objectives through water and sediment monitoring, the control of pressure sources and the design of intervention measures. Cave et al. (2003) consider sediment quality as a "state" indicator while, base on other scientific references, this paper considers sediment quality as an "impact" indicator (APAT 2001).

In **fig. 7.2** the DPSIR scheme is detailed. According to DPSIR scheme one fixed the environmental objectives (quality of river, bathing waters, etc.) monitoring of the state and the quality of the pressure sources allows to decide which measures must be implemented given the driving forces. Impacts are strictly connected with the uses of the considered resource (bathing, drinking, irrigation waters, etc.).

***Figure 7.2** – DPSIR scheme*



7.2.2 Integrated assessement for coastal management

The application of the approach expressed in the new European legal framework (Directives 2000/60/EC and 2006/7/EC) requires the overtaking of distinct analysis for each single matrix (rivers, bathing and marine waters, WWTP effluents, etc.). The new approach favours *integrated quality assessment* of the separated components of the territorial hydro-systems, analysed for their reciprocal relationships in accordance to Driving forces-Pressures-State-Impact-Responses (DPSIR) model.

To protect sea resources from enteric bacteria pollution, coming from the rivers' flow and the WWTPs discharges, environmental management and safeguarding practices must be devised and implemented, based on a sound knowledge of the fate of these micro-organisms in the environment. The proposed approach is based on the recovery of historical data-bases of data from WWTPs controls, of monitoring data about various water matrices (rivers, bathing, coastal and marine waters) and on the assessment of faecal concentration parameters, for the *integrated quality assessment* of microbiologic impact, using the DPSIR model. The *integrated quality assessment* is here presented as preliminary to the more comprehensive *Integrated Coastal Management* (ICM) (Bowen and Riley, 2003; World Bank, 2002; Xue et al. 2004). In synthesis:

- the approach is based on the application of the approach expressed in the new European legal framework (directive 2000/60/EC and directive 2006/7/EC) requires the overtaking of distinct analysis for each single matrix (rivers, marine waters, WWTP effluents, etc.);
- the approach favours ***integrated quality assessment*** of the separated components of the territorial hydro-systems, analysed for their reciprocal relationships in accordance to ***Driving forces-Pressures-State-Impact-Responses (DPSIR) model***;
- the DPSIR model, proposed by the European Environmental Agency, was derived from the simpler model Pressure-State-Responses for which many are the applicatory examples on waters in literature;
- to protect sea resources from enteric bacteria pollution, coming from the rivers flow and the WWTPs discharges, environmental management and safeguarding practices must be devised and implemented, based on a sound knowledge of the fate of these micro-organisms in the environment.

The selected area for the study on the period 2000-2006 (see Chap. 10) is situated along the coast of the province of Venice and the monitoring sites (**tab. 3.5** anf **fig. 3.12**) and involves the following matrices:

- *River waters*: the monitoring points belong to the regional network for monitoring and classification of internal water bodies and has been organized in this configuration since 1/1/2000; they are normally localized on bridges (regional/provincial roads) or other accessible sites on rivers; sampling is carried out 30 cm under the water surface; the sampling frequency is 1/month for a total of 12 samples/year for each monitoring station).
- *Bathing waters*: localized 30 m from the beach; they represent a 500 m wide belt from the shore line; sampling is carried out from a boat 30 cm under the water surface during the bathing monitoring period (1st April-30th September; during the other months bathing water monitoring is not performed); the monitoring stations were integrated in years 2005 and 2006 with two more stations (n. 528 and 529) in the stretch n. VIII (reported in bold type in **tab. 3.5**); for each monitoring station 2 samples/month for 6 month/year were performed.

- *Marine-costal waters*: at 500 m from the coast (the first point of a transept of 3 points from 500 m to 1,5 km from the shore line); sampling carried out from a boat 30 cm under the water surface during the bathing season as well during the rest of the year; the monitoring network is constituted with transepts; this network was changed in 2004; in 2002 and 2003 data on biological parameters were not produced; since 2004 there has been a reduction of the sampling points and consequently the stretches n. II, III and V (**tab. 3.5**) no longer have monitoring stations for the considered biological parameters (the new monitoring points are highlighted in bold).
- *WWTPs*: 9 plants (identified with numbers 1-9 in **tab. 3.5** and **fig. 3.12**) known to have a direct and significant biologic impact on the marine-coastal waters and interested during the bathing monitoring period with integrative controls on effluents (during this period there is a significant increase of tourism; sampling activity is concentrated during the bathing season unless some samples are performed also in the period 1st October-31th March; not in all the considered WWTPs the disinfection system is active all over the year); for two WWTPs (Cavallino n. 7 and Lido n. 8) submarine outfalls allow discharge into the sea about 4 kms off-shore.

7.2.3 Statistical assessment of monitoring data in the coastal integrated analysis

The study focuses on living pollutants (the microorganisms) whose concentration varies over time in relation to their growth and mortality according to an exponential function and depending on many environmental variables (temperature, sun radiation, water salinity, etc.). To represent the microbial data, the mean value of cfu (colony forming unit) was used for a fixed volume of sample. Conventionally the representativeness of the detected environmental data is of the order of one degree of the logarithmic scale.

For an appraisal of the causes of biological pollution detected in sea water, to investigate the relationships among the characterization of WWTPs' discharges, the rivers' water quality (in their last part before the sea mouth) and the sea water quality a statistical assessment of the monitoring and control data was performed with the analysis of variance (one-way ANOVA). ANOVA results for the investigated parameters in the different matrices (rivers, discharges, coastal and marine waters) for each chosen stretch have been calculated for the F test values and for the critical value ($F_{0.05}$) imposing a p-value of 0.05. When variations among matrices (station type groups: rivers, WWTP discharges, bathing waters, sea waters) show significant differences ($F>F_{0.05}$) a multiple comparison was performed to identify the groups that differ significantly from the others.

7.3 Evaluation of the efficiency of WWTP disinfection system and abatement rule

The assessment of the efficiency of the WWTPs' disinfection system was conducted with data from influent and effluent samples (with reference to the disinfection unit), produced by the plant managers. Data on the influent/effluent refer to the period 2006-2011 for Paese and ASI WWTPs, while for Veritas WWTP only to 2012; mean values were considered. Efficiency was calculated with the following formula:

$$\frac{CT_{IN} - CT_{OUT}}{CT_{IN}} 100 = \textit{percentage of abatement}$$

As a general rule the assessment of the abatement efficacy of the disinfection system, requires the percentage of abatement of bacteria (*Total* and *Faecal coliforms*, *Faecal streptococci*, *Escherichia coli*) to be at least 99.99% with two decimal digits and the pathogen, if present in the inflow, must be absent in the outflow (Zann & Sutton, 1995; Ostoich et al., 2007, Ostoich et al. 2013).

7.4 Impact of submarine oufalls

To assess if the two submarine outfalls of WWTPs Lido and cavallino at 4 km from the coast can have an impact on the coastal belt quality the 3D model SHYFEM developed by CNR of Venice (Umgiesser et al., 2008). The studie was developed together with ARPA FVG and CNR for the submarine outfalls of the Northern Adriatic sea. I did not developed the model but supported collegues of ARPA FVG for the simulations.

The 3D version of the finite element model SHYFEM, developed at ISMAR-CNR in Venice (Umgiesser et al. 2008), was implemented and preliminarily applied to investigate the bacterial dispersion and the area of influence of the submarine discharges. Due to the characteristics of the Northern Adriatic Sea, as mentioned above, the numerical simulations were performed during the autumn period, when no stratification occurs and the plume can reach the surface layer, so that occasional bacterial pollution events may ensue. On the contrary, during spring-summer time the presence of the thermocline tends to confine the sewage to the bottom layer.

7.4.1 The SHYFEM model

The 3D SHYFEM model has been implemented to simulate the hydrodynamics of the Northern Adriatic Sea. The model, in its 2D version, has been applied in many studies in the Venice Lagoon area (Umgiesser 2000; Umgiesser et al. 2004; Cucco & Umgiesser 2006). It is a primitive equation model, based on the solution of momentum and continuity shallow water equations. The complete equations, after dividing the water column in vertical layers, are:

$$\frac{\partial u_l}{\partial t} + u_l \frac{\partial u_l}{\partial x} + v_l \frac{\partial u_l}{\partial y} + w_l \frac{\partial u_l}{\partial z} - f v_l = -g \frac{\partial \zeta}{\partial x} - \frac{1}{\rho_0}\frac{\partial p_a}{\partial x} - \frac{g}{\rho_0}\frac{\partial}{\partial x}\int_{-H_l}^{\zeta} \rho' dz$$

$$+ v_t^H \left(\frac{\partial^2 u_l}{\partial x^2} + \frac{\partial^2 u_l}{\partial y^2} \right) + \frac{1}{\rho_0} (\tau_x^{l-1} - \tau_x^l)$$

$$\frac{\partial v_l}{\partial t} + u_l \frac{\partial v_l}{\partial x} + v_l \frac{\partial v_l}{\partial y} + w_l \frac{\partial v_l}{\partial z} + f u_l = -g \frac{\partial \zeta}{\partial y} - \frac{1}{\rho_0}\frac{\partial p_a}{\partial y} - \frac{g}{\rho_0}\frac{\partial}{\partial y}\int_{-H_l}^{\zeta} \rho' dz$$

$$+ v_t^H \left(\frac{\partial^2 v_l}{\partial x^2} + \frac{\partial^2 v_l}{\partial y^2} \right) + \frac{1}{\rho_0} (\tau_y^{l-1} - \tau_y^l)$$

$$\frac{\partial \zeta}{\partial t} + \frac{\partial}{\partial x}(u_l h_l) + \frac{\partial}{\partial y}(v_l h_l) = 0$$

with *l* the vertical layer, (u_l, v_l, w_l) horizontal velocities in (x,y,z) direction, p_a atmospheric pressure, *g* gravitational acceleration, *f* the Coriolis parameter, □ sea level, □□□□□□' water density, H_l depth of the vertical layer *l*, h_l the layer thickness, and v_t^H , horizontal eddy viscosity. The stress terms for each vertical interface are written as:

$$\tau_x^l = v_t^V \left(\frac{\partial u}{\partial z}\right)_l \text{ and } \tau_y^l = v_t^V \left(\frac{\partial v}{\partial z}\right)_l$$

with v_t^V being the vertical eddy viscosity. Boundary conditions for the stress terms are the usual quadratic bulk formula for the wind drag and the bottom friction. The equation for the transport and diffusion of temperature and salinity are:

$$\frac{\partial S_l}{\partial t} + u_l \frac{\partial S_l}{\partial x} + v_l \frac{\partial S_l}{\partial y} + w_l \frac{\partial S_l}{\partial z} = v_s^H \left(\frac{\partial^2 S_l}{\partial x^2} + \frac{\partial^2 S_l}{\partial y^2}\right) + v_s^V \frac{\partial^2 S_l}{\partial z^2} + Q$$

where S_l is the salinity (or temperature) of layer *l*, v_s^H and v_s^V are the horizontal and vertical diffusivities, respectively, and *Q* represents the sources and sinks for salinity and temperature. The 2 momentum equations, the continuity equation and the 2 conservation equations for salinity and temperature, together with the hydrostatic equation and the equation of state, form a set of 7 equations with 7 unknowns that are solved by the finite element method.

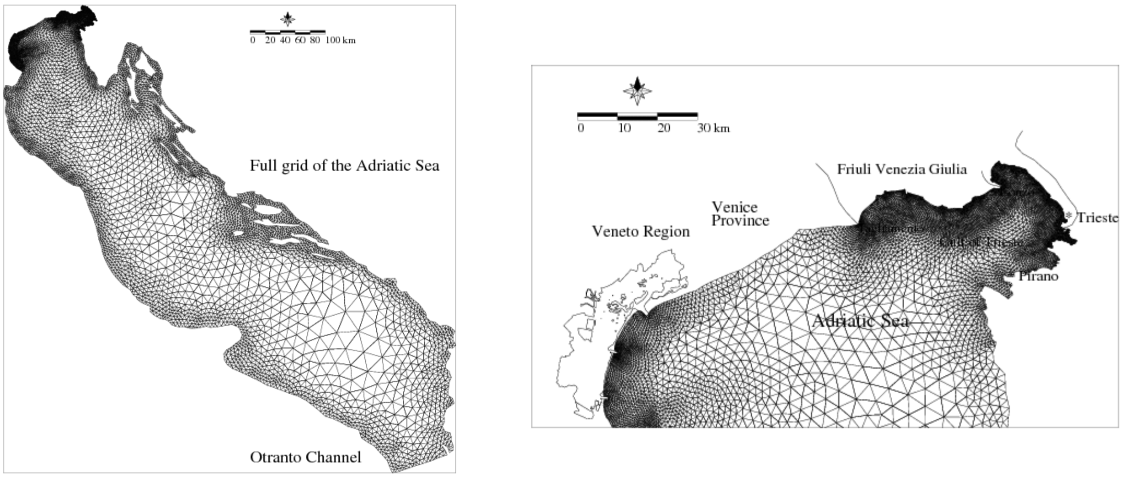
The SHYFEM model applies a finite element Arakawa B grid for the horizontal and z-layers for the vertical discretization. The barotropic pressure gradient, the Coriolis term and the divergence terms in the continuity equation are semi-implicitly discretized, while the bottom friction and the vertical stress terms are fully implicit. The baroclinic, advective and horizontal diffusion terms are explicitly discretized. The model is therefore unconditionally stable with respect to fast gravity waves, Rossby waves, vertical diffusion and bottom friction. The boundary conditions are free slip on material boundaries. On the open boundaries (rivers) either fluxes or water levels have to be prescribed.

7.4.2 The numerical grid

Due to boundary conditions, the modelling of the Northern Adriatic sea would be extremely complicated, therefore for our purposes, the boundary has been moved far from the investigated area, up to the Strait of Otranto, which represents the open boundary. The spatial domain is composed of the Adriatic sea, and the computation grid contains 8,072 nodes and 15,269 elements (**fig. 7.3** - left). The horizontal resolution varies from about 100 meters along the coastline of Veneto and Friuli Venezia-Giulia regions up to 60 km in the central Adriatic sea. The bathymetric data have been derived from the NOAA 1:250000 for the Adriatic Sea while they have been obtained from ARPA FVG for the Northern part of the Adriatic Sea.

The model grid is constructed with an automatic mesh generator, starting from the coastline of the whole basin of the Adriatic Sea. As shown in **fig. 7.3** - right, a higher grid resolution has been imposed in the zones of major interest for the research, such as the coastal areas of the Venice province and of the Friuli Venezia-Giulia region.

***Figure 7.3** – Grid for simulation in Adriatic sea*



7.4.3 Simulation set up

The numerical simulations have been carried out with meteo-marine forcings data (tide, wind, etc.) from autumn 2007. The time step of the simulations is 300 s. Wind and pressure data have been generated by the global atmospheric model of the European Centre for Medium Range Weather Forecast (ECMWF) of Reading, UK, these are available for the whole Mediterranean area, with a spatial step of 0.5 degrees in latitude and longitude. An astronomical tide has been imposed at the strait of Otranto, taking into account the 7 main astronomical components, 4 semi-diurnal (period of 12 hours) M2, S2, N2 and K2 and 3 diurnal (period of 24 hours), K1, O1 and P1.

In the vertical discretization, the water column has been divided into 16 layers. The thickness of these layers, relevant for the Northern Adriatic Sea, range from 3 to 5 meters. For the microbiological parameters, data collected during in situ campaigns by ARPAV and ARPA FVG and data from the treatment plants (WWTPs managers data) for the Veneto region, provided by Veritas, have been used. Estimates of the river basin Authority and of the WWTPs managers have been used for Veneto region rivers. Since most of the submarine discharges (7/9 in Veneto and Friuli-Venezia Giulia) come from treatment plants with a biological stage, a cautious decay time (e-folding time) of 1 day was used as the decay parameter. This parameter has been estimated through literature values (Crane and Moore 1986), but ideally specific studies would be needed to confirm these numbers..

PART III: RESULTS AND DISCUSSION

8. WWTPs' control and monitoring data

8.1 Census of WWTPs and the integrated controls in Veneto

At regional level in Veneto the WWTPs > 2,000 PE are n. 238, of which n. 136 lower than 10,000 PE, n. 85 between 10,000 and 100,000 PE and n. 17 > 100,000 PE; WWTPS < 2,000 PE are n. 285 with a total potentiality of 208,729 PE (the 2.3 % of the whole potentiality in Veneto region see **tab. 8.1**) with reference to year 2009 (Ostoich et al., 2011). The **tabs 8.2-8.3** detail the number of WWTPs present and their nominal potentiality (expressed in PE) subdivided into the provinces and potentiality class.

Table 8.1 *– Number of WWTPs in Veneto region and nominal potentiality for class of PE (source SIRAV cadaster-ARPAV)*

Potentiality class	Number of plants	Total nominal potentiality (PE)
≥ 100.000 AE	17	5533600
10.000-100.000 AE	85	2588218
2.000-10.000 AE	136	565473
< 2.000 AE	285	208729
Total	**523**	**8896020**

Table 8.2 *– Number of WWTPs in Veneto region for potentiality class and province (source SIRAV cadaster-ARPAV)*

Province	Number of WWTPs for each potentiality classes (PE)				
	< 2.000 PE	2.000-10.000 PE	10.000-100.000 PE	≥ 100.000 PE	Total
BL	34	26	3	1	64
PD	21	20	24	1	66
RO	48	19	9	0	76
TV	51	25	16	0	92
VE	21	18	6	7	52
VI	65	16	12	6	99
VR	45	12	15	2	74
Total WWTPs	**285**	**136**	**85**	**17**	**523**

Table 8.3 *– Total nominal potentiality of WWTPs in Veneto region subdivided into class potentiality and province (source SIRAV cadaster-ARPAV)*

Province	WWTPs nominal potentiality for each classe (PE)				
	< 2.000 PE	2.000-10.000 PE	10.000-100.000 PE	≥ 100.000 PE	Total
BL	26,880	99,900	63,000	102,600	292,380
PD	20,850	86,400	649,830	147,000	904,080
RO	40,130	65,650	273,600	0	379,380
TV	33,845	113,233	488,500	0	635,578
VE	9,905	77,940	194,500	1,160,000	1,442,345
VI	36,836	57,350	503,288	3,464,000	4,061,474
VR	40,283	65,000	415,500	660,000	1,180,783
Total potentiality	**208,729**	**565,473**	**2,588,218**	**5,533,600**	**8,896,020**

With reference to the integrated controls of pressure sources (WWTPs in this case) introduced in Chapt. 7, the situation of the integrated controls on WWTPs in Veneto region with the detail of the province of Venice is here brefly reported (**figs 8.1 a-d**). Control data are referred to the activity on WWTPs performed by ARPAV during year 2009 and have been extracted from SIRAV Cadaster. It is evident the higher number of the performed analytical controls in comparison to other types of controls (see plants > 50.000 PE; **fig. 8.1 a**).

From SIRAV Cadaster the WWTPs with potentiality ≥ 10,000 PE have been recovered for Veneto region and for the province of Venice; the list is reported in **tab. 8.4**. The WWTP of Cavarzere was not anymore considered as its final discharge flows into the secondary irrigation networks and it influences the coast in the provinince of Rovigo. Moreover the Portogruaro WWTP was considered because, although it is < 10,000 PE, from historical knowledge of the province of Venice it can have a direct impact on the coastal belt (Ostoich et al., 2012).

Figure 8.1 *– Documentary, technical, managment and analytical controls Total nominal potentiality of WWTPs in Veneto region subdivided into class potentiality and province (source: SIRAV cadaster-ARPAV)*

Fig. 8.1 a

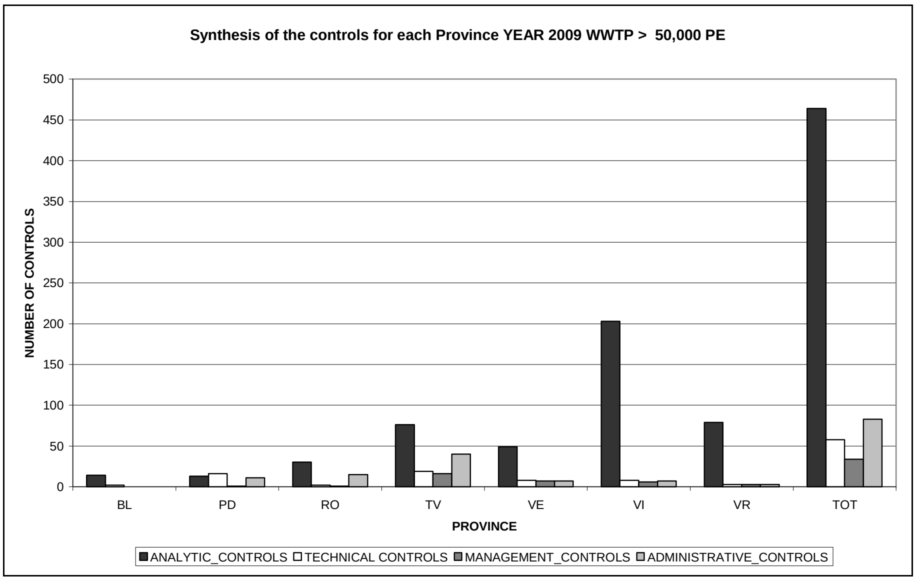


Fig. 8.1 b

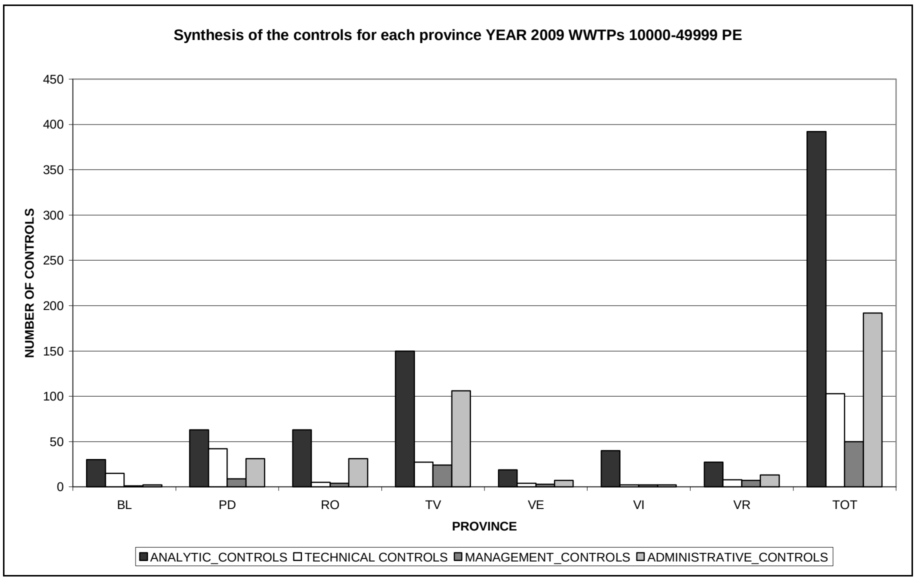


Fig. 8.1 c

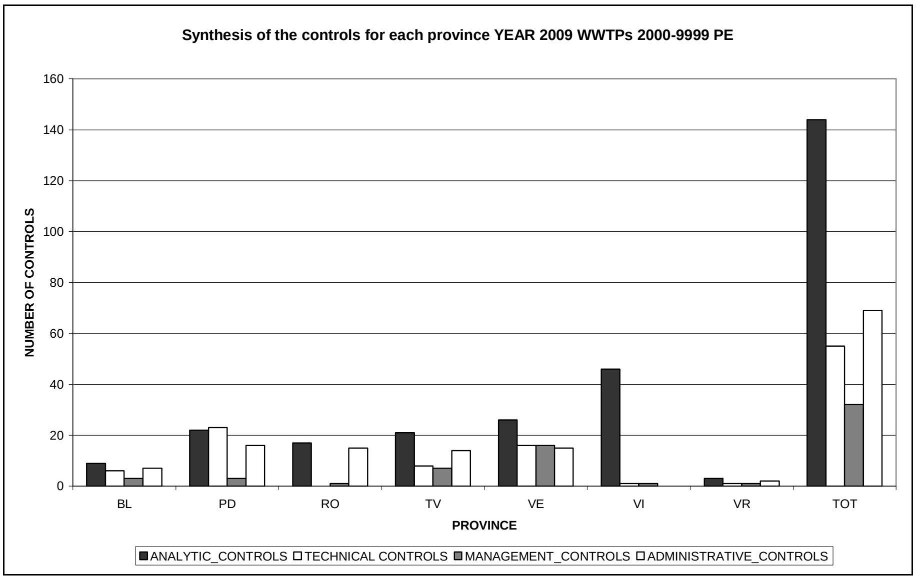


Fig. 8.1 d

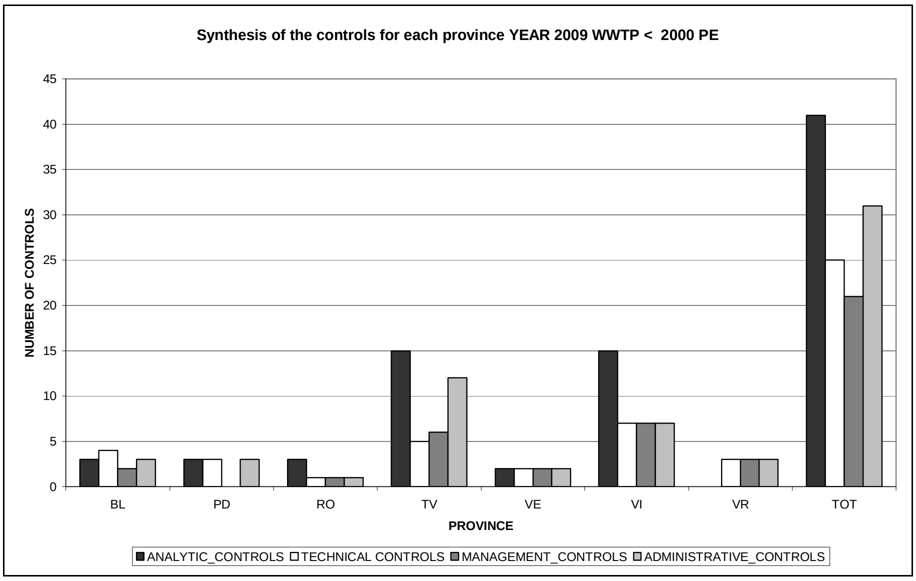


Table 8.4 *– WWTPS ≥10,000 PE in the province of Venice*

SIRAV code	WWTP	Potentiality (PE)
4132	WWTP CAVARZERE-CAVARZERE-VIA PIANTAZZA	17,500
4139	WWTP CHIOGGIA-BRONDOLO	160,000
4140	WWTP VENEZIA-FUSINA VIA DEI CANTIERI	330,000
4143	WWTP VENEZIA-LIDO	60,000
4141	WWTP VENEZIA-CAMPALTO	110,000
4148	WWTP CAORLE-PALANGON	120,000
4155	WWTP JESOLO-VIA ALEARDI	185,000
4158	WWTP S. STINO DI LIVENZA-CANALETTA	10,000
4161	WWTP S. MICHELE AL TAGLIAMENTO-VIA PARENZO	150,000
4164	WWTP QUARTO D'ALTINO-VIA MARCONI	30,000
4165	WWTP S. DONA' DI PIAVE-VIA TRONCO	45,000
4167	WWTP CAVALLINO-TREPORTI-CAVALLINO	105,000
4869	WWTP ERACLEA-ERACLEA MARE - VIA DEI PIOPPI	32,000

Source: (SIRAV-Veneto region-ARPAV)

8.2 Functionality verification data

For information completeness according to the institutional control approach to WWTPs performed by ARPAV, and in consideration that well balanced plants with secondary treatment are able to achieve at least 2 log of abatement for microbiological parameters without disinfection systems (Ostoich et al., 2007; Ragazzo et al., 2007 & 2011), the functionality verifications of the set of 7 WWTPs, for which disinfection was studied, among the chosen plants 15 plants are reported in details in **Annex VII**.

According to Masotti (1999), the 7 plants for which the functionality verification has been performed are classified as reported in **tab. 8.5**; the functionality verificantion allowed to point out critical aspects of each plant (see **Annex VII**). Generally the considered plants of Fusina, San Donà di Piave, Musile di Piave, Jesolo, Eraclea Mare, Caorle and Paese) did not present critical aspects unless with specific aspects each one. It must be observed that Jesolo, Caorle and Eraclea mare are strongly subject to seasonal variations as of the received organic as well as the hydraulics loads. All the plants are total oxidation plants axcept Jesolo, which appears to be a "mean load" plant.

***Table 8.5** – WWTPs classification according to functionality verification performed*

WWTP	Class	Organic sludge load C_F and sludge age θ*
Caorle	Extended aeration plant	C_F = 0.14, θ = 9 day
Eraclea mare	Extended aeration plant	C_F = 0.08, θ = 15 days high season C_F = 0.02, θ = 44 days low season
Jesolo	Mean load plant	C_F = 0.47, θ = 3 day
San Donà di Piave	Extended aeration plant	C_F = 0.06, θ = 18 day
Musile di Piave	Extended aeration plant	C_F = 0.02, θ = 51 day
Fusina	Extended aeration plant	C_F = 0.16, θ = 10 day
Paese	Extended aeration plant	C_F = 0.03, θ = 27 day

*C_F is the sludge or organic load; see Annex V - Eq. 13.

8.3 WWTPs' monitoring data

In the following §§ the monitoring data on the WWTPs' discharges are reported. With regard to data assessment, any of the values which were lower than the LODs were replaced with half of the LOD value as suggested in available literature (Spaggiari & Franceschini, 2000). The WWTPs considered (see Chapter 5) are divided into two groups: the WWTPs considered for their general microbiological impact and the WWTPs considered not only for the microbiological impact but also for the abatement efficiency and comparison of disinfection systems. For both groups the DFBPs potential indicators (those which are investigated in ordinary activity by ARPAV laboratories) have been considered (detailed data are reported in **Annex VIII**).

Chemical sampling is made after 24 hours of sampling while microbiological sampling is made istantaneously the same day of the sampling equipment installation (or closure of the already installed plant manager system) while chemical samples are gathered the following days. For calculation simplicity the day of sampling is considered the microbiological sampling date (the day before the chemical sampling). TC, FC, FS have been monitored till year 2005. Since 2006 sampling have been performed only for EC the microbiological index established by Decree n. 152/2006 Annex V.

Disinfection systems are activated all over the year for only few plants and in the bathing seson for the other in which it is compulsory. In data elaboration the seasonal differences have been accounted where the disinfection is not active all the year. mean, 75° perc, min., max and std. dev values have been calculated and reported for macrodescriptors (organic, eutrophiying and microbiological polluting load), microbiological parameter, seasonal microbiological quality (if applicable), dangerous substances.

The considered period for data elaboration is 2005-2012 (or till 2011 if not completely available depending on the specific plant). The choice has been made considering that just till the beginning of 2005 ARPAV always researched CT, CF, FS and EC in the WWTPs' discharges and then - according to the specific indications of the Decree n. 152/2006 - proceeded only with EC monitoing on WWTPs' discharges as well as on surface water.

For the definition of criticalities of the monitoring stations on rivers, bathing waters and marine-coastal waters as well as the quality of the WWTPs' discharges along the coast the integrated analysis according the *water profile* of the Directive 2006/7/EC was performed on the period 2000-2006 (see Chapter 10). It must be observed that the period was not extended as the monitoring networks were modified (heavily for bathing waters for parameters since 2010). The analysis 2000-2006 allowed to identify major criticalities. Then the analysis of microbiological parameters (EC and IE, if available) has been performed in the period 2005-2012 on WWTPs' discharges and on surface water bodies (rivers, coatal waters).

Data have been exported from Oracle Data-base and and managed with Excel datasheet. For each WWTP a general sheet with all recovered data in the period 2005-2012 have been divided into: macrodescriptors; microbiological data; seasonal microbiological data (according to period of activation of the disinfection systems); dangerous substances; by-products of chlorination; metals (non reported in the thesis results).

8.3.1 WWTPs considered for the general microbiological impact in the province of Venice

The plants considered are the ≥ 10,000 PE plants in the province of Venice. Moreover the Paese WWTP, located in the province of Treviso, has been considered and analysed as a case study for ozone disinfection system. The considered plants are (in order from South-West to North-East of the province with the addition of Paese): Chioggia; Fusina; Campalto; Lido Venezia; Cavallino; Quarto d'Altino; Musile di Piave; San Donà di Piave; Jesolo; Eraclea Mare; San Stino di Livenza; Portogruaro; Caorle; Bibione; Paese (province of Treviso).

For each WWTP, ARPAV data, produced and validated by the provincial laboratories (Venice for most plants and Treviso for Paese), have been exctracted from SIRAV, ordered, elaborated and assessed. The following parameters have been elaborated and assessed:

- macrodescriptors: BOD_5, COD, TSS, Total N, Total P, forms of N (NO_2^-, NO_3^-, NH_4^+), forms of P, EC.

- microbiological parameters: EC (all the years), TC, FC, FS (only few month 2005);
- dangerous organic parameters (by-products): the chlorination by-products, halogen solvents, hydrocharbons,IPA, others;
- DBPs: THMs, halogenated solvents, phenols and chlorophenols;
- Metals (not reported in this study).

Elaboration has been performed with excel data sheet. On the whole period for macrodescriptors and microbiological parameter (only EC) mean, 75° percentile, min, max, std. dev. values have been calculated. Graphs with point values have been produced. It must be observed that 75° perc. is here preferred as it is less influeced by extreme values than the mean (a specific reference can be found in the Italian Decree n. 152/1999). Moreover for EC a graph with the 75° annual percentile value have been calculated and the graphs reportd. In consideration that disinfection systems are not active all the year for all the WWTPs, the seasonal statistical parameters on the 2005-2012 period have been elaborated and reported in tabs as mean, 75° perc., min, max and std. dev. values.

It must be underlined that the considered periods are indicative and high values of EC can be found in the disinfection period too if there is maintenance of disinfection, out of service state, etc. Data are elaborated only for cognitive aim and not for penalty; moreover penalty in case of overtaking of a limit is referred to single sample and not to mean or 75° perc. values.

The following WWTPs have the disinfection system active for all the year: **Fusina; Campalto; Chioggia; S. Stino di Livenza; Portogruaro (till 2012), Paese**. Among these plants only Chioggia has a direct impct on the sea belt quality. For dangerous organic compounds - in particular for the chlorination by-products - the verification of their presence (values > LODs) have ben considered and commented. In the following the elaborated data from ARPAV controls are reported:

WWTPs' discharges data elaboration
VERITAS plants

Campalto WWTP

The WWTP's discharges parameters in the period 2005-2012 are reported in the following **tabs. 8.6-8.7**. and **figs 8.2-8.4**.

Table 8.6 *– Discharge characterization – Macrodescriptors 2005-2012*

Campalto WWTP	BOD_5 (mg/l)	COD (mg/l)	Total Suspended Solids (mg/l)	Total Nitrogen (N) (mg/l)	Total Phosphorous (P) (mg/l)
Mean	7	26	11	8	0
75° PERC	12	30	14	9	0
MIN	1	3	3	1	0
MAX	27	76	34	13	1
STD DEV	6	16	8	3	0

Figure 8.2 *– Discharge characterization - Macrodescriptors*

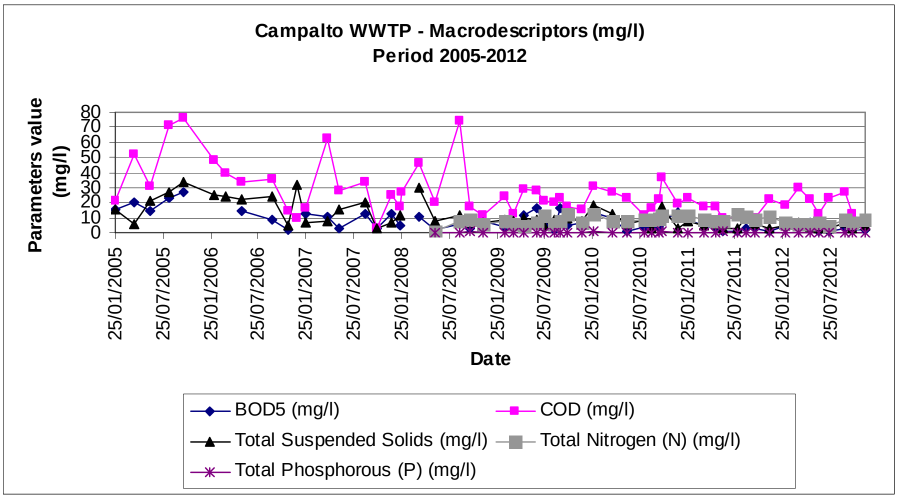
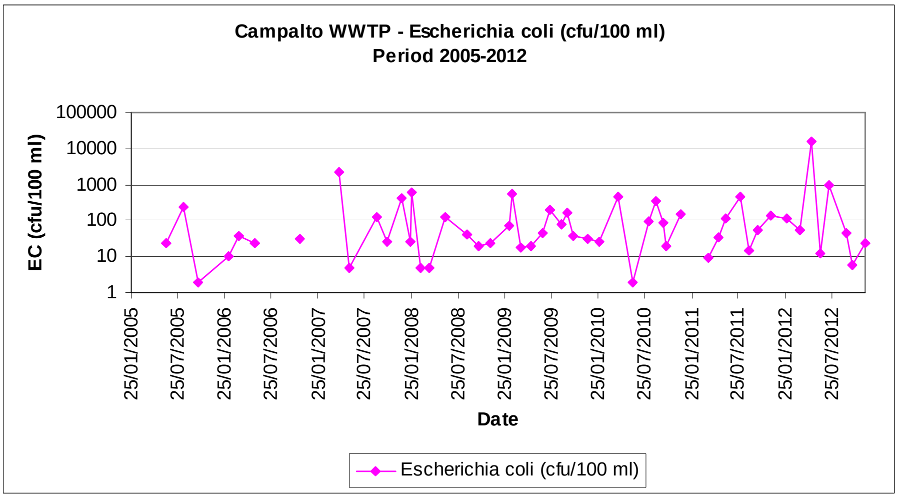


Table 8.7 *– Discharge characterization – EC values on period 2005-2012*

CAMPALTO WWTP	Escherichia coli (cfu/100 ml)
Mean	399
75° PERC	125
MIN	0
MAX	15000
STD DEV	1963

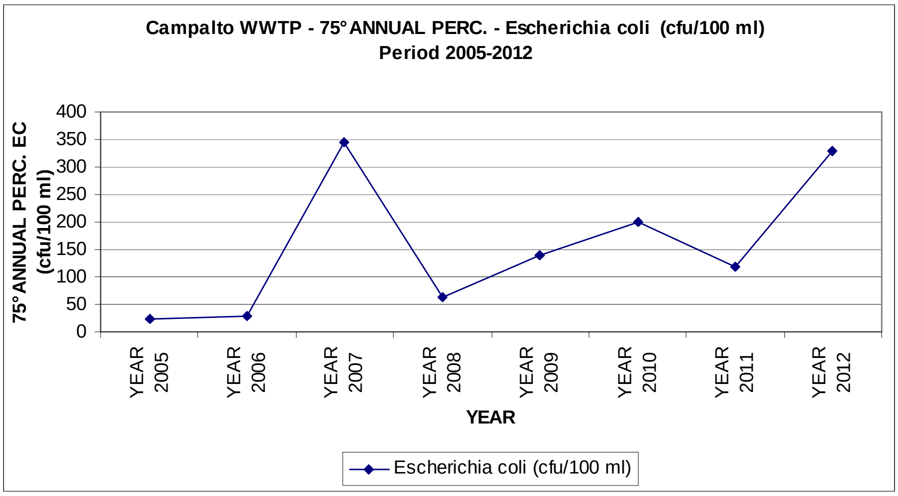
Figure 8.3 *– Discharge characterization - EC*



For Campalto WWTP no seasonal graphs can be drawn as disinfection system is active all over the year. For the monitoring of by-products values higher than LOD have been obtained in the period 2005-2012 only for the following parameters (see annex XXX with for detailed data):

- Chlorophorm;
- Bromophorm;
- Dibromo-chloromethane;
- Dichloro-bromomethane;
- Total Halogenated organic solvents;
- Phenols.
- Aldehydes.

Figure 8.4 *– Discharge characterization – 75° annual percentile EC*



Lido WWTP

The WWTP's discharges parameters in the period 2005-2012 are reported in the following **tabs. 8.8-8.11**. and **figs 8.5-8.7**.

Table 8.8 *– Discharge characterization – Macrodescriptors 2005-2012*

Lido WWTP	BOD_5 (mg/l)	COD (mg/l)	Total Suspended Solids (mg/l)	Total Nitrogen (mg/l)	Total Phosphorous (mg/l)
Mean	5.6	36.0	11.6	5.7	1.1
75° PERC	5.0	44.0	15.0	7.6	1.3
MIN	0.9	9.0	2.5	1.0	0.2
MAX	20.5	114.0	26.0	8.4	2.2
STD DEV	5.7	27.5	6.7	2.4	0.6

Figure 8.5 *– Discharge characterization - Macrodescriptors*

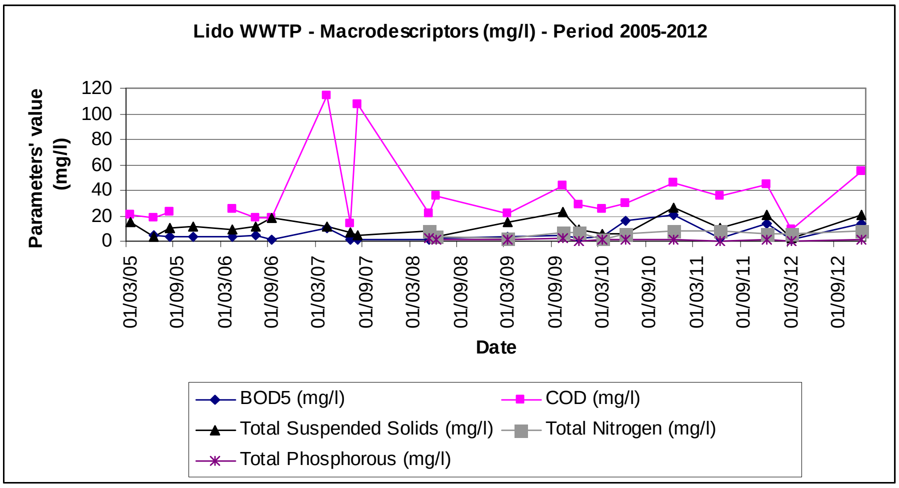


Figure 8.6 *– Discharge characterization - EC*

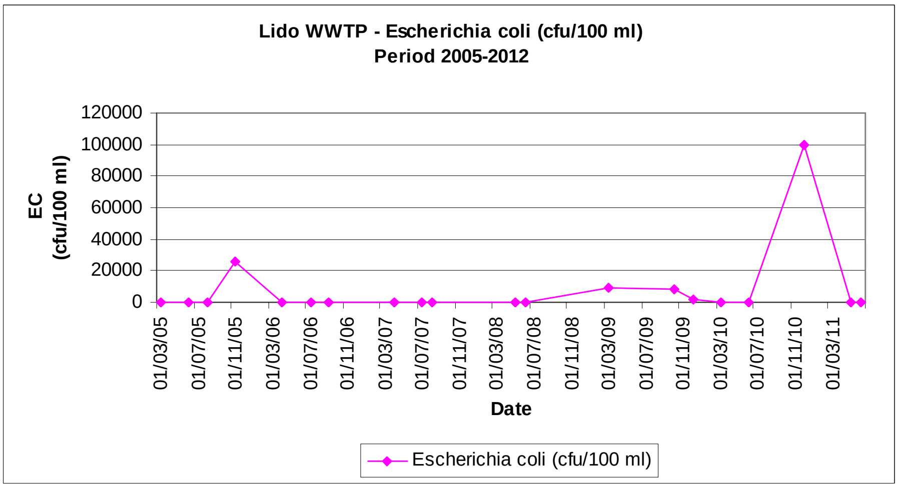


Figure 8.7 *– Discharge characterization – 75° annual percentile EC*

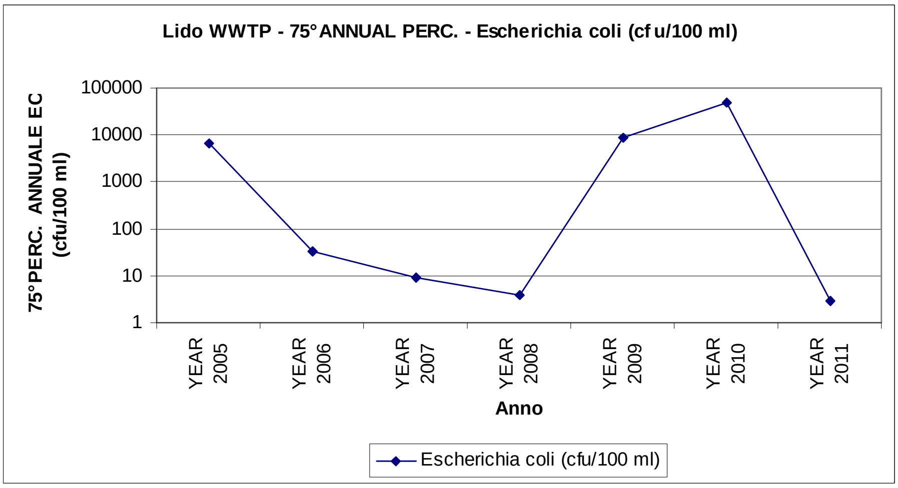


Table 8.9 *– Discharge characterization – EC values on period 2005-2012*

Lido WWTP	Escherichia coli (cfu/100 ml)
Mean	7256
75° PERC	403
MIN	0
MAX	100000
DEV STD	22686

From available data in the period 2005-2012 the microbiological data on the final discharge have been assessed for active disinfection system (bathing season) and not active system (autumn and winter season) havee been calculatedas follows:

Table 8.10 *– Discharge characterization – Seasonal values of EC on period 2005-2012*

DISINFECTION ACTIVE

Lido WWTP	Escherichia coli (cfu/100 ml)
Mean	8
75° PERC	11
MIN	0
MAX	37
STD DEV	12

Table 8.11 *– Discharge characterization – Seasonal values of EC on period 2005-2012*

DISINFECTION NON ACTIVE

Lido WWTP	Escherichia coli (cfu/100 ml)
Mean	20715
75° PERC	17550
MIN	0
MAX	100000
STD DEV	36120

For the monitoring of by-products values higher than LOD have been obtained in the period 2005-2012 only for the following parameters (see **Annex VIII** for detailed data):

- Chlorophorm;
- Bromophorm;
- Dibromo-chloromethane;
- Dichloro-bromomethane;
- Tetra-ethilene-chloride;
- Total organohalogenated solvents;
- Phenols.

<u>**Cavallino WWTP**</u>

The WWTP's discharges parameters in the period 2005-2012 are reported in the following **tabs. 8.12-8.15**. and **figs 8.8-8.10**. The WWTP's discharges parameters in the 2005-2012 period are reported in the following.

Table 8.12 *– Discharge characterization – Macrodescriptors 2005-2012*

Cavallino WWTP	BOD_5 (mg/l)	COD (mg/l)	Total Suspended Solids (mg/l)	Total Nitrogen (mg/l)	Total Phosphorous (mg/l)
Mean	5.4	25.7	9.8	9.4	1.4
75° PERC	5.4	28.8	10.0	11.5	1.3
MIN	1.0	1.9	2.5	2.8	0.2
MAX	23.0	107.0	68.0	14.8	5.0
STD DEV	5.5	18.7	12.1	3.1	1.4

Figure 8.8 *– Discharge characterization - Macrodescriptors*

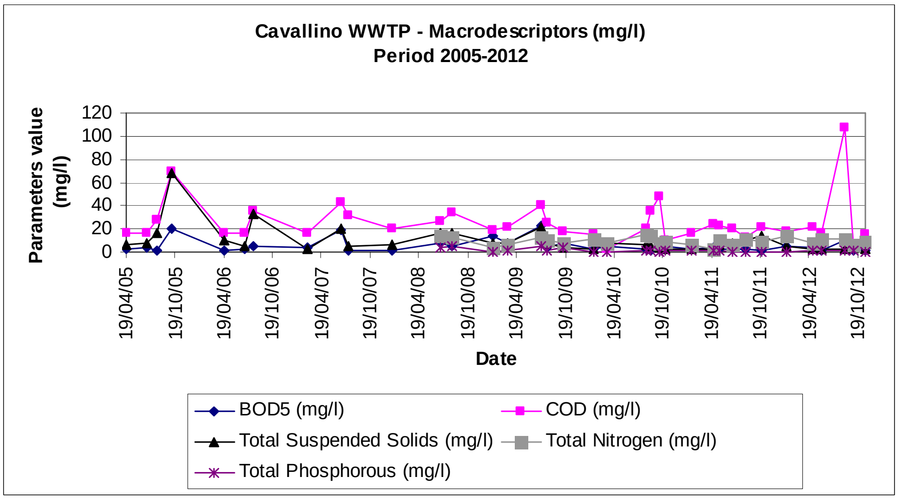


Table 8.13 *– Discharge characterization – EC values on period 2005-2012*

Cavallino WWTP	Escherichia coli (cfu/100 ml)
Mean	15983
75° PERC	1950
MIN	0
MAX	450000
STD DEV	80612

Figure 8.9 *– Discharge characterization - EC*

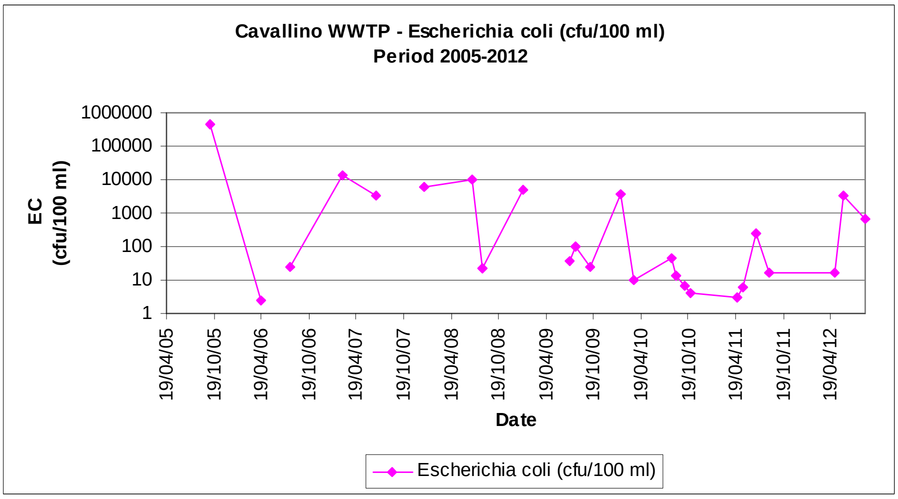
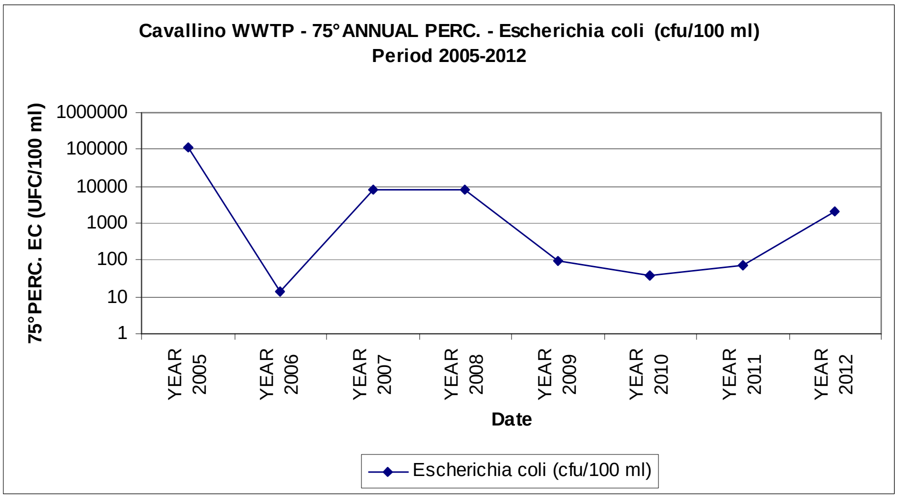


***Figure 8.10** – Discharge characterization – 75° annual percentile EC*



From available data in the period 2005-2012 the microbiological data on the final discharge have been assessed for active disinfection system (bathing season) and not active system (autumn and winter season) havee been calculatedas follows:

***Table 8.14** – Discharge characterization – Seasonal values of EC on period 2005-2012*

DISINFECTION ACTIVE

Cavallino WWTP	Escherichia coli (cfu/100 ml)
Mean	844
75° PERC	96
MIN	0
MAX	10000
STD DEV	2310

***Table 8.15** – Discharge characterization – Seasonal values of EC on period 2005-2012*

DISINFECTION NON ACTIVE

Cavallino WWTP	Escherichia coli (cfu/100 ml)
Mean	47775
75° PERC	5775
MIN	0
MAX	450000
STD DEV	141390

For the monitoring of by-products values higher than LOD have been obtained in the period 2005-2012 only for the following parameters (see **Annex VIII** for detailed data):

- Chlorophorm;
- Bromophorm;
- Dibromo-chloromethane;
- Dichloro-bromomethane;

- Total Halogenated organic solvents;
- Phenols.

Chioggia WWTP

The WWTP's discharges parameters in the period 2005-2012 are reported in the following **tabs. 8.16-8.17**. and **figs 8.11-8.13**. The WWTP's discharges parameters in the 2005-2012 period are reported in the following

Table 8.16 *– Discharge characterization – Macrodescriptors 2005-2012*

Chioggia WWTP	BOD_5 (mg/l)	COD (mg/l)	Total Suspended Solids (mg/l)	Total Nitrogen (N) (mg/l)	Total Phosphorous (P) (mg/l)
Mean	6	34	12	7	1
75° PERC	6	40	10	9	2
MIN	1	3	1	2	0
MAX	34	109	146	21	5
STD DEV	7	23	25	4	1

Figure 8.11 *– Discharge characterization - Macrodescriptors*

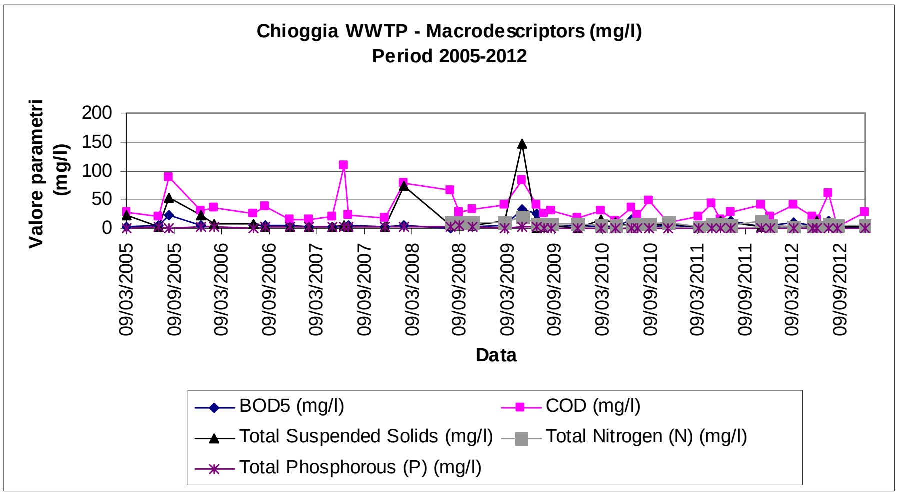


Figure 8.12 *– Discharge characterization - EC*

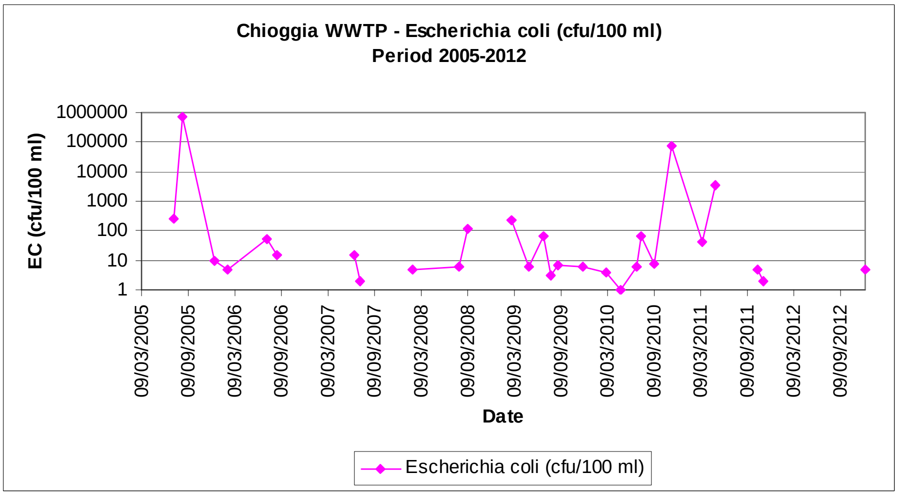


Figure 8.13 *– Discharge characterization – 75° annual percentile EC*

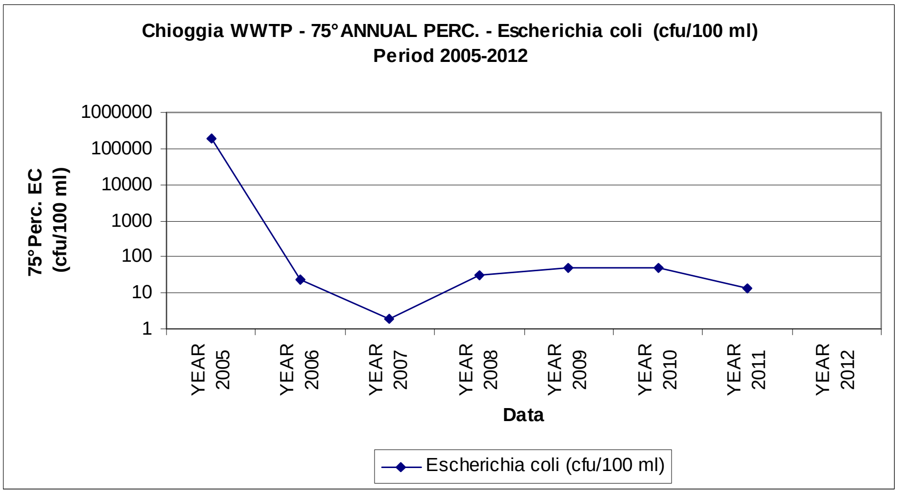


Table 8.17 *– Discharge characterization – EC values on period 2005-2012*

Chioggia WWTP	Escherichia coli (cfu/100 ml)
Mean	19033
75° PERC	15
MIN	0
MAX	740000
STD DEV	113128

For the monitoring of by-products values higher than LOD have been obtained in the period 2005-2012 only for the following parameters (see **Annex VIII** with for detailed data):

- Chlorophorm;
- Bromophorm;
- Dibromo-chloromethane;
- Dichloro-bromomethane;
- Tetra-chloromethane;
- Total Organohalogenated solvents;
- Phenols.

Other WWTPs' managers

Quarto d'Altino WWTP

The WWTP's discharges parameters in the period 2005-2012 are reported in the following **tabs. 8.18-8.21**. and **figs 8.14-8.16**.

Table 8.18 *– Discharge characterization – Macrodescriptors 2005-2012*

Quarto d'Altino WWTP	BOD_5 (mg/l)	COD (mg/l)	Total Suspended Solids (mg/l)	Total Nitrogen (mg/l)	Total Phosphorous (mg/l)
Mean	11,6	33,7	9,2	16,2	1,1
75° PERC	15,6	34,8	10,0	20,5	1,3
MIN	1,4	16,0	2,5	6,9	0,1
MAX	60,0	112,0	35,0	26,5	5,5
STD DEV	10,4	18,3	7,2	5,2	1,2

Table 8.19 *– Discharge characterization – EC values on period 2005-2012*

Quarto d'Altino WWTP	Escherichia coli (cfu/100 ml)
Mean	10161
75° PERC	95
MIN	0
MAX	290000
STD DEV	49100

Figure 8.14 *– Discharge characterization - Macrodescriptors*

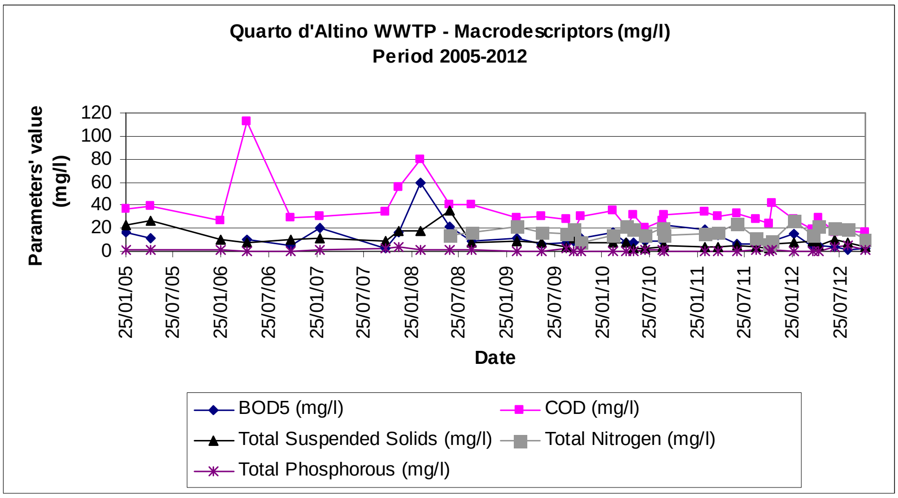


Figure 8.15 *– Discharge characterization - EC*

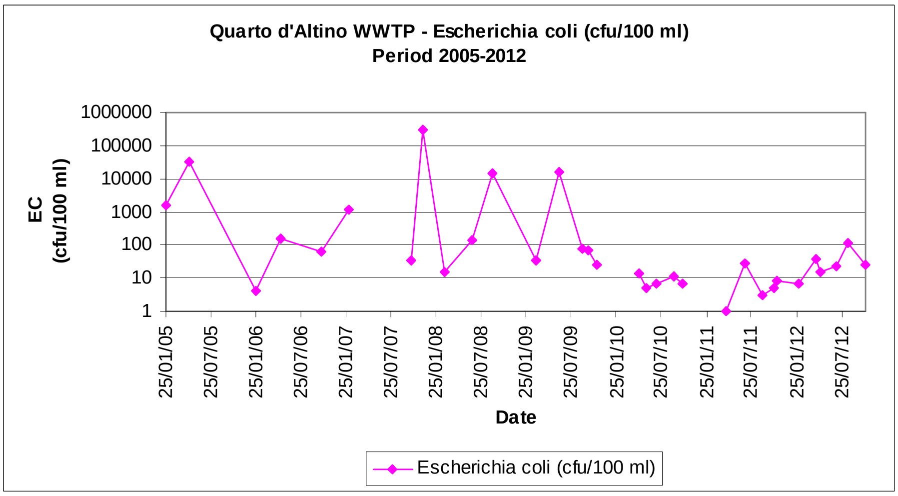


***Figure 8.16** – Discharge characterization – 75° annual percentile EC*

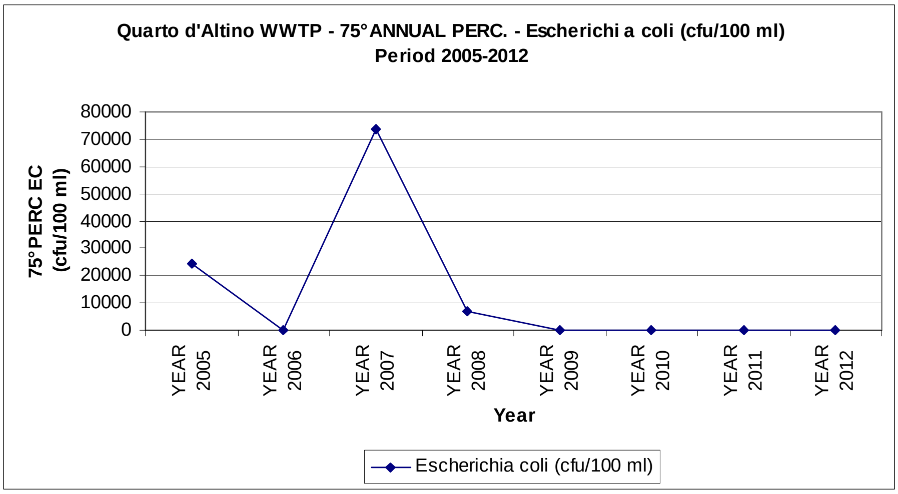


***Table 8.20** – Discharge characterization – Seasonal values of EC on period 2005-2012*

DISINFECTION ACTIVE

Quarto d'Altino WWTP	Escherichia coli (cfu/100 ml)
Mean	3684
75° PERC	140
MIN	1
MAX	32000
STD DEV	8822

***Table 8.21** – Discharge characterization – Seasonal values of EC on period 2005-2012*

DISINFECTION NON ACTIVE

Quarto d'Altino WWTP	Escherichia coli (cfu/100 ml)
Mean	16277
75° PERC	54
MIN	0
MAX	290000
STD DEV	68314

For the monitoring of by-products values higher than LOD have been obtained in the period 2005-2012 only for the following parameters (see **Annex VIII** for detailed data):

- Chlorophorm;
- Total Halogenated organic solvents;
- Phenols.

S. Stino di Livenza WWTP

The WWTP's discharges parameters in the period 2005-2012 are reported in the following **tabs. 8.22-8.25** . and **figs 8.17-8.19**.

***Table 8.22** – Discharge characterization – Macrodescriptors 2005-2012*

S. Stino L. WWTP	BOD_5 (mg/l)	COD (mg/l)	Total Suspended Solids (mg/l)	Total Nitrogen (mg/l)	Total Phosphorous (mg/l)
Mean	18.5	48.8	24.5	32.4	3.8
75° PERC	22.9	60.0	32.0	41.3	5.7
MIN	5.0	16.0	4.0	7.1	0.9
MAX	44.9	114.0	78.0	53.8	7.9
STD DEV	9.9	22.2	21.9	12.6	2.1

***Figure 8.17** – Discharge characterization - Macrodescriptors*

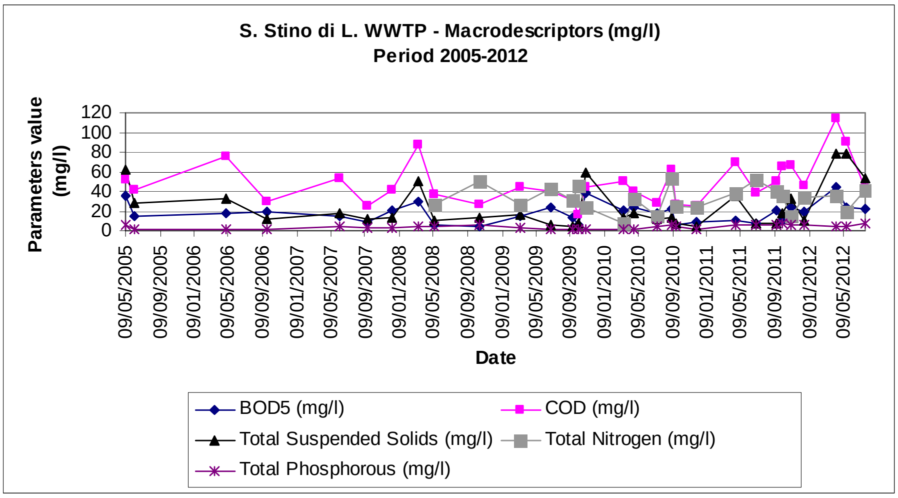


***Figure 8.18** – Discharge characterization - EC*

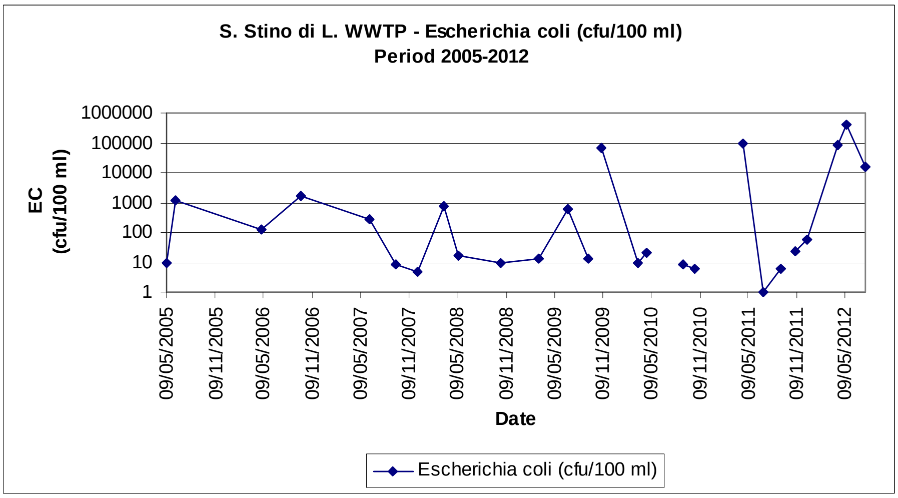
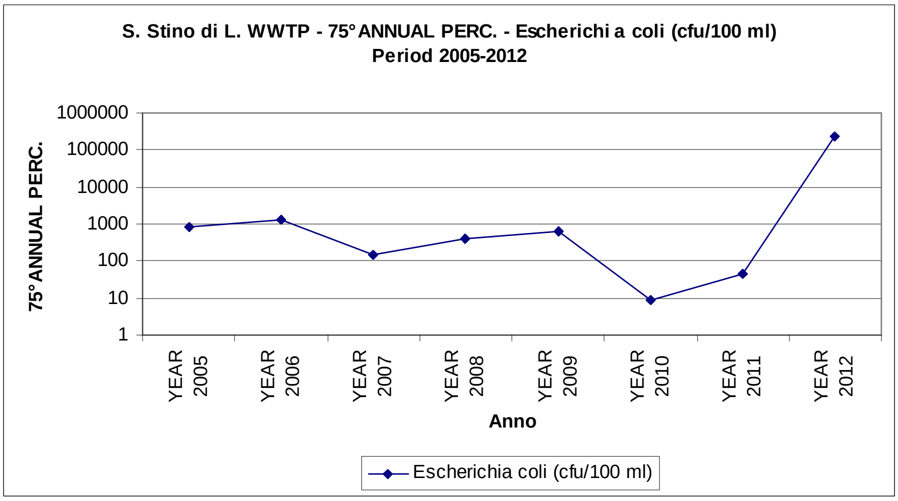


***Table 8.23** – Discharge characterization – EC values on period 2005-2012*

S. Stino L.WWTP	Escherichia coli (cfu/100 ml)
Mean	21961
75° PERC	725
MIN	0
MAX	390000
STD DEV	74070

***Figure 8.19** – Discharge characterization – 75° annual percentile EC*



From available data in the period 2005-2012 the microbiological data on the final discharge have been assessed for active disinfection system (bathing season) and not active system (autumn and winter season) havee been calculatedas follows:

***Table 8.24** – Discharge characterization – Seasonal EC values on period 2005-2012*

DISINFECTION ACTIVE

S. Stino L. WWTP	Escherichia coli (cfu/100 ml)
Mean	32886
75° PERC	1563
MIN	0
MAX	390000
STD DEV	93856

***Table 8.25** – Discharge characterization – Seasonal EC values on period 2005-2012*

DISINFECTION NON ACTIVE

S. Stino L. WWTP	Escherichia coli (cfu/100 ml)
Mean	5573
75° PERC	30
MIN	0
MAX	66000
STD DEV	19031

For the monitoring of by-products values higher than LOD have been obtained in the period 2005-2012 only for the following parameters (see **Annex VIII** with for detailed data):

- Trichloroethilene;
- Total organo-halogenated solvents;
- Phenols.

Portogruaro WWTP

The WWTP's discharges parameters in the period 2005-2012 are reported in the following **tabs. 8.26-8.27**. and **figs 8.20-8.22**.

Table 8.26 *– Discharge characterization – Macrodescriptors 2005-2012*

Portogruaro WWTP	BOD_5 (mg/l)	COD (mg/l)	Total Suspended Solids (mg/l)	Total Nitrogen (mg/l)	Total Phosphorous (mg/l)
Mean	18.1	56.5	35.3	29.7	3.6
75° PERC	20.2	54.0	20.0	33.1	4.4
MIN	5.0	22.0	2.5	21.0	0.3
MAX	73.0	310.0	372.0	43.7	6.3
STD DEV	15.6	66.6	87.3	6.3	1.5

Figure 8.20 *– Discharge characterization - Macrodescriptors*

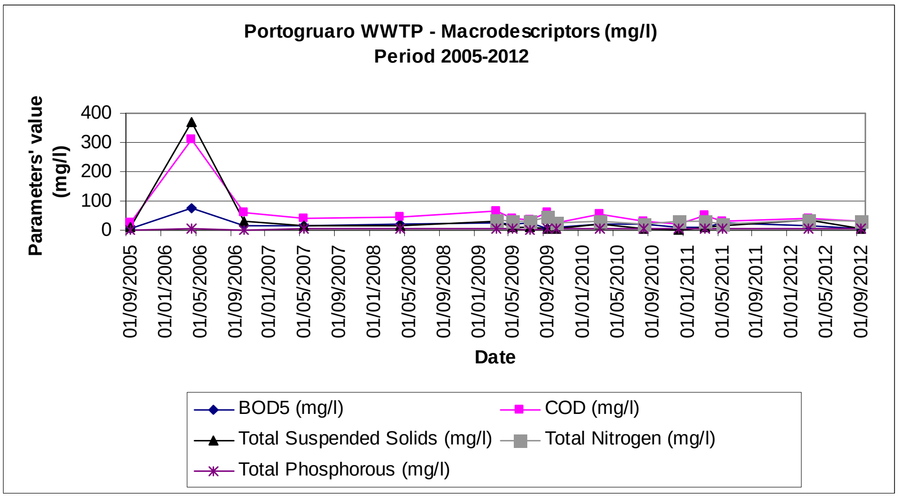


Figure 8.21 *– Discharge characterization - EC*

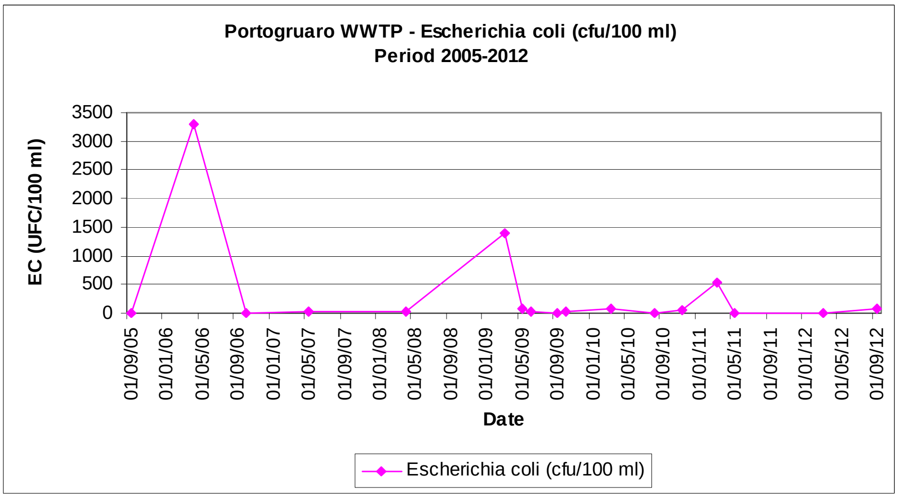


Figure 8.22 *– Discharge characterization – 75° annual percentile EC*

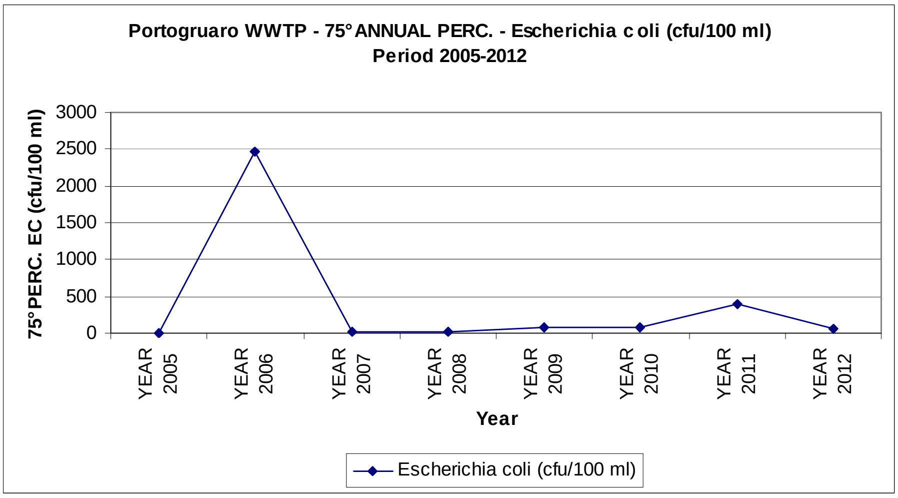


Table 8.27 *– Discharge characterization – EC values on period 2005-2012*

Portogruaro WWTP	Escherichia coli (cfu/100 ml)
Media	330
75° PERC	82
MIN	0
MAX	3300
DEV STD	841

In the Portogruaro WWTP, according to the Province of Venice dispositions, the disinfection must be active all the year. For the monitoring of by-products values higher than LOD have been obtained in the period 2005-2012 only for the following parameters (see **Annex VIII** for detailed data):

- Phenols.

Bibione WWTP

The WWTP's discharges parameters in the period 2005-2012 are reported in the following **tabs. 8.28-8.31**. and **figs 8.23-8.25**.

Table 8.28 *– Discharge characterization – Macrodescriptors 2005-2012*

DATA	BOD_5 (mg/l)	COD (mg/l)	Total Suspended Solids (mg/l)	Total Nitrogen (mg/l)	Total Phosphorous (mg/l)
Mean	3.5	19.5	11.5	8.2	1.1
75° PERC	3.4	22.5	14.0	9.3	1.2
MIN	0.2	2.0	2.5	3.0	0.2
MAX	25.0	88.0	34.0	15.4	5.3
STD DEV	4.2	15.8	8.1	3.4	1.0

Table 8.29 *– Discharge characterization – EC values on period 2005-2012*

Bibione WWTP	Escherichia coli (cfu/100 ml)
Mean	1392
75° PERC	770
MIN	0
MAX	10000
STD DEV	2618

Figure 8.23 *– Discharge characterization - Macrodescriptors*

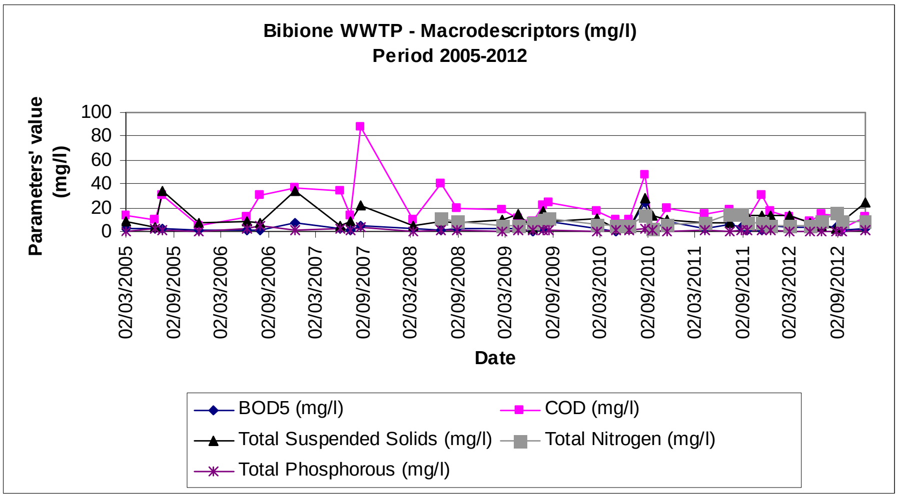


Figure 8.24 *– Discharge characterization - EC*

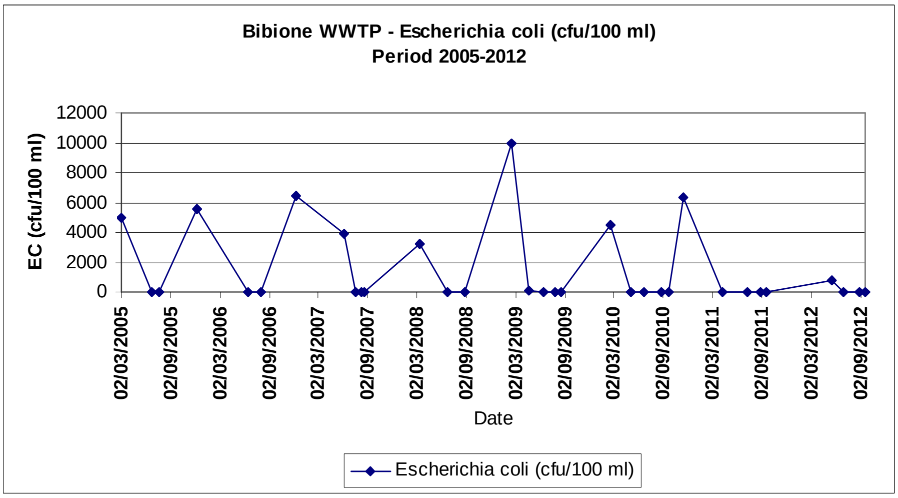
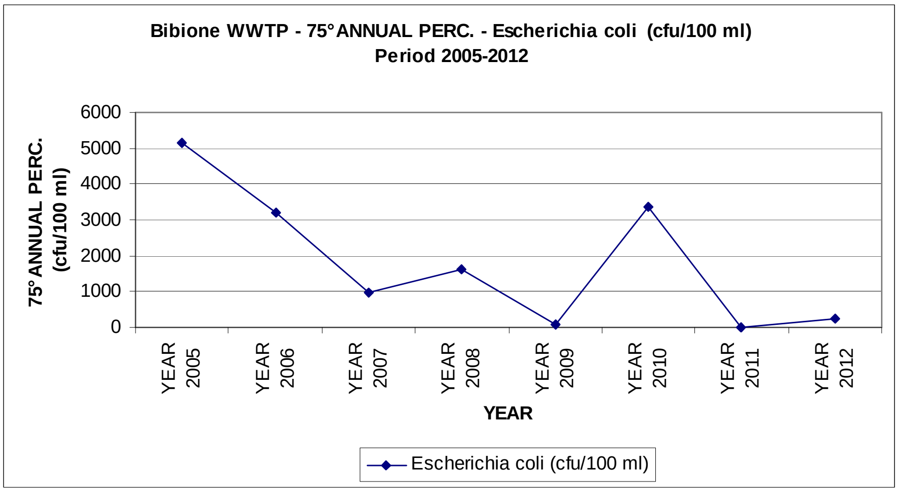


Figure 8.25 *– Discharge characterization – 75° annual percentile EC*



From available data in the period 2005-2012 the microbiological data on the final discharge have been assessed for active/non active disinfection system as follows:

Table 8.30 *– Discharge characterization – Seasonal values of EC on period 2005-2012*

DISINF. ACTIVE

Bibione WWTP	Escherichia coli (cfu/100 ml)
Mean	190
75° PERC	21
MIN	0
MAX	3900
STD DEV	771

Table 8.31 *– Discharge characterization – Seasonal values of EC on period 2005-2012*

DISINF. NOT ACTIVE

Bibione WWTP	Escherichia coli (cfu/100 ml)
Mean	5857
75° PERC	6350
MIN	3200
MAX	10000
STD DEV	2135

For the monitoring of by-products values higher than LOD have been obtained in the period 2005-2012 only for the following parameters (see **Annex VIII** for detailed data):

- Chlorophorm;
- Bromophorm;
- Dibromo-chloromethane;
- Dichloro-bromomethane;
- Total organohalogenated solvents;
- Phenols.

8.3.2 WWTPs considered for the disinfection abatement capacity

Fusina WWTP

The WWTP's discharges parameters in the period 2005-2012 are reported in the following **tabs. 8.32-8.33** and **figs 8.26-8.28**.

Table 8.32 *– Discharge characterization – Macrodescriptors 2005-2012*

Fusina WWTP	BOD_5 (mg/l)	COD (mg/l)	Total Suspended Solids (mg/l)	Total Nitrogen (mg/l)	Total Phosphorous (mg/l)
Mean	10	33	17	9	1
75° PERC	12	37	23	11	1
MIN	1	9	3	4	0
MAX	40	142	56	14	5
STD DEV	8	24	12	2	1

Figure 8.26 *– Discharge characterization - Macrodescriptors*

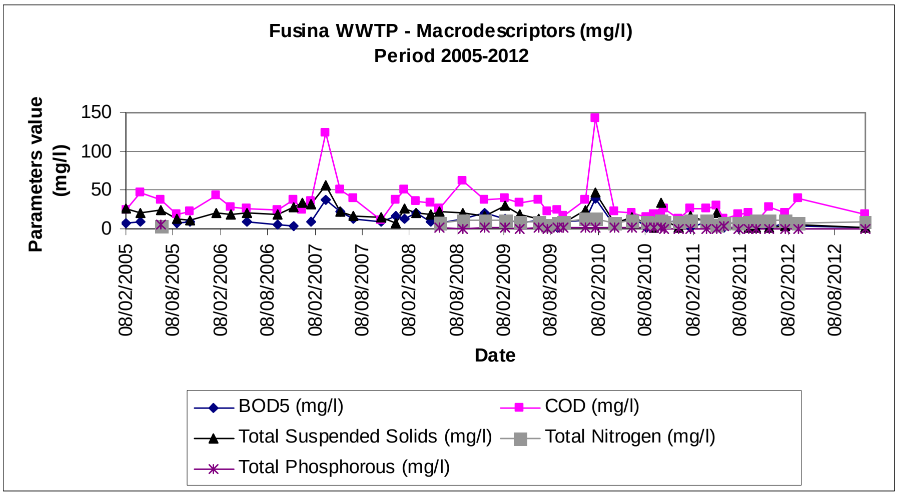


Figure 8.27 *– Discharge characterization - EC*

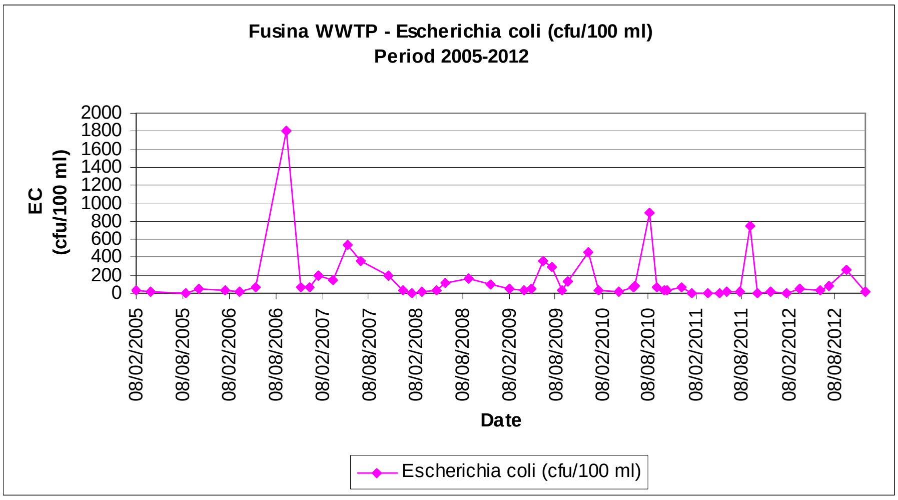


***Figure 8.28** – Discharge characterization – 75° annual percentile EC*

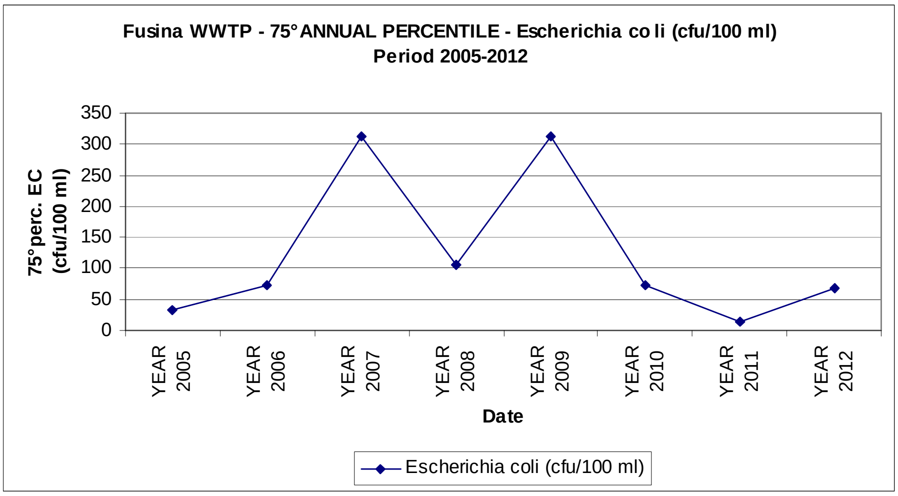


***Table 8.33** – Discharge characterization – EC on period 2005-2012*

Fusina WWTP	Escherichia coli (cfu/100 ml)
Mean	151
75° PERC	130
MIN	1
MAX	1800
DEV STD	295

In the case of Fusina WWTP, the disinfection system is active all the year so no differences are tied to the activation/disact. of the system. For the monitoring of by-products values higher than LOD have been obtained in the period 2005-2012 only for the following parameters (see **Annex VIII** with for detailed data):

- Chlorophorm; Bromophorm;
- Dibromo-chloromethane; Dichloro-bromomethane;
- Total Halogenated organic solvents;
- Phenols.

<u>**Jesolo WWTP**</u>

The WWTP's discharges parameters in the period 2005-2012 are reported in the following **tabs. 8.34-8.37**. and **figs 8.29-8.31**.

***Table 8.34** – Discharge characterization – Macrodescriptors 2005-2012*

Jesolo WWTP	BOD_5 (mg/l)	COD (mg/l)	Total Suspended Solids (mg/l)	Total Nitrogen (mg/l)	Total Phosphorous (mg/l)
Mean	8.0	26.6	11.1	16.1	1.1
75° PERC	9.3	31.3	15.0	20.0	1.4
MIN	1.7	8.0	2.0	7.3	0.2
MAX	22.5	66.0	34.0	24.4	4.4
STD DEV	5.3	13.7	7.8	4.9	0.8

***Figure 8.29** – Discharge characterization - Macrodescriptors*

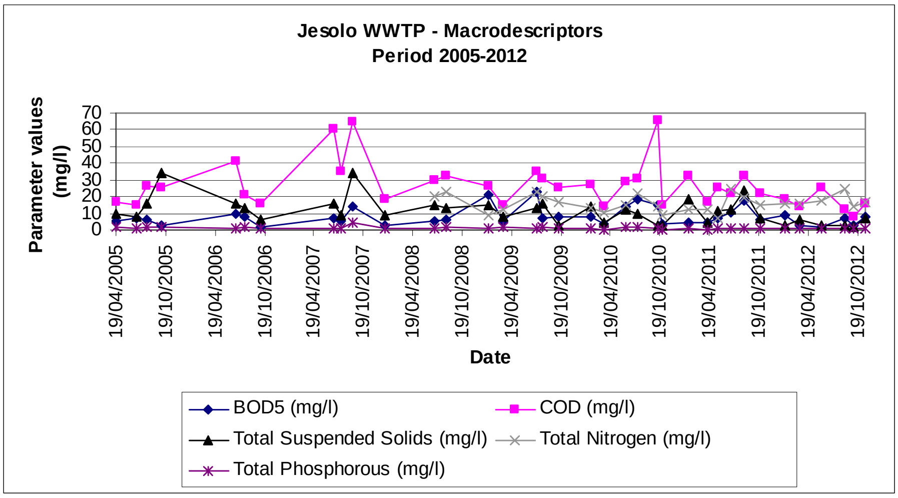


***Figure 8.30** – Discharge characterization - EC*

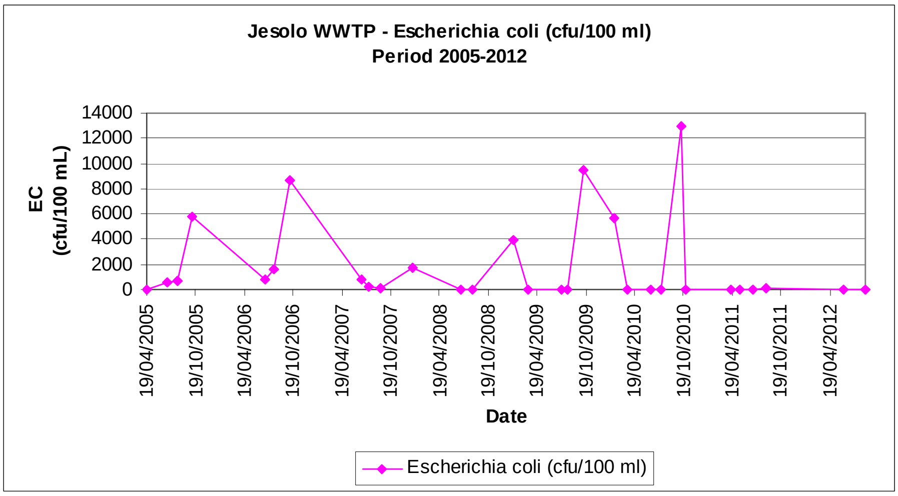


***Figure 8.31** – Discharge characterization – 75° annual percentile EC*

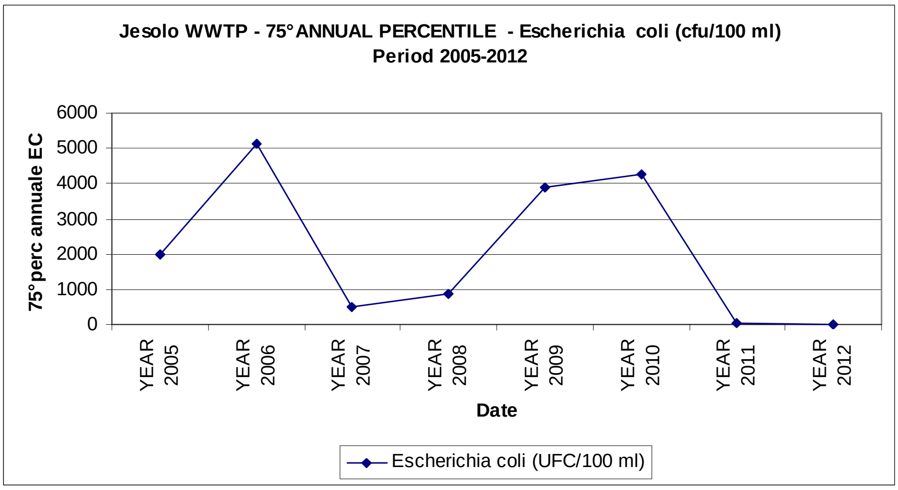


__Table 8.35__ – Discharge characterization – EC values on period 2005-2012

Jesolo WWTP	Escherichia coli (cfu/100 ml)
Mean	1783
75° PERC	1395
MIN	0
MAX	13000
STD DEV	3366

From available data in the period 2005-2012 the microbiological data on the final discharge have been assessed for active/non active disinfection system as follows:

__Table 8.36__ – Discharge characterization – Seasonal values of EC on period 2005-2012

DISINFECTION ACTIVE

Jesolo WWTP	Escherichia coli (cfu/100 ml)
Mean	235
75° PERC	228
MIN	0
MAX	1600
STD DEV	409

__Table 8.37__ – Discharge characterization – Seasonal values of EC on period 2005-2012

DISINFECTION NON ACTIVE

Jesolo WWTP	Escherichia coli (cfu/100 ml)
Mean	6040
75° PERC	8900
MIN	17
MAX	13000
STD DEV	4265

For the monitoring of by-products values higher than LOD have been obtained in the period 2005-2012 only for the following parameters (see annex XXX with for detailed data):

- Chlorophorm;
- Bromophorm;
- Dibromo-chloromethane;
- Dichloro-bromomethane;
- Total Organohalogenated solvents;
- Phenols;
- Chlorophenols.

Eraclea mare WWTP

The WWTP's discharges parameters in the period 2005-2012 are reported in the following **tabs. 8.38-8.41**. and **figs 8.32-8.34**.

__Table 8.38__ – Discharge characterization – Macrodescriptors 2005-2012

Eraclea mare WWTP	BOD_5 (mg/l)	COD (mg/l)	Total Suspended Solids (mg/l)	Total Nitrogen (mg/l)	Total Phosphorous (mg/l)
Mean	5	28	13	15	1
75° PERC	8	33	16	19	1
MIN	0	7	3	7	0
MAX	29	125	52	22	3
STD DEV	5	21	12	4	1

__Figure 8.32__ – Discharge characterization - Macrodescriptors

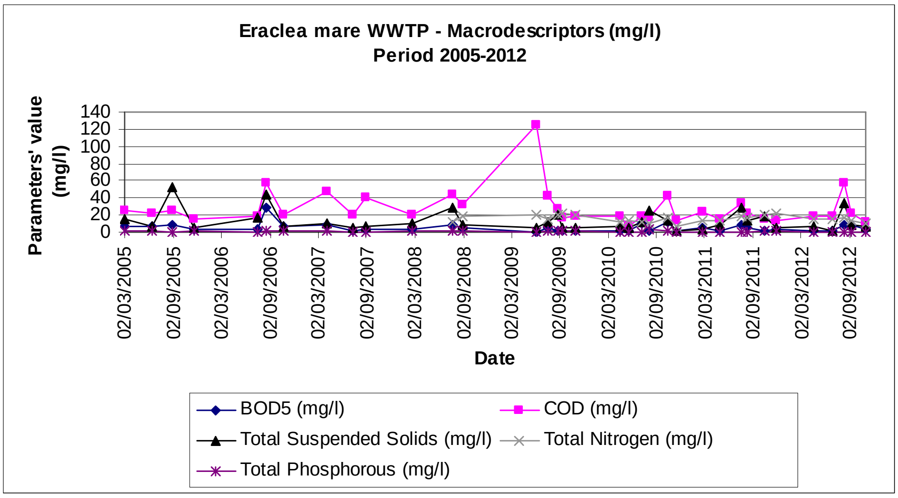


__Table 8.39__ – Discharge characterization – EC values on period 2005-2012

Eraclea mare WWTP	Escherichia coli UFC/100ml
Mean	3132
75° PERC	3200
MIN	0
MAX	25000
STD DEV	6300

__Figure 8.33__ – Discharge characterization - EC

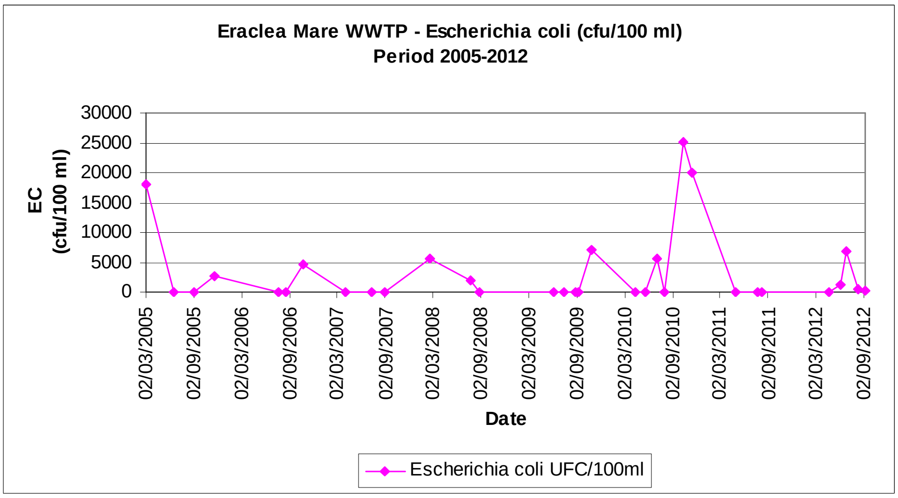
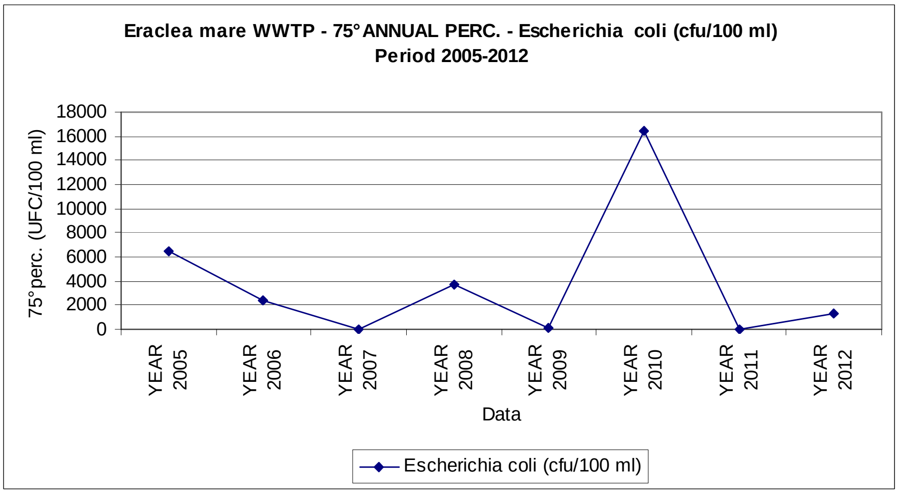


***Figure 8.34** – Discharge characterization – 75° annual percentile EC*



From available data in the period 2005-2012 the microbiological data on the final discharge have been assessed for active/non active disinfection systemas follows:

***Table 8.40** – Discharge characterization – Seasonal values of EC on period 2005-2012*

DISINFECTION ACTIVE

Eraclea mare WWTP	Escherichia coli cfu/100ml
Mean	689
75° PERC	110
MIN	0
MAX	6900
STD DEV	1747

***Table 8.41** – Discharge characterization – Seasonal values of EC on period 2005-2012*

Eraclea mare WWTP	Escherichia coli cfu/100ml
Mean	11857
75° PERC	19000
MIN	2700
MAX	25000
STD DEV	8897

For the monitoring of by-products values higher than LOD have been obtained in the period 2005-2012 only for the following parameters (see **Annex VIII** for detailed data):

- Chlorophorm;
- Bromophorm;
- Dibromo-chloromethane;
- Dichloro-bromomethane;
- Total Halogenated organic solvents;
- Phenols.

San Donà di P. WWTP

The WWTP's discharges parameters in the period 2005-2012 are reported in the following **tabs. 8.42-8.45** and **figs 8.35-8.37**.

Table 8.42 *– Discharge characterization – Macrodescriptors 2005-2012*

San Donà di P. WWTP	BOD_5 (mg/l)	COD (mg/l)	Total Suspended Solids (mg/l)	Total Nitrogen (mg/l)	Total Phosphorous (mg/l)
Mean	13.4	47.9	33.2	16.1	2.4
75° PERC	10.8	33.3	11.0	18.4	3.4
MIN	1.8	9.0	2.0	4.3	0.0
MAX	124.5	690.0	805.0	62.7	19.5
STD DEV	23.9	112.8	133.7	10.6	3.2

Figure 8.35 *– Discharge characterization - Macrodescriptors*

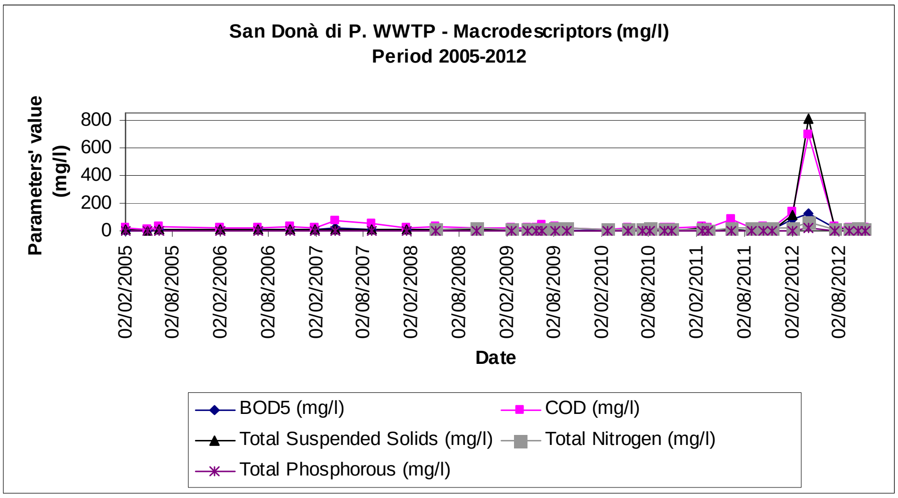


Figure 8.36 *– Discharge characterization - EC*

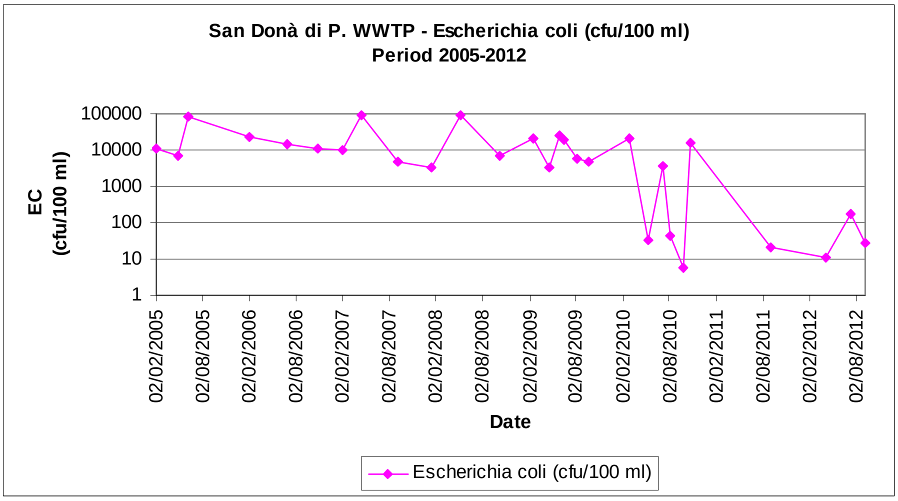


***Figure 8.37** – Discharge characterization – 75° annual percentile EC*

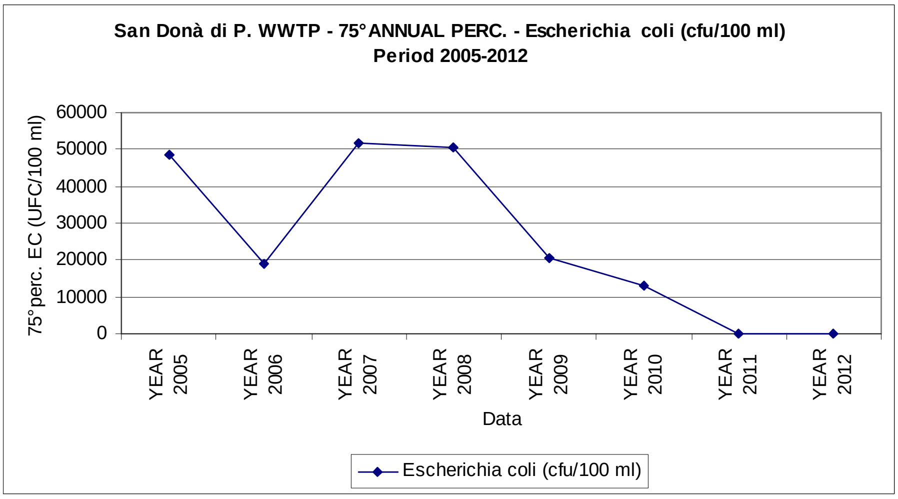


***Table 8.43** – Discharge characterization – EC values on period 2005-2012*

San Donà di P. WWTP	Escherichia coli (cfu/100 ml)
Mean	17340
75° PERC	19500
MIN	6
MAX	94000
STD DEV	27267

From available data in the period 2005-2012 the microbiological data on the final discharge have been assessed for active disinfection system (bathing season) and not active system (autumn and winter season) havee been calculatedas follows:

***Table 8.44** – Discharge characterization – Seasonal values of EC on period 2005-2012*

DISINFECTION ACTIVE

S. Donà di P. WWTP	Escherichia coli UFC/100ml
Mean	19070
75° PERC	17000
MIN	6
MAX	94000
STD DEV	32930

***Table 8.45** – Discharge characterization – Seasonal values of EC on period 2005-2012*

DISINFECTION NON ACTIVE

S. Donà di P. WWTP	Escherichia coli (cfu/100 ml)
Mean	13689
75° PERC	21000
MIN	3300
MAX	23000
STD DEV	6886

For the monitoring of by-products values higher than LOD have been obtained in the period 2005-2012 only for the following parameters (see **Annex VIII** with for detailed data):

- Chlorophorm;
- Dibromo-chloromethane;
- Dichloro-bromomethane;
- Total Halogenated organic solvents;
- Phenols.

Musile di P. WWTP

The WWTP's discharges parameters in the period 2005-2012 are reported in the following **tabs. 8.46-8.49**. and **figs 8.38-8.40**.

Table 8.46 *– Discharge characterization – Macrodescriptors 2005-2012*

Musile di P. WWTP	BOD_5 (mg/l)	COD (mg/l)	Total Suspended Solids (mg/l)	Total Nitrogen (mg/l)	Total Phosphorous (mg/l)
Mean	3.6	14.5	7.6	12.2	1.5
75° PERC	4.4	15.3	10.0	15.6	1.9
MIN	0.5	3.0	1.4	6.4	0.5
MAX	13.1	35.0	24.0	20.7	3.3
STD DEV	3.0	5.0	5.1	4.1	0.7

Figure 8.38 *– Discharge characterization - Macrodescriptors*

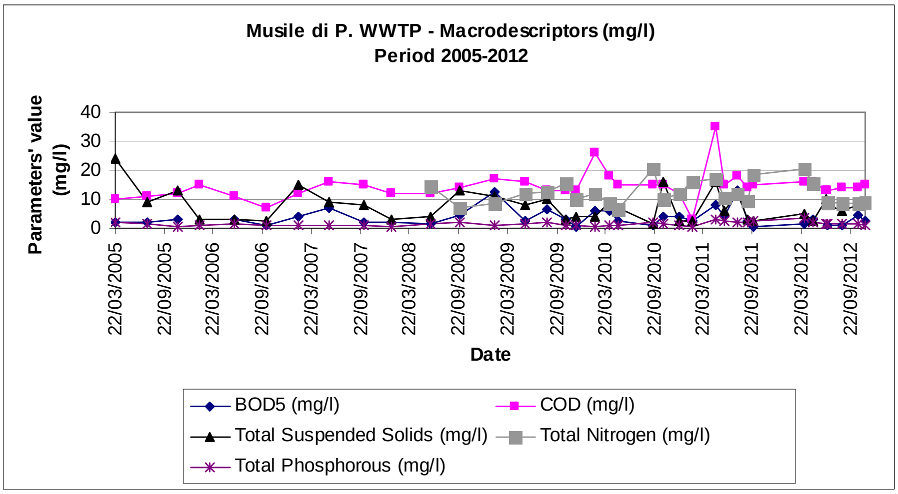


Table 8.47 *– Discharge characterization – EC values on period 2005-2012*

Musile di P. WWTP	Escherichia coli (cfu/100 ml)
Mean	7125
75° PERC	10000
MIN	0
MAX	43000
STD DEV	9314

Figure 8.39 *– Discharge characterization - EC*

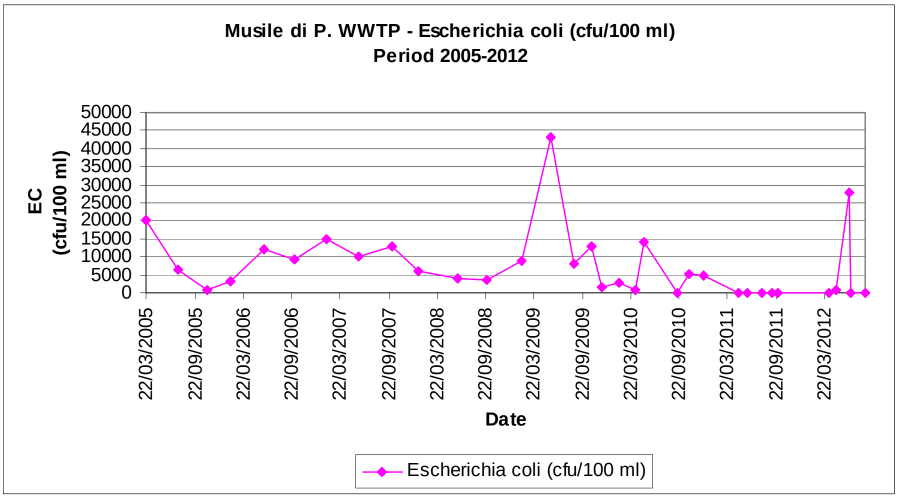
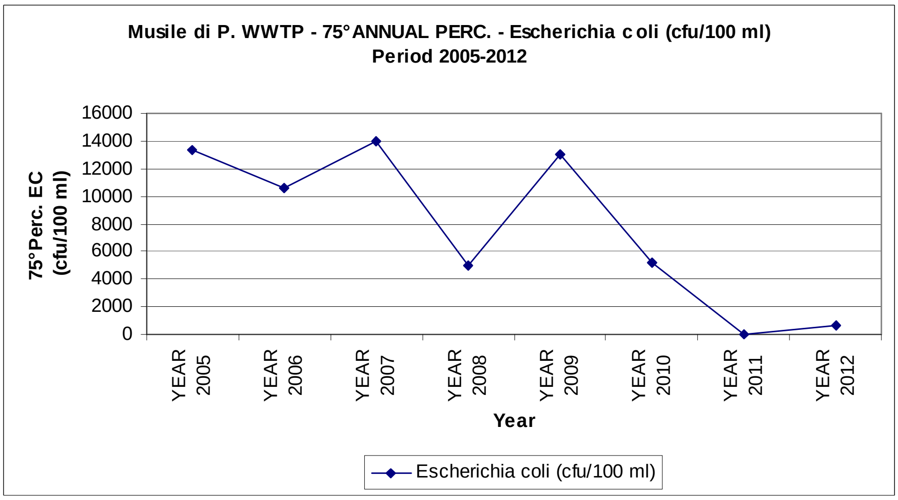


Figure 8.40 *– Discharge characterization – 75° annual percentile EC*



From available data in the period 2005-2012 the microbiological data on the final discharge have been assessed for active/non active disinfection system as follows:

Table 8.48 *– Discharge characterization – Seasonal values of EC on period 2005-2012*

DISINFECTION ACTIVE

Musile di P. WWTP	Escherichia coli (cfu/100 ml)
Mean	6557
75° PERC	8575
MIN	0
MAX	43000
STD DEV	11131

Table 8.49 *– Discharge characterization – Seasonal values of EC on period 2005-2012*

DISINFECTION NON ACTIVE

Musile di P. WWTP	Escherichia coli (cfu/100 ml)
Mean	8141
75° PERC	12250
MIN	980
MAX	20000
STD DEV	5612

For the monitoring of by-products values higher than LOD have been obtained in the period 2005-2012 only for the following parameters (see **Annex VIII** with for detailed data):

- Chlorophorm;
- Tetrachloroethilene;
- Phenols.

Caorle WWTP

The WWTP's discharges parameters in the period 2005-2012 are reported in the following **tabs. 8.50-8.53** and **figs 8.41-8.43**.

Table 8.50 *– Discharge characterization – Macrodescriptors 2005-2012*

Caorle WWTP	BOD_5 (mg/l)	COD (mg/l)	Total Suspended Solids (mg/l)	Total Nitrogen (mg/l)	Total Phosphorous (mg/l)
Mean	4.7	24.1	8.5	11.7	1.4
75° PERC	5.5	28.0	10.0	15.8	1.9
MIN	0.2	12.0	2.5	3.8	0.1
MAX	19.4	48.0	29.0	21.9	5.8
STD DEV	4.0	8.4	5.5	5.2	1.3

Figure 8.41 *– Discharge characterization - Macrodescriptors*

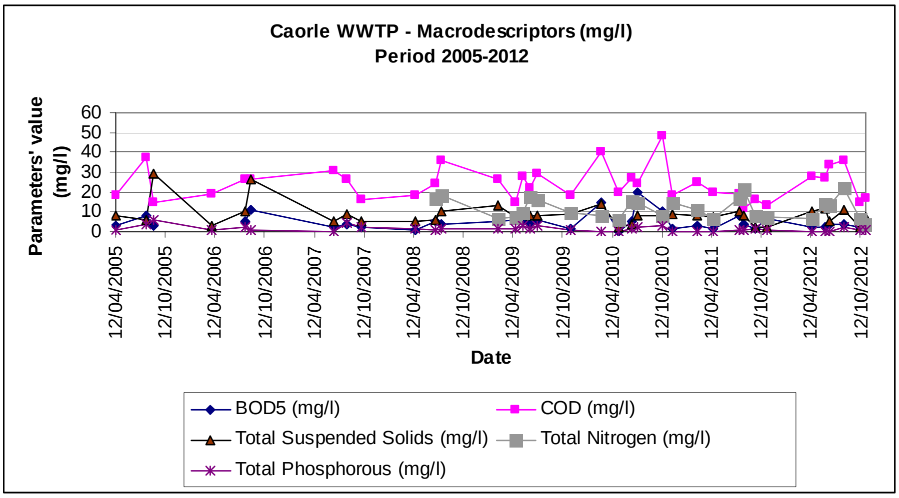


Table 8.51 *– Discharge characterization – EC values on period 2005-2012*

Caorle WWTP	Escherichia coli (cfu/100 ml)
Mean	4453
75° PERC	1123
MIN	0
MAX	57000
STD DEV	11668

Figure 8.42 *– Discharge characterization - EC*

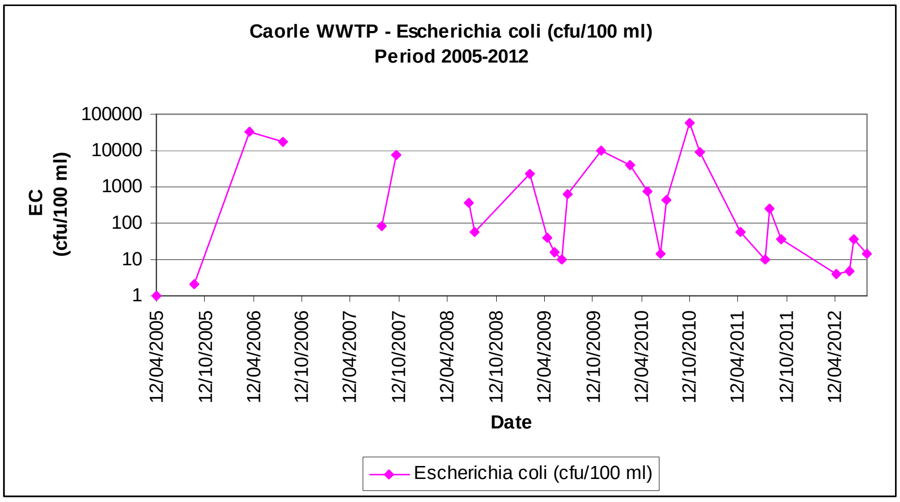
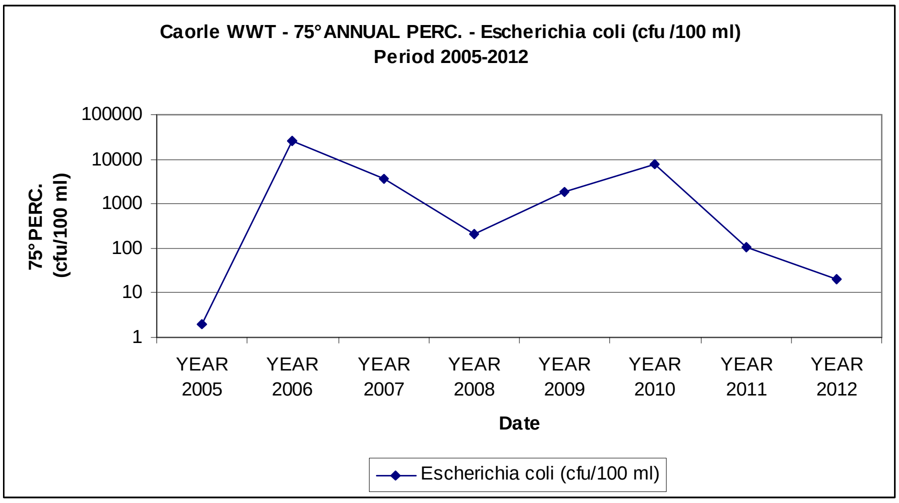


Figure 8.43 *– Discharge characterization – 75° annual percentile EC*



From available data in the period 2005-2012 the microbiological data on the final discharge have been assessed for active disinfection system (bathing season) and not active system (autumn and winter season) havee been calculatedas follows:

Table 8.52 *– Discharge characterization – Seasonal values of EC on period 2005-2012*

DISINFECTION ACTIVE

Caorle WWTP	Escherichia coli (cfu/100 ml)
Mean	832
75° PERC	80
MIN	0
MAX	18000
STD DEV	3583

Table 8.53 *– Discharge characterization – Seasonal values of EC on period 2005-2012*

DISINFECTION NON ACTIVE

Caorle WWTP	Escherichia coli (cfu/100 ml)
Mean	17386
75° PERC	20850
MIN	2300
MAX	57000
STD DEV	20057

For the monitoring of by-products values higher than LOD have been obtained in the period 2005-2012 only for the following parameters (see annex XXX with for detailed data):

- Chlorophorm;
- Bromophorm;
- Dibromo-chloromethane;
- Dichloro-bromomethane;
- Tetra-chloro-ethilene;
- Total halogenated organic solvents;
- Phenols.

Paese WWTP

The WWTP's discharges parameters in the period 2005-2012 are reported in the following **tabs. 8.54-8.55**. and **figs 8.44-8.45**.

Table 8.54 *– Discharge characterization – Macrodescriptors 2005-2012*

Paese WWTP	COD (mg/L)
Mean	50.5
75° PERC	62.5
MIN	25.0
MAX	100.0
STD DEV	19.1

***Figure 8.44** – Discharge characterization - Macrodescriptors*

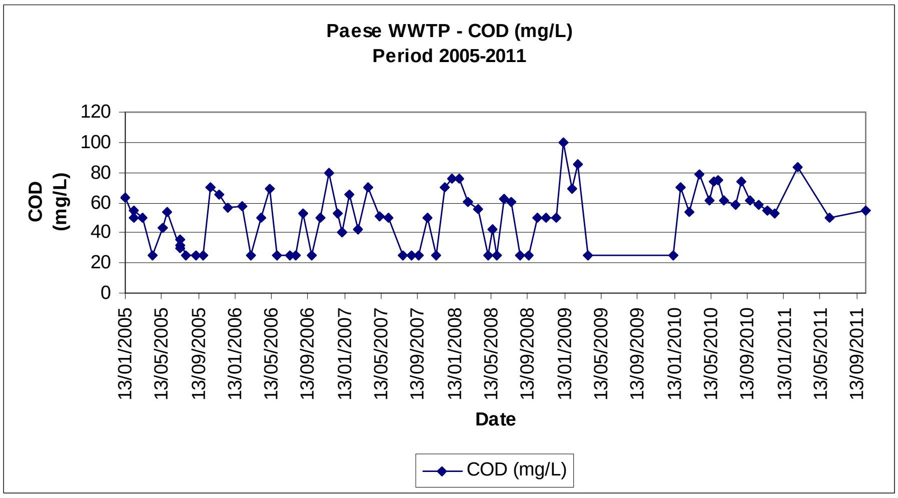
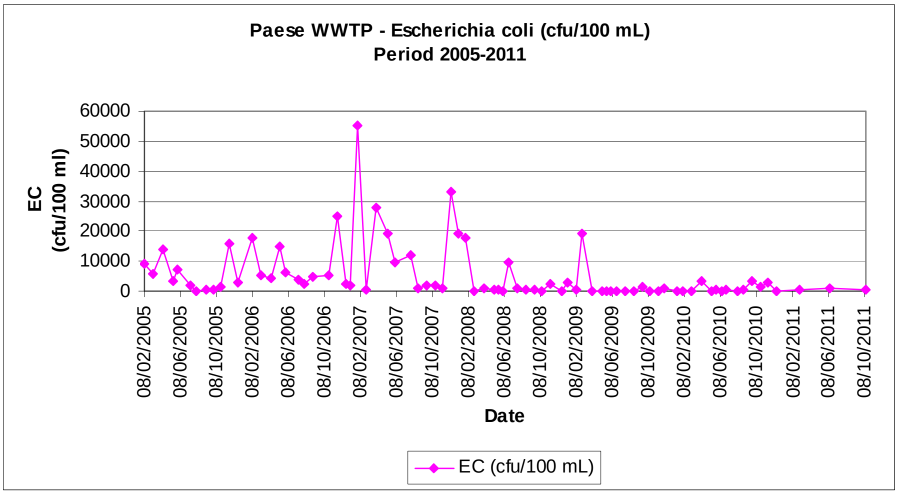


***Table 8.55** – Discharge characterization – Seasonal values of EC on period 2005-2012*

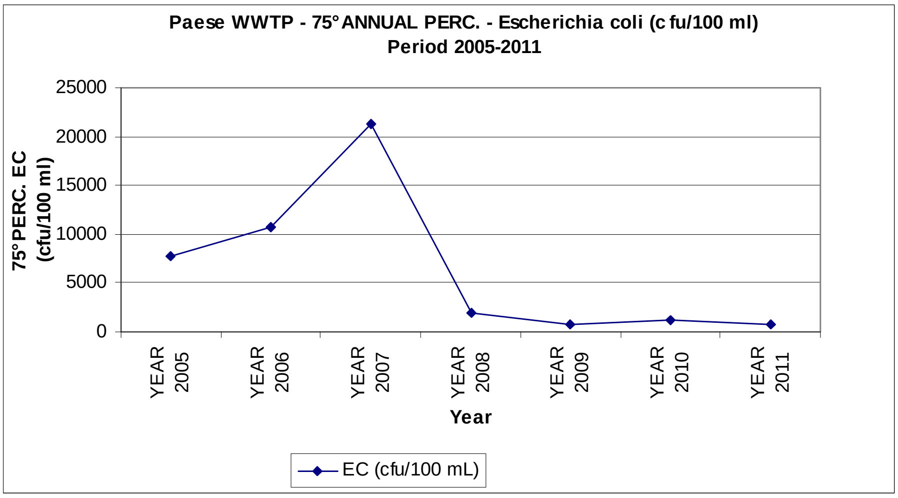
Paese WWTP	EC (cfu/100 mL)
Mean	5171
75° PERC	5125
MIN	3
MAX	55000
DEV STD	9101

***Figure 8.45** – Discharge characterization - EC*



From available data in the period 2005-2012 the microbiological data on the final discharge have been assessed for active disinfection system (bathing season) and not active system (autumn and winter season) havee been calculatedas follows:

Figure 8.46 *– Discharge characterization – 75° annual percentile EC*

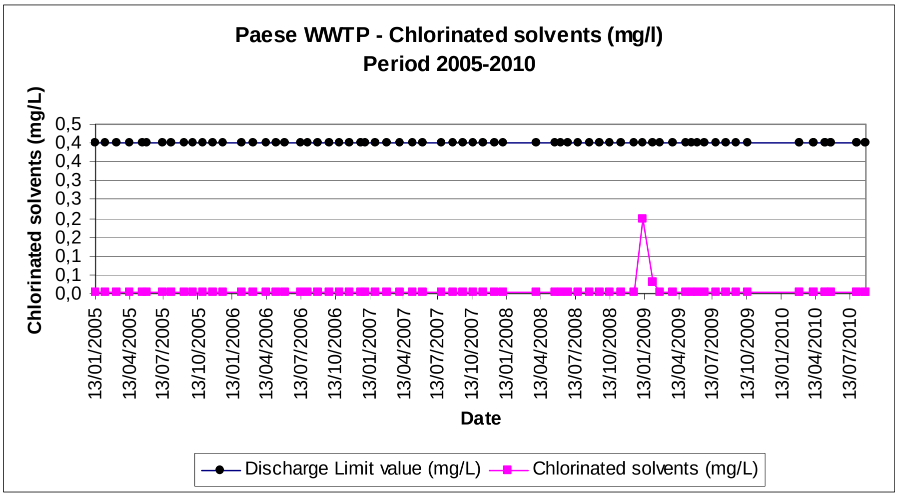


For the monitoring of by-products values higher than LOD have been obtained in the period 2005-2012 only for the following parameters (see **Annex VIII** for detailed data):

- Chlorinated solvents.

For the identified parameter the measured values together with the discharge limit vale are reported in **fig. 8.47**:

Figure 8.47 *– Discharge characterization – 75° annual percentile EC*



8.4 Considerations on microbiological and DBPs' data of WWTPs' discharges

8.4.1 Microbiological parameters

In the assessment of EC data it must be remembered that disinfection is activated all over lhe year only in few plants; in the othe it is activatec only in the bathing period. It is evident therefore that mean and 75° perc. value is affected by higher value in the period without disinfection.

In different cases it is evident a constat improvement of the microbiological quality of the final effluent in consideration of the improvement in the existing system (the case of UV for Fusina pnat) or the passage from no disinfection, to disinfection with hypochlorite and now with PFA (case of S. Donà di P.).

In consideration that normally a well functioning plant abates at least 2 log of enteric bacteria conc. The functionality verification approach appears useful for the general control of plants ≥ 10,000 PE

8.4.2 By-products of disinfection

As reported in literature for chlorine/chlorine compounds disinfection the indicators considered (THMs – chlorophorm, dichlorobromomethane and dibromochloromethane and chlorinated solvent) are normally researched by ARPAV laboratory; there is evidence of their presence in particular in the plants which apply HYPO. In any case their presence is low and always under not only the limits for discharge, but also reuse standards and surface water quality standards (for details see **Annex VIII**). Normally its value is around 1/10 of drinking water quality standard.

As indicate by Song et al. (2010) in plants with incomplete nitrification there is higher probability to produce Halonitromethane (HNMs), which present high toxicity for man; from the same study the favourable condition to produce HNMs is ozononation followed by chlorination (while ozonation alone does not produce HNMs); it is evident in this case that functionality verification could be useful for this evaluation.

ARPAV laboratory does not determine HNMs, neither HAAs, Haloketones. Only Aldehydes and Ketones have been determined qualitatively during PFA sperimentation in 2012 on Jesolo WWTP (see Chap. 9).

9. Disinfection systems' comparison

9.1 Introduction

The efficiency abatement verification has been made using plants' managers data (Veritas, ASI, SIBA-Veolia). In a previous study by ARPAV (Ostoich et al. 2007) in some of the WWTPs of **tab. 3.5** and **fig. 3.12** an investigation has been made comparing entering raw WW and final discharge after the disinfection system.

Data entering disinfection units and the corresponding exiting values of treated WW have been asked to the plant managers for the following WWTP: Fusina, Jesolo, Eraclea mare, San Donà di Piave, Musile di Piave, Caorle. All the WWTPs managed by ASI applied disinfection systems with Hypochlorite. Since 8th Dec. 2012 (practically since March 2013) all these plants, after the full scale experimentation, according to the compulsory disinfection period, passed to the PFA disinfection system. Jesolo plant presents data with hypochlorite till the beginning of 2011 then with PFA (full scale experimentation); Eraclea mare plant presents data with hypochlorite till 2010 and then with PFA.

9.2 The BIOPRO results

In the project Biopro, funded by the Procince of Venice and conductec by ARPAV, allowed a preliminary comparison of the different disinfection systems was made (Ostoich et al., 2007). In this project nine public WWTPs were considered together with an industrial plant with ozone (the plants are reported in **tab. 3.5** and **fig. 3.12**). In **fig. 9.1** and **9.2** mean data [$\log_{10}$(mean)] produced in the integrative study during the years 2003-2004 for the influents and effluents of the WWTPs considered are presented; in this case the private industrial treatment plant n. 10 (ozone disinfection system) is considered too.

Figure 9.1 *– Comparison of logarithmic mean values, years 2003-2004 of the different faecal indicators in the influents and effluents of WWTPs (with the disinfection systems) and the private treatment plant, selected in the study. The WWTPs 2 and 8 have no characterization of influent.*

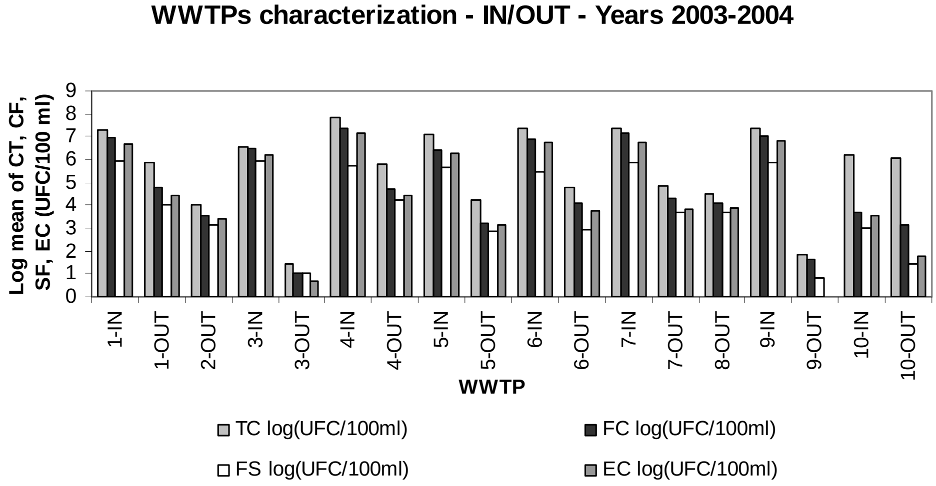
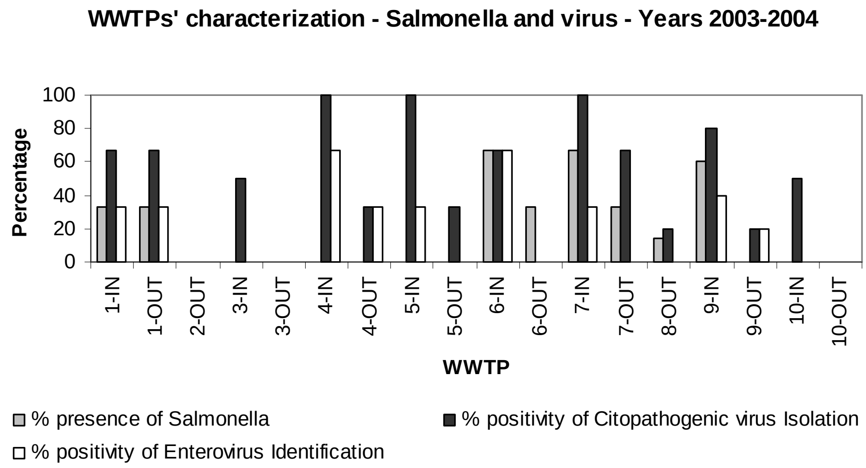
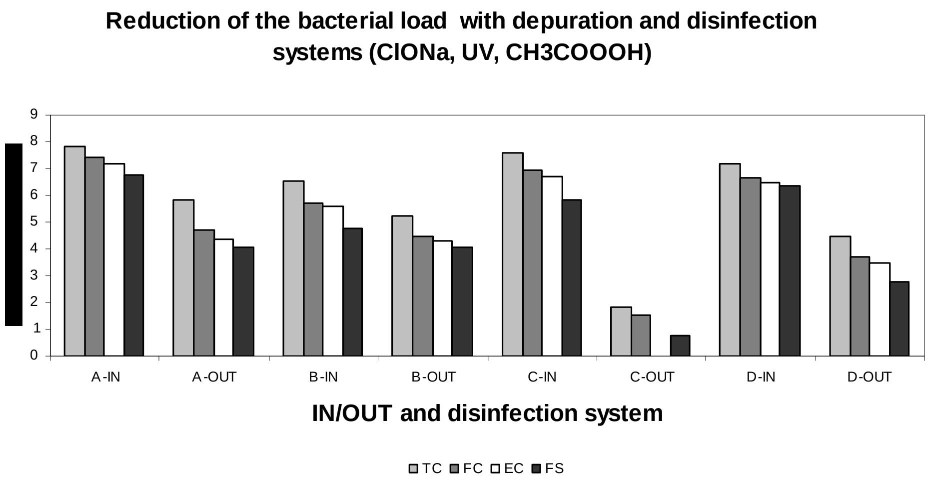


Figure 9.2 *– Percentage of presence of Salmonella and of positivity of Cytopathogenic Virus and Enterovirus Identification on the influents and effluents of the public WWTPs and the private treatment plant for the integrative campaign (2003-2004*



The graph in **fig. 9.3** (period 2003-2004) shows the abatement of the bacterial loads during the depuration processes, according to disinfection technologies applied, with the period of activation in the investigated WWTPs. The histograms refer to the mean concentration of the micro-organisms assessed in the period of the study. The microbiological analysis carried out values from 10^6 and 10^8 (cfu/100 mL) with reduction variable according to the treatment as showed in the graph; the UV technology appears to produce higher reduction, less evident for peracetic acid.

Figure 9.3 *– Reduction of bacterial loads expressed as ISPF in the years 2003-2004 (**A** with hypochloride disinfection - period 1/04-30/09; **B** without hypochloride disinfection - period 1/10-31/03; **C** with UV disinfection; **D** with Peracetic Acid*



The disinfection systems guarantee the abatement of faecal indicators normally of at least two orders (**fig. 9.1**). The mean level in the final discharge is higher in WWTPs were the total load is higher than the normal project capacity of treatment of the plants (i.e. n. 1, 2, 4). The disinfection efficacy is confirmed for *Salmonella*, but for Enterovirus it depends on the type of disinfection.The treatment processes with UV associated with light chlorination (WWTP n. 9) produce a remarkable reduction; this reduction is less evident for peracetic acid.

From **fig. 9.3** the normal capacity of faecal bacteria abatement of WWTP without disinfection is of more than one order (case B); it must be considered that this situation corresponds also to the period of the lowest or no tourist presence. From **figs 9.1** and **9.3** the mean level of microbiological contamination in the raw sewage is evident (here we are interested for WWTP only to EC parameter according to actual regulations).

9.3 Abatement efficiency

The abatement efficiency, according to available data supplied by the plants' managers, have been analysed only on the following plants:

- Fusina (VERITAS, PAA and then ultrafiltration with UV);
- Jesolo WWTP (ASI, Chlorine, PAA and PFA);
- Eraclea Mare (ASI Chlorine and PFA);
- Paese WWTP (SIBA, Ozone).

For each plant one or two disinfection technologies have been experimented. Comparison on the same plant in the same condision are easier. In the following §§ we consider the abatement efficiency and the disinfection techniques.

9.3.1 UV rays - Fusina WWTP

The IN/OUT data for WW subject to the final disinfection system with ultrafiltration and UV lamps have been supplied by the plant manager only for 2012. Data on the abatement efficiency are reported in **tab. 9.1**. The graph of the abatement is reported in **fig, 9.4**; only data of 2012 were supplied by the plant manager.

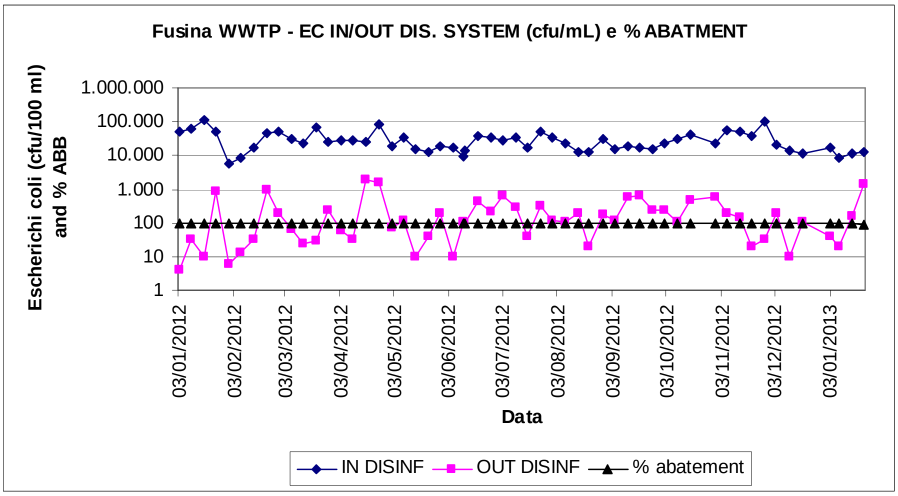
Table 9.1 *– Fusina WW data before and after disinfection unit – Year 2012*

Date	IN DISINF	OUT DISINF	% abatement
03/01/2012	48840	4	99.99
10/01/2012	61310	31	99.95
17/01/2012	111990	10	99.99
24/01/2012	48840	882	98.19
31/01/2012	5940	6	99.90
07/02/2012	8330	13	99.84
14/02/2012	17220	32	99.81
21/02/2012	46110	921	98.00
28/02/2012	51720	201	99.61

Date	IN DISINF	OUT DISINF	% abatement
06/03/2012	30760	63	99.80
13/03/2012	23590	25	99.89
20/03/2012	68670	28	99.96
27/03/2012	24810	238	99.04
03/04/2012	29090	61	99.79
10/04/2012	27550	31	99.89
17/04/2012	26100	1.986	92.39
24/04/2012	86640	1.576	98.18
02/05/2012	18600	75	99.60
08/05/2012	32550	121	99.63
15/05/2012	15650	10	99.94
22/05/2012	13140	41	99.69
29/05/2012	19350	199	98.97
05/06/2012	16640	10	99.94
11/06/2012	9590	110	98.85
12/06/2012	13340	98	99.27
19/06/2012	36540	450	98.77
26/06/2012	34480	211	99.39
03/07/2012	27550	613	97.77
10/07/2012	34480	281	99.19
17/07/2012	16740	41	99.76
24/07/2012	51720	327	99.37
31/07/2012	32550	122	99.63
07/08/2012	23590	109	99.54
14/08/2012	12230	199	98.37
20/08/2012	12460	20	99.84
28/08/2012	29870	168	99.44
04/09/2012	15970	122	99.24
11/09/2012	19180	576	97.00
18/09/2012	17000	630	96.29
25/09/2012	16000	240	98.50
02/10/2012	23590	241	98.98
09/10/2012	30760	108	99.65
16/10/2012	39680	480	98.79
30/10/2012	23590	591	97.49
06/11/2012	54750	203	99.63
13/11/2012	48840	146	99.70
20/11/2012	36540	20	99.95
27/11/2012	98040	31	99.97
04/12/2012	20980	187	99.11
11/12/2012	13760	10	99.93
18/12/2012	11780	107	99.09

Date	IN DISINF	OUT DISINF	% abatement
03/01/2013	17590	41	99.77
08/01/2013	8330	20	99.76
15/01/2013	11450	160	98.60
22/01/2013	12460	1.354	89.13

Figure 9.4 *– Fusina WW data before and after disinfection unit – 2012*



According to the proposed abatement rule the obtained abatement is <u>very satisfactory</u> as most of the measured data determine at least 99.00 % abatement; no data have been supplied for Salmonella and/or Enterovisus, neither instutional control data on the discharge were available for these parameters, so the proposed rule (see **Chapt. 7**) cannot be completely applied.

9.3.2 Sodium hypochloride (HYPO) and Peracetic acid (PAA) - Jesolo WWTP

The assessment of the abatement capacity (efficiency) has been performed with data supplied by ASI SpA. The same plant was managed with PAA disinfection system (2006) and with HYPO disinfection (2011).

During 2006 the plant had the PAA disinfection active; PAA dosing is reported in **tab. 9.2**. The abatement efficiency is reported in **tab 9.3**) (referred to *Escherichia coli*) and **tab. 9.4** (referred to *Enterococci*). During 2011 the disinfection was performed with Sodium hypochlorite (**tab. 9.4**).

From the tabs reported it is evident that disinfection efficiency increases passing from PAA to HYPO. In this case the comparison can be made as the plant is always the same and the management is performed by the same company in the same conditions. Disinfection is considered always in the high seson period.

Table 9.2 *– Jesolo WWTP – PAA dosing - 2006*

DATE	WWTP	DISINFECTANT	Flow - during sample mc/h	DISINFECTANT mg/L	Ritention Time min
21/08/06	JESOLO	**PAA**	1498	**1.0**	**15**
22/08/06	JESOLO	**PAA**	1879	**0.9**	**12**
23/08/06	JESOLO	**PAA**	1228	**0.9**	**18**
28/08/06	JESOLO	**PAA**	1580	**1.0**	**14**
29/08/06	JESOLO	**PAA**	1448	**1.2**	**15**
30/08/06	JESOLO	**PAA**	1597	**1.6**	**14**
31/08/06	JESOLO	**PAA**	1693	**1.6**	**13**
04/09/06	JESOLO	**PAA**	1422	**1.5**	**16**
05/09/06	JESOLO	**PAA**	1439	**1.6**	**15**
06/09/06	JESOLO	**PAA**	1286	**1.8**	**17**
07/09/06	JESOLO	**PAA**	1265	**2.0**	**18**
12/09/06	JESOLO	**PAA**	1123	**2.1**	**20**
13/09/06	JESOLO	**PAA**	1268	**2.0**	**17**
14/09/06	JESOLO	**PAA**	1314	**1.9**	**17**

Table 9.3 *– Jesolo WWTP - Abatement efficiency with PAA – EC*

DATE	Escherichia Coli_IN cfu/100mL	Escherichia Coli_OUT cfu/100mL	EC_IN Log	EC_OUT Log	EC ABAT Log	% EC ABAT
21/08/06	204545	50909	**5.3**	**4.7**	**0.6**	**75.11**
22/08/06	145455	10270	**5.2**	**4.0**	**1.2**	**92.94**
23/08/06	159091	4369	**5.2**	**3.6**	**1.6**	**97.25**
28/08/06	36486	991	**4.6**	**3.0**	**1.6**	**97.28**
29/08/06	37838	599	**4.6**	**2.8**	**1.8**	**98.42**
30/08/06	55856	630	**4.8**	**2.8**	**2.0**	**98.87**
31/08/06	23423	446	**4.4**	**2.7**	**1.7**	**98.10**
04/09/06	61261	414	**4.8**	**2.6**	**2.2**	**99.32**
05/09/06	72072	5000	**4.9**	**3.7**	**1.2**	**93.06**
06/09/06	48198	599	**4.7**	**2.8**	**1.9**	**98.76**
07/09/06	54505	284	**4.7**	**2.5**	**2.3**	**99.48**
12/09/06	36036	99	**4.6**	**2.0**	**2.6**	**99.73**
13/09/06	18182	167	**4.3**	**2.2**	**2.0**	**99.08**
14/09/06	33333	81	**4.5**	**1.9**	**2.6**	**99.76**

Table 9.4 *– Jesolo WWTP - Abatement efficiency with PAA - IE*

DATE	Enterococci_IN cfu/100mL	Entero OUT cfu/100mL	ENT_IN Log	ENT_OUT Log	ENT ABAT Log	% ENT ABAT
21/08/06	18468	10909	**4.3**	**4.0**	**0.2**	**40.93**
22/08/06	7966	5676	**3.9**	**3.8**	**0.2**	**28.75**
23/08/06	9406	5721	**4.0**	**3.8**	**0.2**	**39.18**
28/08/06	1935	1306	**3.3**	**3.1**	**0.2**	**32.51**
29/08/06	2520	2027	**3.4**	**3.3**	**0.1**	**19.56**
30/08/06	3510	2793	**3.6**	**3.5**	**0.1**	**20.43**
31/08/06	1665	721	**3.2**	**2.9**	**0.4**	**56.70**
04/09/06	4955	1545	**3.7**	**3.2**	**0.5**	**68.82**
05/09/06	2835	2545	**3.5**	**3.4**	**0.0**	**10.23**
06/09/06	3300	1500	**3.5**	**3.2**	**0.3**	**54.55**
07/09/06	2160	613	**3.3**	**2.8**	**0.5**	**71.62**
12/09/06	2723	333	**3.4**	**2.5**	**0.9**	**87.77**

DATE	Enterococci_IN cfu/100mL	Entero OUT cfu/100mL	ENT_IN Log	ENT_OUT Log	ENT ABAT Log	% ENT ABAT
13/09/06	1847	414	**3.3**	**2.6**	**0.7**	**77.59**
14/09/06	2027	315	**3.3**	**2.5**	**0.8**	**84.46**

From **tab. 9.2** a non satisfactory abatement is evident in the first days of its activation. In the following **tabs 9.5-9.7** the 2011 functioning of the same plant with HYPO is reported.

Table 9.5 *– Jesolo WWTP – HYPO dosing - 2011*

DATE	WWTP	DISINFECTANT	Flow - during sample mc/h	DISINFECTANT mg/L	Ritention Time min
24/05/11	JESOLO	**Cl2**	742	**1.9**	**30**
31/05/11	JESOLO	**Cl2**	809	**1.9**	**27**
07/06/11	JESOLO	**Cl2**	810	**2.5**	**27**
14/06/11	JESOLO	**Cl2**	986	**2.9**	**22**
21/06/11	JESOLO	**Cl2**	899	**2.6**	**25**
28/06/11	JESOLO	**Cl2**	1163	**2.3**	**19**
05/07/11	JESOLO	**Cl2**	1289	**2.5**	**17**
12/07/11	JESOLO	**Cl2**	1090	**2.8**	**20**
19/07/11	JESOLO	**Cl2**	1126	**3.2**	**20**
26/07/11	JESOLO	**Cl2**	1161	**2.9**	**19**
02/08/11	JESOLO	**Cl2**	1359	**3.0**	**16**
09/08/11	JESOLO	**Cl2**	1375	**3.0**	**16**
16/08/11	JESOLO	**Cl2**	1411	**2.8**	**16**
23/08/11	JESOLO	**Cl2**	1430	**2.8**	**15**
30/08/11	JESOLO	**Cl2**	1143	**3.0**	**19**
06/09/11	JESOLO	**Cl2**	1251	**2.8**	**18**
13/09/11	JESOLO	**Cl2**	1117	**2.5**	**20**

Table 9.6 *– Jesolo WWTP - Abatement efficiency with HYPO - EC*

DATE	Escherichia Coli_IN cfu/100mL	Escherichia Coli_OUT cfu/100mL	EC_IN Log	EC_OUT Log	EC ABAT Log	% EC ABAT
24/05/11	36000	9	**4.6**	**1.0**	**3.6**	**99.98**
31/05/11	37000	50	**4.6**	**1.7**	**2.9**	**99.86**
07/06/11	1400000	10	**6.2**	**1.0**	**5.2**	**100.00**
14/06/11	42000	9	**4.6**	**1.0**	**3.7**	**99.98**
21/06/11	30000	58	**4.5**	**1.8**	**2.7**	**99.81**
28/06/11	28000	57	**4.5**	**1.8**	**2.7**	**99.80**
05/07/11	91000	110	**5.0**	**2.0**	**2.9**	**99.88**
12/07/11	83000	220	**4.9**	**2.3**	**2.6**	**99.73**
19/07/11	55000	21	**4.7**	**1.3**	**3.4**	**99.96**
26/07/11	64000	160	**4.8**	**2.2**	**2.6**	**99.75**
02/08/11	34000	63	**4.5**	**1.8**	**2.7**	**99.81**
09/08/11	56000	5	**4.8**	**0.7**	**4.1**	**99.99**
16/08/11	410000	210	**5.6**	**2.3**	**3.3**	**99.95**
23/08/11	110000	83	**5.0**	**1.9**	**3.1**	**99.92**
30/08/11	19000	2	**4.3**	**0.3**	**4.0**	**99.99**
06/09/11	88000	18	**4.9**	**1.3**	**3.7**	**99.98**
13/09/11	58000	2300	**4.8**	**3.4**	**1.4**	**96.03**

Table 9.7 *– Jesolo WWTP - Abatement efficiency with HYPO - IE*

DATE	Enterococci_IN cfu/100mL	Entero OUT cfu/100mL	ENT_IN Log	ENT_OUT Log	ENT ABAT Log	% ENT ABAT
24/05/11	490	5	**2.7**	**0.7**	**2.0**	**98.98**
31/05/11	360	16	**2.6**	**1.2**	**1.4**	**95.56**
07/06/11	37000	940	**4.6**	**3.0**	**1.6**	**97.46**
14/06/11	770	8	**2.9**	**0.9**	**2.0**	**98.96**
21/06/11	1600	230	**3.2**	**2.4**	**0.8**	**85.63**
28/06/11	1900	120	**3.3**	**2.1**	**1.2**	**93.68**
05/07/11	3400	540	**3.5**	**2.7**	**0.8**	**84.12**
12/07/11	3000	230	**3.5**	**2.4**	**1.1**	**92.33**
19/07/11	3500	99	**3.5**	**2.0**	**1.5**	**97.17**
26/07/11	33000	27	**4.5**	**1.4**	**3.1**	**99.92**
02/08/11	2.00	320	**3.4**	**2.5**	**0.9**	**87.69**
09/08/11	5900	130	**3.8**	**2.1**	**1.7**	**97.80**
16/08/11	23000	1500	**4.4**	**3.2**	**1.2**	**93.48**
23/08/11	3300	350	**3.5**	**2.5**	**1.0**	**89.39**
30/08/11	1300	2	**3.1**	**0.3**	**2.8**	**99.85**
06/09/11	2300	45	**3.4**	**1.7**	**1.7**	**98.04**
13/09/11	1200	230	**3.1**	**2.4**	**0.7**	**80.83**

9.3.2 Performic Acid (PFA) - Eraclea mare WWTP

During 2011 the disinfection of Eraclea mare plant was performed with PFA; PFA dosing is reported in **tab. 9.8**, while abatement data are reported in **tabs 9.8-9-10**.

Table 9.8 *– Eraclea mare WWTP – PFA dosing*

DATE	WWTP	DISINFECTANT	Flow - during sample mc/h	DISINFECTANT mg/L	Ritention Time min
09/05/11	ERACLEA	**PFA**	133	**0.7**	**11**
16/05/11	ERACLEA	**PFA**	124	**0.7**	**12**
30/05/11	ERACLEA	**PFA**	95	**0.6**	**16**
13/06/11	ERACLEA	**PFA**	127	**1.0**	**12**
20/06/11	ERACLEA	**PFA**	145	**1.1**	**10**
27/06/11	ERACLEA	**PFA**	133	**1.2**	**11**
04/07/11	ERACLEA	**PFA**	134	**1.1**	**11**
18/07/11	ERACLEA	**PFA**	156	**1.1**	**10**
01/08/11	ERACLEA	**PFA**	239	**0.9**	**6**
08/08/11	ERACLEA	**PFA**	162	**1.0**	**9**
16/08/11	ERACLEA	**PFA**	170	**1.0**	**9**
22/08/11	ERACLEA	**PFA**	195	**1.0**	**8**
29/08/11	ERACLEA	**PFA**	159	**1.0**	**9**
05/09/11	ERACLEA	**PFA**	190	**0.9**	**7.9**

***Table 9.9** – Eraclea mare WWTP - Abatement efficiency with PFA- EC*

DATE	Escherichia Coli_IN cfu/100mL	Escherichia Coli_OUT cfu/100mL	EC_IN Log	EC_OUT Log	EC ABAT Log	% EC ABAT
09/05/11	12000	2	**4.1**	**0.3**	**3.8**	**99.98**
16/05/11	9800	8	**4.0**	**0.9**	**3.1**	**99.92**
30/05/11	31000	280	**4.5**	**2.5**	**2.0**	**99.10**
13/06/11	220000	14	**5.3**	**1.2**	**4.2**	**99.99**
20/06/11	9900	5	**4.0**	**0.7**	**3.3**	**99.95**
27/06/11	42000	23	**4.6**	**1.4**	**3.3**	**99.95**
04/07/11	55000	270	**4.7**	**2.4**	**2.3**	**99.51**
18/07/11	62000	360	**4.8**	**2.6**	**2.2**	**99.42**
01/08/11	36000	35	**4.6**	**1.5**	**3.0**	**99.90**
08/08/11	62000	45	**4.8**	**1.7**	**3.1**	**99.93**
16/08/11	370000	410	**5.6**	**2.6**	**3.0**	**99.89**
22/08/11	63000	290	**4.8**	**2.5**	**2.3**	**99.54**
29/08/11	10000	37	**4.0**	**1.6**	**2.4**	**99.63**
05/09/11	41000	12	**4.6**	**1.1**	**3.5**	**99.97**

***Table 9.10** – Eraclea mare WWTP - Abatement efficiency with PFA - IE*

DATE	Enterococci_IN cfu/100mL	Entero OUT cfu/100mL	ENT_IN Log	ENT_OUT Log	ENT ABAT Log	% ENT ABAT
09/05/11	4400	340	**3.6**	**2.5**	**1.1**	**92.27**
16/05/11	3300	31	**3.5**	**1.5**	**2.0**	**99.06**
30/05/11	3300	50	**3.5**	**1.7**	**1.8**	**98.48**
13/06/11	5500	99	**3.7**	**2.0**	**1.7**	**98.20**
20/06/11	990	3	**3.0**	**0.5**	**2.5**	**99.70**
27/06/11	1800	15	**3.3**	**1.2**	**2.1**	**99.17**
04/07/11	4000	16	**3.6**	**1.2**	**2.4**	**99.60**
18/07/11	4900	63	**3.7**	**1.8**	**1.9**	**98.71**
01/08/11	3800	54	**3.6**	**1.7**	**1.9**	**98.58**
08/08/11	6400	12	**3.8**	**1.1**	**2.7**	**99.81**
16/08/11	21000	1100	**4.3**	**3.0**	**1.3**	**94.76**
22/08/11	3200	400	**3.5**	**2.6**	**0.9**	**87.50**
29/08/11	1600	230	**3.2**	**2.4**	**0.8**	**85.63**
05/09/11	4700	38	**3.7**	**1.6**	**2.1**	**99.19**

9.3.3 Ozone – Paese WWTP

The data supplied by the Paese plant manager refer to the monitoring activities performed on wastewaters with ozone at the discharge point and at the entry point of the disinfection system for the period 2006-2011. Since 2009, sampling activities have been performed by the plant manager with automatic and cooled samplers; quantities were sample fixed on a 24 hour time period; in previous years the sampling activity varied and included: instantaneous samples, samples every 3 hours, samples on a 24 hour time period.

Despite considering measurement errors for the controlled microbiological parameters (TC, FC, SF, EC, *Salmonella spp.*; depending on the maintenance conditions of samples, the mean sample performed, the possibilities of contamination of the sample, etc.) and the limitations in the representativeness of the inflow sample, the abatement percentage, which was calculated on the annual mean value of the samples measured in the outlet and in the inlet of the disinfection section, did not produce entirely satisfactory results (**tab. 9.11**). Although data are mostly higher than 99% (always for the parameter EC) and the pathogen (*Salmonella*) is nearly always absent in the outlet, it must be observed that the 99.99% abatement percentage has not been reached: according to Zann & Sutton (1995) this is the objective to be achieved specifically when the water in the receiving water body is intended for human use (bathing and irrigation waters, fish and mollusc life conditions) (Ostoich et al, 2013).

Table 9.11 *– Paese WWTP - Abatement efficiency of the disinfection system with the ozone system for the period 2006-2011 (Source: Paese WWTP manager, 2011)*

Year	TC	FC	EC	FS	Salmonella *spp.*
2006	99.4	99.61	99.62	99.36	*
2007	91.84	97.19	99.15	97.12	Absent ***
2008	95.51	99.03	99.46	99.66	Absent
2009	98.55	99.71	99.88	99.68	Absent
2010	95.81	99.53	99.86	99.94	Absent
2011	98.37	99.53	99.87	99.84	Absent

* Unsearched for Parameter *** present only in 3 samples in the period considered

In 11 cases *Salmonella* was detected in the disinfection inlet, but not in the outlet, in the period 2006-2011; while in 4 cases in the same period it was detected in the outlet as well as in the inlet in January, June, August and November. Therefore no seasonal differences are apparently evident; problems could refer to the heavy entry loads, to the type of wastewater (domestic/industrial/liquid wastes) and to the functioning of the disinfection system.

In some cases it is not clear, especially during 2007, what the causes are for the lower abatement percentages. In fact the dosage of ozone was not regular which may be an explanation for the pathogen found in the final discharge and, consequently, the lower abatement efficiency. Moreover, it must be observed that the values of microbiological parameters in the inflow wastewaters were particularly high in many cases (i.e: 30/03/2011 inlet to disinfection system: TC = 57000; FC = 28000; EC = 20000; FS = 2000 cfu/100 mL; outlet from the disinfection system: TC = 810; FC = 150; EC = 130; FS = 12 cfu/100 mL; source: Paese plant manager).

9.4 DBPs of chlorine and its products

ARPAV data have reported and commented in **Chapt. 8**. Here we present data supplied by ASI plant manager. Chlorination DBPs have been analyzed by ASI laboratory in n. 5 plants (Caorle, Jesolo, Eraclea mare, San Donà di Piave and Musile di Piave). For simplicity in the following **tabs 9.12-9.13** data on THMs are reported for Jesolo and San Donà di Piave in the years in which HYPO was adopted. The final level of THMs is compared with the limit value for drinking water (Decree n. 31/2001). It is evident that only few data overtake the limit for drinking water (but at the discharge). Moreover a synthesis of data obtained in 5 years of monitoring on the cited 5 WWTPs are reported in **tab. 9.14**. In this table the comparison of THMs level with Italian and international standards on THMs are defined.

Table 9.12 *– Chlorination disinfection by-products – Jesolo WWTP –ASI data*

Jesolo			2011	(during 2012 the PFA has been used)					
N° DATA	NH4	N-NH4	Cl2 Dosed	Cl2 free	Total Cl2	Cl2/N-NH4	Retention time	THM	E.Coli out
175	mg/L	mg/L	mg/L	mg/L	mg/L	Ratio	min	mg/L	Cfu/100mL
mean	3,8	3,0	2,4	0,11	0,9	4,7	33	11	141
min	0,2	0,2	1,4	0,02	0,00	0,3	15	2	2
max	14,7	11,4	3,6	0,7	2,0	21,5	89	48	2300
								>30	>1000
							N° DATA	3	1

Jesolo			2010						
N° DATA	NH4	N-NH4	Cl2 Dosed	Cl2 free	Total Cl2	Cl2/N-NH4	Retention time	THM	E.Coli out
175	mg/L	mg/L	mg/L	mg/L	mg/L	Ratio	min	mg/L	Cfu/100mL
mean	1,9	1,4	2,5	0,12	0,9	9,7	21	15	18
min	0,2	0,2	1,3	0,05	0,52	0,2	12	3	5
max	12,8	10,0	3,6	0,3	1,4	19,7	34	55	91
								>30	>1000
							N° DATA	3	0

Jesolo			2009						
N° DATA	NH4	N-NH4	Cl2 Dosed	Cl2 free	Total Cl2	Cl2/N-NH4	Retention time	THM	E.Coli out
190	mg/L	mg/L	mg/L	mg/L	mg/L	Ratio	min	mg/L	Cfu/100mL
mean	---	---	2,9	0,15	1,1	---	29	12	19
min	---	---	2,0	0,05	0,34	---	9	2	5
max	---	---	4,0	0,4	2,1	---	54	43	120
								>30	>1000
							N° DATA	3	0

Table 9.13 *– Chlorination disinfection by-products – San Donà di Piave WWTP –ASI data*

San Donà			2012						
N° DATA	NH4	N-NH4	Cl2 Dosed	Cl2 free	Total Cl2	Cl2/N-NH4	Retention time	THM	E.Coli out
133	mg/L	mg/L	mg/L	mg/L	mg/L	Ratio	min	mg/L	Cfu/100mL
mean	0,7	0,5	2,1	0,07	0,4	20,0	29	11	435
min	0,1	0,0	1,1	0,02	0,07	0,3	19	3	9
max	8,8	6,9	3,2	0,2	1,0	47,5	46	23	4400
								>30	>1000
							N° DATA	0	1

San Donà			2011						
N° DATA	NH4	N-NH4	Cl2 Dosed	Cl2 free	Total Cl2	Cl2/N-NH4	Retention time	THM	E.Coli out

135	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*Ratio*	*min*	*mg/L*	*Cfu/100mL*
mean	1,3	1,0	2,0	0,10	0,7	14,4	27	11	11
min	*0,1*	*0,1*	*1,1*	*0,04*	*0,05*	*0,1*	*19*	*2*	*5*
max	14,9	11,6	3,7	0,6	1,9	47,8	37	38	23
								>30	**>1000**
							N° DATA	*1*	*0*

San Donà			**2010**						
N° DATA	***NH4***	***N-NH4***	***Cl2 Dosed***	***Cl2 free***	***Total Cl2***	***Cl2/N-NH4***	***Retention time***	***THM***	***E.Coli out***
136	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*Ratio*	*min*	*mg/L*	*Cfu/100mL*
mean	0,4	0,3	2,0	0,06	0,4	10,4	26	18	593
min	*0,1*	*0,1*	*0,8*	*0,02*	*0,08*	*0,0*	*17*	*3*	*5*
max	5,2	4,0	3,7	0,3	0,9	47,1	49	36	6600
								>30	**>1000**
							N° DATA	*3*	*4*

Table 9.14 *– Chlorination by-products – Synthesis data on 5 WWTPs for 5 years monitoring – ASI data*

THM Limit value (µg/l)	**N. analysis**	**Percentage**	**Reference regulation on drinking water**
< 100	1,131	99.6%	Drinking water UK
< 50	1,061	93%	Drinking water Germany
< 30	917	81%	Drinking water Italy

ASI experimentation data confirm that is possible to use chlorine with low impact without necessity of final quenching. This aspect was realized working with WW with Cl_2 dosages from 0.5 to 15 mg/l (breakpoint test). The break-point dosages for real WW are reported in **tab.9.15**.

The tendency to form THMs grows with high concentration of Chlorine (Cl_2 = 50 mg/l) and contact time of 24 h. ASI did not find HAAs as well as N-nitrosodimethylamine (NDMA) in all the analysis performed in 2012. In systems with a complete nitrification controlled application of chlorine and compounds in disinfection produces acceptable THMs level for drinking water (Ragazzo et al., 2011).

Table 9.15 *– Chlorination Breakpoint dosages –ASI data for 5 samples of final WW*

THM formation: different Cl2 dosages, Contact Time 30 min.

WWTPs	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5
Cl2 2 mg/L (Cl2/N ratio)	4,8 *(4)*	4,3 *(4)*	11 *(4)*	13 *(4)*	1,8 *(0,6)*
Cl2 3 mg/L (Cl2/N ratio)	8,1 *(7)*	9,8 *(6)*	21 *(6)*	22 *(6)*	3,2 *(0,8)*
Cl2 5 mg/L (Cl2/N ratio)	24 *(11)*	32 *(10)*	55 *(10)*	54 *(10)*	3,9 *(1,4)*
Cl2 7 mg/L (Cl2/N ratio)	50 *(16)*	96 *(14)*	91 *(14)*	82 *(14)*	5,7 *(1,9)*
Breakpoint Ratio	*16*	*12*	*14*	*14*	

9.5 Disinfection with Performic Acid (PFA)

9.5.1 ASI experimentation

ASI during 2012, after the full-scale experimentations in Caorle (2005) and Eraclea mare (2011), proceeded to another period of experimentation of PFA for the final disinfection of the Jesolo WWTP (Ragazzo et al., 2013). The system, developed by Kemira Oyj, is based on Hydrogen Peroxide (HP) and Formic Acid (FA) mixing to produce, throughout the Performic acid (PFA) formation, the final disinfection solution.

In order to establish its reliability in field application conditions, the research was carried out in two functional stages batch trial experimentations and full scale plant applications, all performed between April 2005 and September 2011. A summary of the experimental phases is shown in **tab. 9.16**. For dosages and contact times ASI refer to the average values of real minimum and maximum working conditions.

***Table 9.16** – Summary of disinfection full scale trial first step: A and B phases*

FC = faecal coliforms, EC = *E. coli* , ENT = enterococci

Phase	WWTP	Year	Season	Bacterial Indicators	Disinfectant	Dosage mg/L	Contact time min
						Average	*min - max*
Phase_**A**	**CAORLE**	2005	winter	FC – EC - ENT	PFA	0,6 - 1,7	13 - 39
Phase_**B**	**CAORLE**	2006	summer	FC – EC - ENT	PFA	0,9 - 2,3	19 - 47
Phase_**C**	**ERACLEA**	2011	summer	EC - ENT	PFA	0,7 - 1,2	7 - 18
Phase_**D**	**JESOLO**	2006	summer	FC – EC - ENT	PAA	1,0 - 2,0	13 - 19
Phase_**E**	**CAORLE**	2008	summer	EC - ENT	HClO	1,0 - 4,8	13 - 35
Phase_**F**	**JESOLO**	2011	summer	FC – EC - ENT	HClO	2,1 - 3,0	16 - 28

9.5.2 ARPAV experimental campaign on DBPs of PFA disinfection in Jesolo WWTP

During the ASI experimentation of PFA ARPAV was required to make scrrening control of DBPs during this phase: three samplings were performed sampling in the enetering point of disinfection system and in the final discharge. Therefore 6 analytic results are available.

According to the effective available analytical technique ARPAV analyzed in quantitative way the classes reported in **tab. 9.17**; the results of the anlysis of the 6 samples are reported in **tab. 9.18**.

***Table 9.17** – ARPAV screening on DBPS IN and OUT disinfection Jesolo WWTP*

Class of compounds	Compounds
Phenols and Chlorophenols	Phenol sum Phenol 2,4,6-Trichlorophenol 2-Chlorophenol 4-Chlorophenol 3-Chlorophenol PCP 2,4-Chlorophenol
Organohalogenated compounds	Sum of organohalogenated compounds Tribromomethane

Class of compounds	Compounds
	Trichloromethane Dibromochloromethane Bromodichloromethane Trichoroethilene Tetrachloroethilene Vynil-chloride 1,2-dichloroethane 1,1,2 Trichloethane 1,1-Dichloroethilene 1,2-dichloroethilene cis 1,2-dichloroethilene trans 1,2-dichloropropane 1,1-dichloroethane 1,2-dibromoethane 1,2,3-trichloropropane Esachlorobutadiene Benzene Toluene Ethilbenzene Xylenes (o+m+p) Styrene

Table 9.18 *– Results of ARPAV screening on DBPs IN and OUT disinfection - Jesolo WWTP - 2012*

Sample	Result
Fist sample SIRAV code 500028437 Date 18/07/2012 **IN**	**Phenol 0.12 µg/l** **Toluene 0.05 µg/l** GC analysis combined with Purge & Trap and Mass spectrometry for the research of volatile substances has pointed out the presence, with the support of the library NIST, of **substituted aldehydes**. GC analysis combined with MS after solvent extraction has pointed out the presence, with the support of the library NIST of **tetrahydrofuran substituted, fatty acids, phtalates, substuituted phenols**.
Second sample SIRAV code 27000211 Date 18/07/2012 **OUT**	**Phenol 0.05 µg/l** GC analysis combined with Purge & Trap and Mass spectrometry for the research of volatile substances has pointed out the presence, with the support of the library NIST, of **substituted aldehydes and ketones.** GC analysis combined with MS after solvent extraction has pointed out the presence, with the support of the library NIST of **phtalic anydrides**, **fatty acids, phtalates**.
Third sample SIRAV code 500028437 Date 13/08/2012 **IN**	**Phenols sum 0.70 µg/l** **Phenol 0.70 µg/l** GC analysis combined with Purge & Trap and Mass spectrometry for the research of volatile substances has not pointed out the presence, with the support of the library NIST, of any type of compounds. GC analysis combined with MS after solvent extraction has pointed out the presence, with the support of the library NIST of **tetrahydrofuran substituted, ketones, fatty acids, phtalates**
Fourth sample	**Phenols sum 0.52 µg/l**

Sample	Result
SIRAV code 27000211 Date 13/08/2012 **OUT**	**Phenol 0.52 µg/l** GC analysis combined with Purge & Trap and Mass spectrometry for the research of volatile substances has not pointed out the presence, with the support of the library NIST, of any significant substance. GC analysis combined with MS after solvent extraction has pointed out the presence, with the support of the library NIST of **tetrahydrofuran substituted, fatty acids, phtalates, substuituted phenols**
Fifth sample SIRAV code 500028437 Date 17/09/2012 **IN**	**Phenol 0.09 µg/l** GC analysis combined with Purge & Trap and Mass spectrometry for the research of volatile substances has not pointed out the presence, with the support of the library NIST, of any significant substance. GC analysis combined with MS after solvent extraction has pointed out the presence, with the support of the library NIST of **fatty acids and phtalates**.
Sixth sample SIRAV code 27000211 Date 17/09/2012 **OUT**	**Phenol 0.04 µg/l** GC analysis combined with Purge & Trap and Mass spectrometry for the research of volatile substances has not pointed out the presence, with the support of the library NIST, of any significant substance. GC analysis combined with MS after solvent extraction has pointed out the presence, with the support of the library NIST of **fatty acids and phtalates**.

Considerations:

In the ARPAV analysis only data > LOD applied have been considered. In two cases on three for phenols influent values are higher than effluent values. Phenol is not correlated to ozone disinfection. The parameters of **tab. 9.17** have already been assessed for the specific WWTP (see **Chapt. 8** and **Annex VIII**).

9.6 Disinfection costs

Veritas supplied an estimation of the costs of HYPO, PAA and UV. It must be observed that this estimation takes care of the characteristics of the two considered plants (Fusina and Campalto). Data are reportd in **tab. 9.19**.

Table 9.19 *– Disinfection costs – Source: Veritas SpA*

	Fusina WWTP		Campalto WWTP	
Year	**Dinfection technique**	**Cost (€/1000 m^3)**	**Dinfection technique**	**Cost (€/1000 m^3)**
2000	HYPO	3.2	HYPO	3.12
2010	PAA	6.7	PAA	8.7
2012	UV	2*	UV	9.5

* calculation based on the energy cost

From the above table costs of PAA appear very high. UV is high in particular in Campalto were very high energy costs are reqired as the plant has been realized to achieve the reuse limit (EC<10 cfu/100 ml).

10. Microbiological impact on the coastal belt

10.1 Integrated real analysis 2000-2006

The proposed approach of this analyses, following the DPSIR framework, takes into account monitoring data of all the interested matrices (rivers, bathing waters, marine waters) and controls on the effluents discharged directly into the sea or through the rivers near to the considered coastal area from the WWTPs. The coast was divided into stretches, each of them connected to a river body (stretches n. VI and VII do not present river mouths) and which could be considered homogeneous according to geographical, physical and hydrological features (**tab. 3.5** and **fig. 3.12**).

In this assessment, carried out over the period 2000-2006, the samples considered were: a) 871 for rivers, b) 7273 for bathing waters; c) 353 for marine-coastal waters; d) 179 for WWTPs. For each stretch data were described statistically for the sample size, the mean and the values of the 5th and the 95th percentile. In **tabs 10.1-10-11** data for only 5 (selected for reasons of space) of the 8 stretches are reported as mean values of cfu/100 mL in the considered period together with percentile values (5th and 95th percentiles) for the microbiologic parameters TC, FC, SF, EC; for the parameter Salmonella only the presence/absence percentage is reported; in the same Tabs with the n. of samples the total number of samples (repetitions on the same point of measurement) for the considered period in each river monitoring station and for each WWTP discharge are reported; for bathing and sea waters the n. of samples is the total number as sum of the samples on each station of the considered stretch (see Tab. 1 for the identification of the stations) with their repetitions during the years. The reported data refer to the most significant stretches.

The parameters TC, FC, FS are available for all the matrices; the parameter EC is reported only for surface waters and WWTP discharges, as it was not monitored during the considered years in the bathing and in the sea water monitoring stations. For reason of space and in consideration to the potential biological impact on the coastal belt, the results of the ANOVA statistical assessment for only three selected stretches are reported in **tab. 10.12**; the assessment was performed for: stretch I Tagliamento river mouth; stretch V Sile river mouth; stretch VIII Brenta-Bacchiglione and Adige river mouths (Ostoich et al. 2010).

Table 10.1 *– Stretch I – cfu/100 mL*

	N. of samples	TC Mean	TC 5th – 95th percentile	FC mean	FC 5th – 95th percentile	FS mean	FS 5th – 95th percentile	EC mean	EC 5th – 95th percentile
River station n. 432	81	1517	200 - 3500	578	50 - 2500	120	28 - 350	334	20 - 1000
WWTP n. 1	19	146670	4 - 692500	14079	0 - 67600	2747	0 - 12710	6268	0 - 32400
Bathing waters	601	28	0 - 110	5	0 - 24	3	0 - 11	-	
Marine-coastal waters	64	104	0 - 993	11	0 – 81	9	0 – 40	-	-

***Table 10.2** – Stretch I*

Period 2000-2006	Salmonella	
	N. of positive/Tot. N.	% of positive
River station n. 432	25/81	30.8
WWTP n. 1	0/10	0
Bathing waters	0/137	0
Marine-coastal waters	0/51	0

***Table 10.3** – Stretch II – cfu/100 mL*

	N. of samples	TC mean	TC 5th – 95th percentile	FC mean	FC 5th – 95th percentile	FS mean	FS 5th – 95th percentile	EC mean	EC 5th – 95th percentile
River station n. 433	81	20421	1600 - 80900	2754	354 - 6500	478	84 - 1580	1733	310 - 4680
River station n. 71	28	12734	275 - 52550	1289	32 - 4345	415	8 - 1760	894	22 - 3155
WWTP n. 3	9	708265	21 - 2984000	51931	6 - 164000	20496	6 - 93160	33757	0 - 139200
Bathing waters	624	194	0 – 986	27	0 – 119	3	0 - 16	-	
Marine-coastal waters	8	318	0 – 1336	67	0 - 274	9	0 - 21	-	

***Table 10.4** – Stretch II*

Period 2000-2006	Salmonella	
	N. of positive/Tot. N.	% of positive
WWTP n. 3	3/7	42.8
Rivers Station n. 433	32/81	39.5
Rivers Station n. 71	10/28	35.7
Bathing waters	6/146	4.1
Marine-coastal waters	0/8	0

***Table 10.5** – Stretch V – cfu/100 mL*

	N. of samples	TC mean	TC 5th – 95th percentile	FC mean	FC 5th – 95th percentile	FS mean	FS 5th – 95th percentile	EC mean	EC 5th – 95th percentile
River station n. 237	83	23347	2500 - 72400	3822	652 - 9490	720	48 - 2870	2711	521 - 6580
WWTP n. 5	20	23468	0 - 135000	3524	0 - 15960	8218	0 - 61000	2314	0 - 8200
River station n. 238	82	8756	402 - 36900	1192	110 - 4980	188	20 - 480	682	51 - 2295
WWTP n. 6	26	55809	19 - 267000	4519	0 - 26000	726	7 - 2365	2492	0 - 9975
Bathing waters	1069	58	0 - 165	21	0 - 55	2	0 - 10	-	
Marine-coastal waters	8	220	5 – 879	46	2 – 161	17	1 – 62	-	

Table 10.6 – *Stretch V*

Period 2000-2006	Salmonella	
	N. of positive/Tot. N.	% of positive
River station n. 237	38/83	45,7
WWTP n. 5	1/10	10
River station n. 238	27/82	32,9
WWTP n. 6	5/15	33,3
Bathing waters	4/202	1,9
Marine-coastal waters	0/8	0

Table 10.7 – *Stretch VI – cfu/100 mL*

	N. of samples	TC mean	TC 5th – 95th percentile	FC mean	FC 5th – 95th percentile	FS mean	FS 5th – 95th percentile	EC mean	EC 5th – 95th percentile
WWTP n. 7	17	34702	18 - 167500	8197	3 - 38550	1432	2 - 7700	29241	0 - 106000
Bathing waters	1072	3	0 - 11	1.1	0 - 4	1.1	0 - 4	-	-
Marine-coastal waters	59	14	0 - 58	4	0 - 17	6	0 - 9	-	-

Table 10.8 – *Stretch VI*

Period 2000-2006	Salmonella	
	N. of positive/Tot. N.	% of positive
WWTP n. 7	1/10	10
Bathing waters	1/132	0.7
Marine-coastal waters	0/50	0

Table 10.9 – *Stretch VIIIa – cfu/100 mL*

	N. of samples	TC mean	TC 5th – 95th percentile	FC mean	FC 5th – 95th percentile	FS mean	FS 5th – 95th percentile	EC mean	EC 5th – 95th percentile
River Station n. 436	82	17789	368 - 60450	1859	64 - 6565	220	3 - 698	1145	27 - 4060
River Station n. 437	103	7566	312 - 32800	980	61 - 4380	178	10 - 629	581	36 - 3270
WWTP n. 9	28	9991	0 - 43700	1244	0 - 2730	168	0 - 1455	29728	0 - 1748
Bathing waters VIIIa+b	1474	737	0 - 3035	124	0 - 365	4.7	0 - 20	-	-
Marine-coastal waters VIIIa+b	110	2433	0 - 12350	206	0 - 760	31	0 - 107	-	-

Table 10.10 – *Stretch VIIIb – cfu/100 mL*

	N. of samples	TC mean	TC 5th – 95th percentile	FC mean	FC 5th – 95th percentile	FS mean	FS 5th – 95th percentile	EC mean	EC 5th – 95th percentile
River station n. 217	83	11837	78 - 65300	1451	10 - 6370	194	1 - 570	823	10 - 2780
River station n. 222	84	8183	65 - 33850	1025	9 - 5085	209	0 - 801	603	3 - 2425

***Table 10.11** – Stretch VIII*

Period 2000-2006	Salmonella	
	N. of positive/Tot. N.	% of positive
River Brenta station n. 436	37/82	45.1
River Adige station n. 437 Brenta	24/103	23.3
WWTP n. 9	0/19	0
River Adige station n. 217	32/83	38.5
River Adige Station n. 222	17/84	20.2
Bathing waters	35/503	7
Marine-coastal waters	2/94	2.1

***Table 10.12** – Results of ANOVA statistical assessment*

Stretch	Parameter	F	$F_{0.05}$	DG
I	EC	11.4	3.9	*
	TC	24.6	2.7	2^
	FC	54.9	2.7	2^
	FS	65.8	2.7	2^
	Salmonella	26.6	3.0	1^
V	EC	1.4	3.9	*
	TC	93.0	2.6	2^
	FC	140.7	2.6	D^^
	FS	35.3	2.6	2^
	Salmonella	36.4	2.6	D^^
VIII	EC	12.4	3.9	*
	TC	111.9	2.6	D^^
	FC	96.8	2.6	D^^
	FS	101.1	2.6	D^^
	Salmonella	2.0	2.6	E**

F = F test value; $F_{0.05}$: F test critical value imposing a p-value of 0.05;
DG: matrices that significant differ from the others. * only two matrices.
^ Matrices legend: 1 river stations, 2 WWTP, 3 bathing stations and 4 marine-coastal stations.
^^D: significant differences between matrices 1-2 and 3-4.
** E: no significant difference among all matrices.

As already introduced for each homoneneous stretch (see **tab. 3.5**) microbiological data on water (fresh and sea water) monitoring stations and WWTPs' discharges are presented and assessed. *Integrated analysis* assesses the water quality of each stretch identified as a unique and strictly interconnected system with the aim of producing a synthetic evaluation of the biological impact on the coastal waters. This approach to the analysis of environmental data, in conformity with the 2000/60/EC *Water Framework Directive* is a preliminary application of the *bathing water profile* required by Directive 2006/7/EC concerning the management of bathing water quality. Although more information is needed, the analysis offers a static outlook of the environmental biological contamination of waters with mean data; the ANOVA statistical assessment was used to confirm the aspects deduced from mean values of monitoring and control data for each stretch.

It is not possible to make a correlation with rain and/or river flows as data on discharge controls are not frequent, particularly in autumn and winter when for all of the WWTPs (except three: n. 3, 5 and 9 in which disinfection is all year round) the disinfection systems are active only during the bathing period. Moreover, in autumn and winter it is not possible to verify the biological impact of the WWTP discharges without active disinfection systems as the river monitoring stations are generally localized upward (except for two WWTPs: n. 3 and 5) and bathing waters are not monitored. With the available data a seasonal evaluation cannot be significant and therefore the study is relative only to the general circulation of biological pollution (mean data on year basis).

With reference to disinfection systems, Zann and Sutton (1995) point out that it is important to note that though 99,9% reduction in pathogens may at first appear satisfactory, this is often not enough. In fact the discharge of non-disinfected raw or primary/secondary sewage effluents into bathing waters is expected to represent a local health risk without further dilution/die-off of at least 1000-fold, as can occur through deepwater sea outfall. In sea waters, the effect of salinity on microorganism mortality must be considered; as all of the considered WWTPs' discharges come from treatment plants with a biological stage, a cautious decay time (e-folding time) of 1 day can be considered to be the decay parameter in sea waters; this parameter has been estimated through literature values (Crane and Moore 1986; Evison 1988; Mancini 1978), but ideally specific studies would be needed to confirm these numbers.

In Italy, the bathing guidelines currently in force (Decree n. 470/1982 for the period 2000-2006), which transposed the previous Directive on bathing waters (EC, 1976), prescribe maximum concentrations of FC, TC and FS for human recreational use for the microbiological quality of coastal waters.

It must be pointed out that, in this study and in the following discussion, the standard values for the suitability of bathing water are used only as indicative quality benchmarks, as according to the Italian law in force during the period of the study, a single breach is enough to cause the temporary closure of the beach concerned. Moreover, it must be remembered that the reported mean values of WWTP discharges consider the entire period (every year from 2000 to 2006) including the periods where the disinfection systems were not always active. Indeed the disinfection systems are active either all year round or only in the bathing season according to the specific plant, and therefore the mean values offer only an indicative evaluation of microbiological contamination. The decision to impose the activation of the disinfection systems all year round or only in the bathing season is taken by the control Authority (Province).

Two stretches (n. VI and VII) present the WWTPs' discharge about 4 km from the shoreline with submarine outfalls. Grohmann et al. (1993) observed that the realization of three deepwater ocean outfalls in the bay of Sydney drastically reduced the presence of pathogens along the costs used for bathing and this – according to the faecal indicators used in this study – seems to be respected. In many cases the pathogen is identified in the river waters but not in the WWTP discharges which can support the hypothesis of animal contamination (animal excrements used in agriculture).

Stretch I – Tagliamento river mouth, beaches of Bibione and Porto Baseleghe: for faecal parameters in relation to the values in the years considered it must be pointed out that:

- the level of contamination in the river is constant in the years; there are no high mean values;
- the bathing and marine-coastal waters do not appear to be directly influenced by the impact of the WWTP (see **tab. 10.12** for the statistical assessment) and present mean values lower than the limit established for bathing waters.

At the WWTP discharge for a total of 10 samples, no one sample was found positive for the *Salmonella* pathogen parameter. The same can be observed for bathing and marine waters; *Salmonella* was found in 30% of the cases in surface waters.

Stretch II – Lemene river mouth, Valle Vecchia and Caorle: for this stretch, data is available from two river monitoring stations (n. 433 and n. 71) and discharge from WWTP n. 3. The whole assessment finds a mean level of faecal pollution of rivers with values of around 10^4 cfu/100 mL for TC, 10^3 for FC and 10^2 for FS with a positive trend (lower concentration) of the water quality in years 2005 and 2006. In the considered years the WWTP n. 3, found upstream of the analyzed hydrographic system had lowered its pollution loads. If until 2002 it was possible to observe (not reported here) a significant influence of the WWTP on the river quality, in the last 4 years the situation appears to have definitely improved. Mean data for bathing and marine-coastal waters appear on values to be almost lower than legal standards (Decree n. 152/1999 and Decree n. 470/1982). Over the years, it has become evident that the significant improvement of the quality of the waters is probably due to the improvement of the efficiency of the WWTP and its disinfection system. The *Salmonella* pathogen is present in 3 out of 7 (42,8%) samples in the WWTP discharge. The presence of *Salmonella* is also high in both of the river monitoring stations (39% and 35%, see Tab. 6), while, on the other hand, values are not significant in bathing and marine-coastal waters.

Stretch III – Livenza river mouth, beaches of Santa Margherita, Valle Altanea and Duna Verde: the considered stretch contains river monitoring station n. 72 on the Livenza river and the WWTP n. 2 which discharges its wastewaters near the town of Caorle, into the Saetta channel and before its conjunction with the Livenza river. It is possible to observe mean values of microbiological pollution for faecal parameters, which is similar to the values in other water bodies, and a dilution of 2 logarithmic orders of the same parameters in bathing waters. The bathing waters present satisfactory quality which is below the limit standards (expressed as mean values). Data on the WWTP discharges appear acceptable, always below 10^4 cfu/100 mL for TC. The analysis of the WWTP's effluents do not present any positive case of the *Salmonella* pathogen. The pathogen undergoes the effects of dilution, with a presence of 33% in river waters, 4% in bathing waters and none in marine-coastal waters.

Stretch IV – Piave river mouth, beaches of Eraclea and Jesolo: it is evident that over the considered period, the quality of the WWTP's discharge (order of 10^5 cfu/100 mL for TC) worsens in this area, while the analysis of the quality of the Piave river indicates water quality that appears constantly acceptable. No particular effects on bathing waters are evident. The *Salmonella* pathogen is identified in percentages comparable in river waters as well as in WWTP discharges (28% and 30% respectively) and is strongly diluted in bathing waters (3%) and in marine-coastal waters (2%).

Stretch V – Sile river mouth, beaches of Porto Piave Vecchia and Cavallino: two WWTPs are present in this area, n. 5, downstream from river monitoring station n. 237 (Quarto d'Altino), and n. 6 near the tourist city of Jesolo, downstream from station n. 238 (a river monitoring station situated in the stretch of the Sile-Piave Vecchia river, close to Valle Dragojesolo). The river presents significant mean faecal pollution levels for both stations n. 237 and n. 238 (10^4 cfu/100 mL for TC). It must be observed that upstream, the river receives high organic loads from the town of Treviso and from the drainage of sludge used in agriculture. The effluent from WWTP n. 6, near the river mouth, most heavily influences the quality of the bathing waters. WWTP n. 6 presents a positive percentage, higher than that of WWTP n. 5 (33% and 10% respectively) for the *Salmonella* pathogen. However, the highest percentages of positivity can be found in the river (45% in the upstream stations and 33% in the downstream stations) for the whole period 2000-2006. ANOVA results for the statistical assessment are reported in **tab. 10.12**.

Stretch VI – San Nicolò (Lido of Venice) mouth, beaches of Punta Sabbioni and Lido of Venice (no rivers): WWTP n. 7, which impacts this area, discharges directly into the sea at a distance of about 4 km from the coast-line through a submarine outfall. The disinfection system is activated only in the bathing period. Low levels of contamination of bathing waters can be observed; this result confirms the predictions of the modeling study for the dispersion of microbiological pollution along the coast (Scroccaro et al., 2005). For WWTP n. 7, 10% of analyses of the *Salmonella* pathogen were positive on a total of 10 samples; for bathing waters *Salmonella* was identified only in 1 case on 132 with very low percentages present.

Stretch VII – Malamocco mouth, Alberoni and Pellestrina (no rivers): also in this stretch as in, stretch n. VI, the WWTP's effluents are discharged directly into the sea (about 4 km from the coast) with a submarine outfall. From the reported monitoring and control data, there is evidence of a very low level of microbiological pollution for bathing waters, although for WWTP n. 8, in the period 2002-2004, high values of TC (10^4 cfu/100 mL) were registered; it must be observed that disinfection with NaClO for this plant is prescribed only in the period 1st April-30th September, therefore the mean value in a year takes account of the values registered with disinfection activated as well as the periods without disinfection. *Salmonella* was not detected on the WWTP's discharge.

Stretch VIII – Brenta and Adige river mouths, beaches of Ca' Roman, Sottomarina and Isola Verde: stretch n. VIII includes the area of the Brenta and Adige river mouths and the stretch of coast between Ca' Roman beach (south of Pellestrina beach), Sottomarina and Isola Verde beaches. The whole area was subdivided into two sub-areas (VIII a and b) in order to better present environmental information from a graphic and geographical point of view. In general, for the Brenta and Adige rivers, the mean faecal pollution levels are of the same order, or higher than those from the WWTP n. 9, with values at a level of 10^4 cfu/100 mL for both rivers (**tab. 10.12**). ANOVA analysis points out a dichotomy between on one side river and WWTP matrices and on the other side bathing and marine matrices; however in bathing and marine water of this stretch there are for all the microbiologic parameters the highest mean values than in the other stretches. It can be argued that a significant impact is registered in bathing and marine-coastal waters which, for a long time, have given the highest microbiological level of contamination along the coast of the Province of Venice. Similar considerations can be made for the *Salmonella* pathogen, which appears with very high positivity percentages in the stations of the Brenta and Adige rivers, while it is not found in the WWTP's effluents. Positive percentages of 7% and 2% are measured in bathing and marine-coastal waters respectively, with high probability bound to the river loads.

From the *integrated areal analysis* of biological parameters in all of the homogeneous stretches investigated along the coast, high mean levels of faecal contamination can be found in many cases. Amongst the stretches the most critical situation can be found in stretch n. VIII for Ca' Roman, Sottomarina and Isola Verde shores. These results can be widely attributed to pressure sources from the Brenta and Adige rivers rather than to local contributions. This analysis offers a static representation of the pollution phenomena as it does not consider meteorological, hydrological and marine (tide, stream) parameters. These aspects were considered and assessed in a previous study with the support of a mathematical dispersion model (Scroccaro et al. 2005; Ostoich et al, 2006; Scroccaro et al. 2009).

Stretches n. VI and VII, which correspond to the area from Punta Sabbioni (Cavallino shore, N-E) to the Pellestrina shore (S-W), are those which present the best conditions for faecal contamination parameters (low pollution level). This situation can probably be explained given that WWTPs n. 7 and n. 8 have two submarine outfalls at a distance of about 4 km from the coast line and therefore discharge at a distance away from the bathing and marine–coastal monitoring stations; in these two stretches there are also no river mouths, which could heavily condition the quality of the sea water.

A diffuse origin of pathogens (*Salmonella* discovered in rivers as well as in the WWTP discharges especially when disinfection is not activated) is clearly evident. In general, it was not possible to consider the different behaviour of WWTP discharges with seasonal reference as the majority of WWTPs do not activate disinfection systems all year round, but only during the bathing period; moreover, data on discharges control were rare over the autumn-winter season (1st October-31st March) and bathing water monitoring in this period is not carried out.

10.2 Impact of the submarine outfalls

For the two submarine outfalls from the WWTPs of Lido and Cavallino, according to the study developed with ARPA FVG and ISMAR of Venice (Scroccaro et al., 2010) the results seem to highlight that the two discharges of the Veneto region are not noticeable. Results of modeling are presented, with respect to the understanding of biological wastewater treatment mechanisms and to plant management. The greatest effort consisted in the integration of modeling, monitoring and laboratory analysis to study the relationships between environmental and physical parameters, and bacterial survival, based on literature data. Numerical simulations were carried out with the 3D version of the finite element model SHYFEM for a 3 month period in autumn 2007 in order to evaluate the bacterial pollution dispersion along the coasts of Veneto and Friuli Venezia-Giulia regions.

Meteo-marine forcings were imposed as boundary conditions and EC concentration values were prescribed at the points corresponding to the submarine outfall positions. The input data used for the concentration of EC were based on actual measures on samples of wastewater collected over the year, at the outfalls of the WWTP, during normal routine control analyses performed by Veritas. Only the order of magnitude of these values has been used in the simulations.

Many tests have been performed to evaluate scenarios with different discharge concentration values. In particular two cases are presented:

1) constant discharge concentration equal to 10.000 cfu/100mL (Test1)
2) constant discharge concentration equal to 100.000 cfu/100mL (Test3).

Some results for Test1 and Test3 are presented in **figs 10.1-10.5** as instantaneous pictures of concentration for the microbiological parameters, *Escherichia coli*. **Figs 10.1** and **10.3** are representative of the surface layer, while **figs 10.2** and **10.4** show results for the subsurface layer. In both cases, results show that during autumn 2007 the discharges of the submarine outfalls of the province of Venice seem to have no impact on the surface water quality. Further results have been elaborated to identify the area of influence of each discharge point. These maps were obtained by computing the bacterial quantity due to a specific discharge which influences the elements in the model grid. When this quantity exceeds the threshold of 30%, the element is assigned to that discharge point. The area represented with the same background intensity indicates the influence zones of the discharge. Results are presented in **fig. 10.5** for Test3. <u>The results seem to highlight that the two discharges of the Veneto region are not noticeable</u>.

Figure 10.1 *– Results of the simulation*

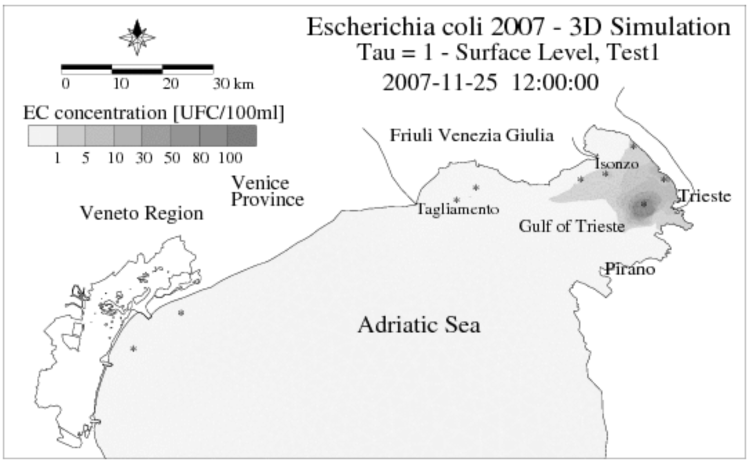


***Figure 10.2** – Results of the simulation*

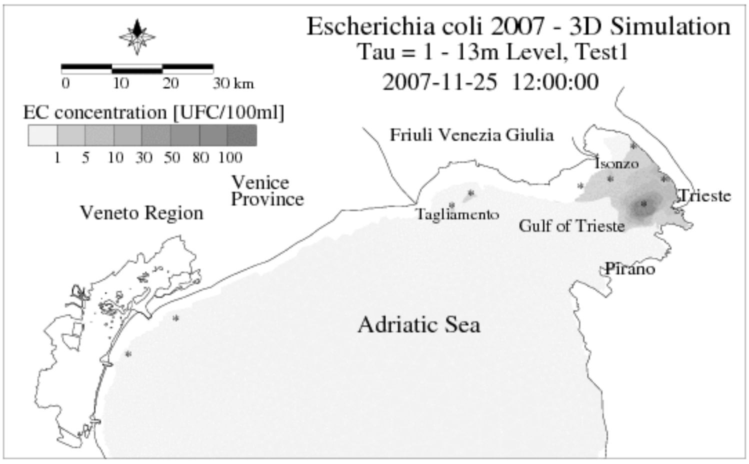


***Figure 10.3** – Results of the simulation*

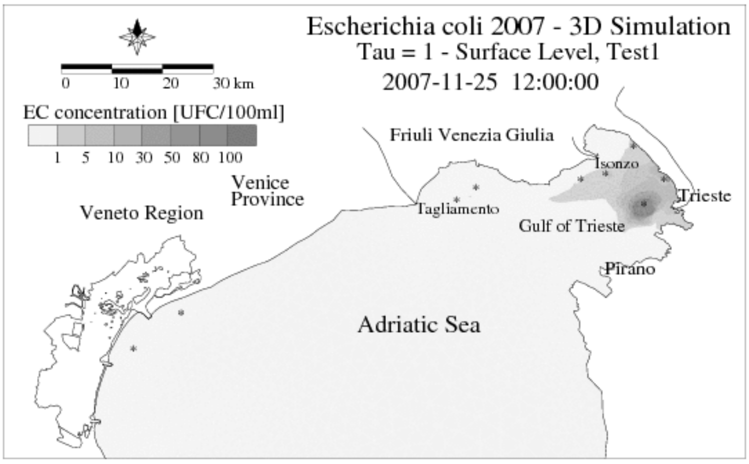


***Figure 10.4** – Results of the simulation*

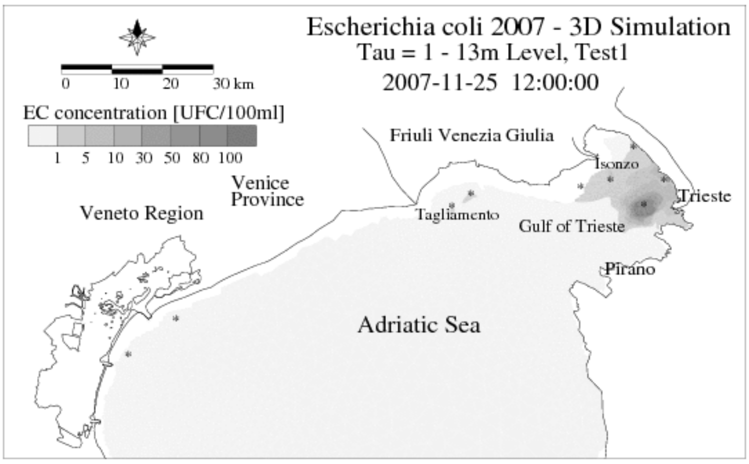
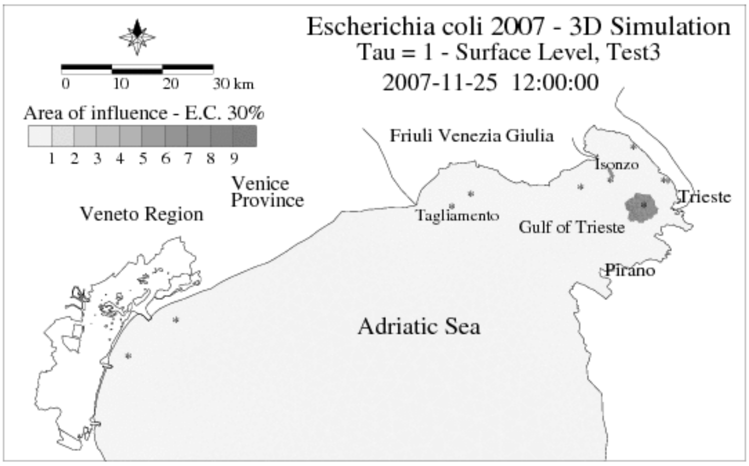


Figure 10.5 *– Results of the simulation*



10.3 Rivers waters monitoring in the final stretch

10.3.1 Monitoring data presentation on 2005-2012 period

For each river basin the final(s) monitoring station(s) has/have been considered. If available also the upward and downward monitoring station with reference to the WWTP's discharge (see for example Jesolo) are reported in order to assess the microbiological impact of the plant. The aim in the choice of the monitoring stations was the verification of the level of microbiological contamination from the upstream stretch before the influence of the coastal zone (if possible). The surface water monitoring station on rivers for the assessment of microbiological impact in the period 2005-2012 (if 2012 not available till 2011; 75° perc. assessed till 2011 always) are reported in **tab. 10.13**; for thei localization see **tab. 3.5**. The 75° perc. is the statistical parameter indicated by Decree n. 152/1999 for water classification (PLM), still a valid technical reference.

Table 10.13 *– River monitoring stations chosen in the assessment of the microbiological impact*

Rivers basin	River	Station	Commune	Locality
Tagliamento	Tagliamento	432	SM al Tagliamento	Highway A4 bridge
Lemene	Lemene	433	Concordia Sagittaria (VE)	Pontile 500 m a Sud di Concordia
	Lemene	76	Caorle (VE)	Ponte levatoio Marango
Livenza	Livenza	61	Motta di Livenza (TV)	Gonfo di Sopra
	Livenza	72	Torre di Mosto (VE)	Bocca Fossa
Piave-Livenza plain	Brian-Taglio channel	435	Torre di Mosto (VE)	Ponte Loc. Stretti
Piave	Piave	304	Susegana (TV)	Ponte Priula SS 13
	Piave	65	Fossalta di Piave	Ponte di barche
Sile	Sile	81	Silea (TV)	Cendon
	Sile	237	Quarto d'Altino (VE)	Fossa d'Argine
	Sile	238	Jesolo (VE)	Torre Caligo presa acquedotto
	Sile	148	Jesolo (VE)	Ponte Jesolo-Cavallino
Venice Lagoon	Naviglio Brenta	137	Mira (VE)	Malcontenta SS 309

Rivers basin	River	Station	Commune	Locality
watershed	Zero	143	Quarto d'Altino (VE)	Poian - Ponte
	Dese	481	Marcon (VE)	Ponte
	Marzenego-Osellino	489	Mestre-Venezia (VE)	Viale Vespucci
Brenta	Brenta	118	Ponte di Brenta (PD)	Ponte SS. 515
	Brenta	212	Chioggia (VE)	Brondolo ponte SS. 309
	Brenta	436	Chioggia (VE)	Ca' Pasqua Ponte nuovo
Bacchiglione	Bacchiglione	174	Ponte S. Nicolò	Passarella Via Mascagni
	Bacchiglione	181	Pontelongo	Terranova - approdo
Fratta-Gorzone	Fratta-Gorzone	201	Stanghella (PD)	Ponte Gorzone
	Fratta-Gorzone	437	Cavarzere (VE)	Valcerere Dolfina
Adige	Adige	221	Rosolina (RO)	Portesine - Presa acquedotto Albarella
	Adige	222	Chioggia (VE)	Cavanella d'Adige presa acquedotto

Source: ARPAV, Rapporto Acque, 2010.

For each surface water monitoring station mean, 75° percentile, min. max values of EC on the whole period 2005-2011 have been assessed as well as Salmonella presence/absence.

River Tagliamento

Only one monitoring station is considered. No data quality are available from upward area. For station n. 432 mean, 75° percentile, min. max values on the whole period 2005-2011 have been assessed as well as Salmonella presence/absence.

***Figure 10.6** – Tagliamento river*

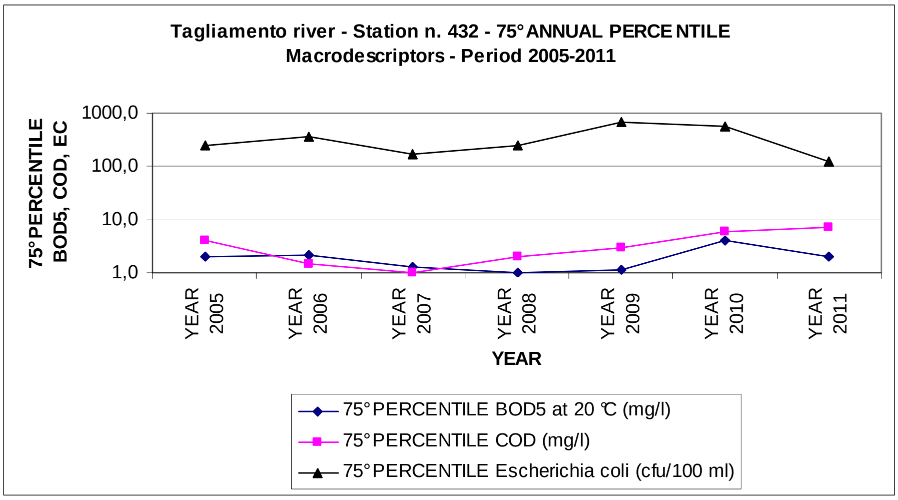


Table 10.14 *– Station 432*

Station 432	Escherichia coli (cfu/100 ml)	Enterococci (cfu/100 ml)
Mean	448	196
75° PERC	323	140
MIN	0	9
MAX	6700	3300
STD DEV	998	465

Figure 10.7 *– Tagliamento river*

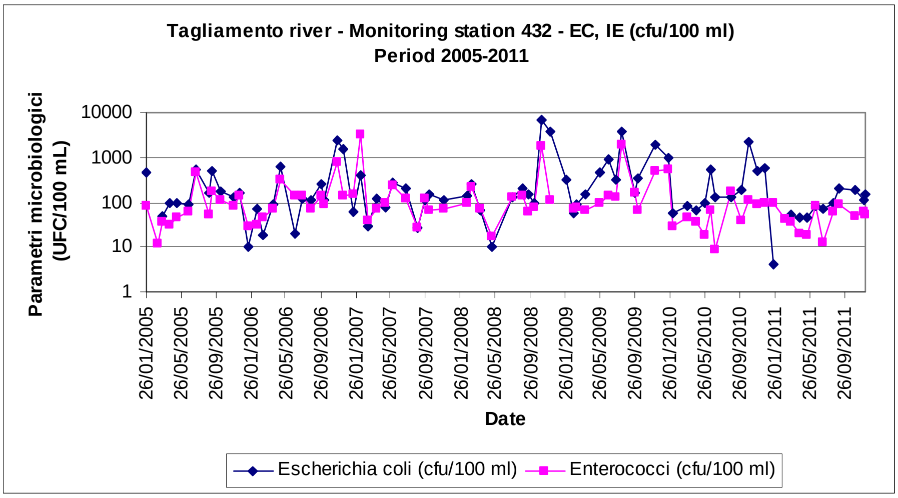
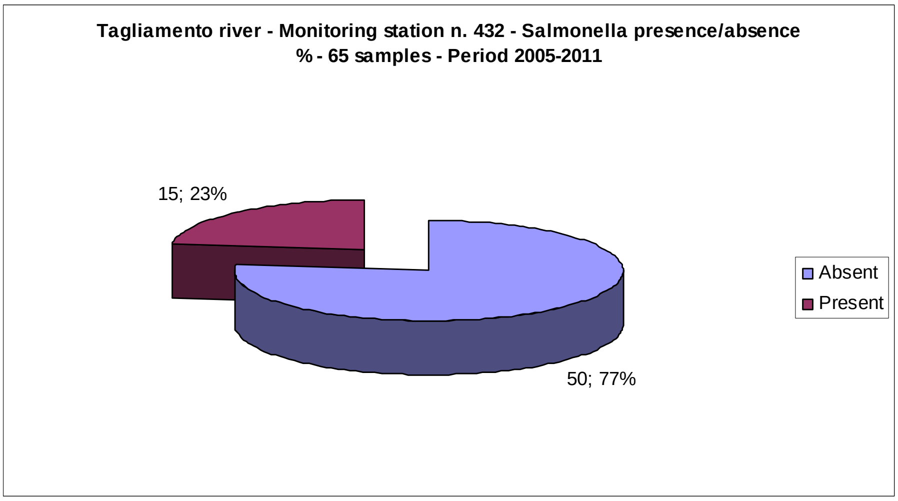


Figure 10.8 *– Tagliamento river*



Lemene river

Two monitoring stations have been considered: n. 433 in Concordia Sagittaria (downward Portogruaro and its WWTP) and n. 76 in Caorle near the river mouth.

Figure 10.9 *– Lemene river*

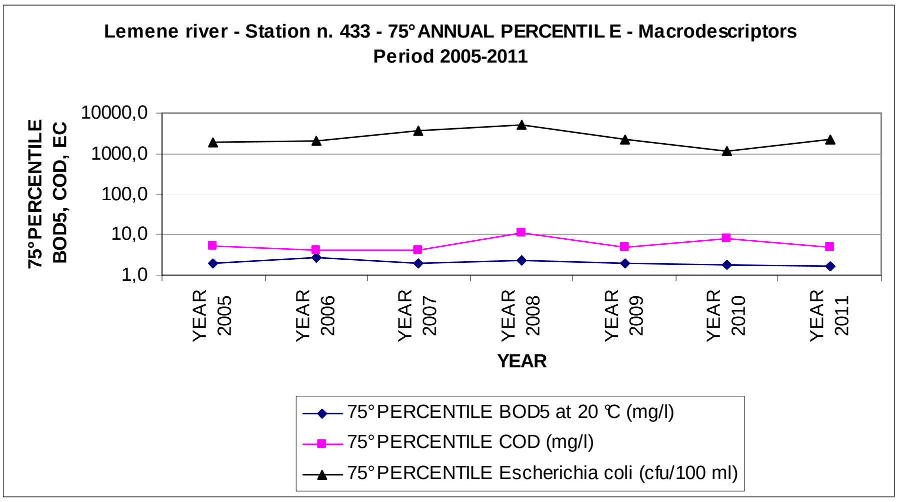
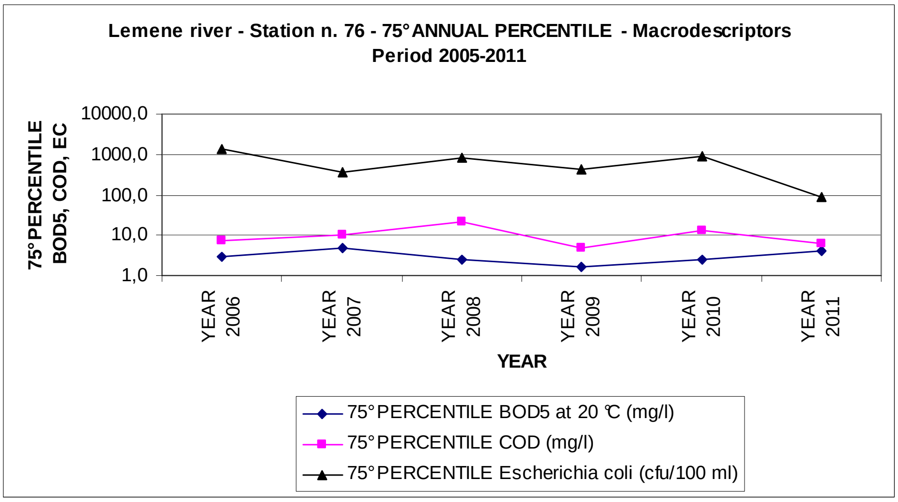


Figure 10.10 *– Lemene river*



Station n. 433 (Concordia Sagittaria near Portogruaro)

Table 10.15 *– Station 433*

Station 433	Escherichia coli (cfu/100 ml)	Enterococci (cfu/100 ml)
Mean	1676	726
75° PERC	2100	480
MIN	0	13
MAX	7500	7800
STD DEV	1619	1471

Figure 10.11 *– Lemene river*

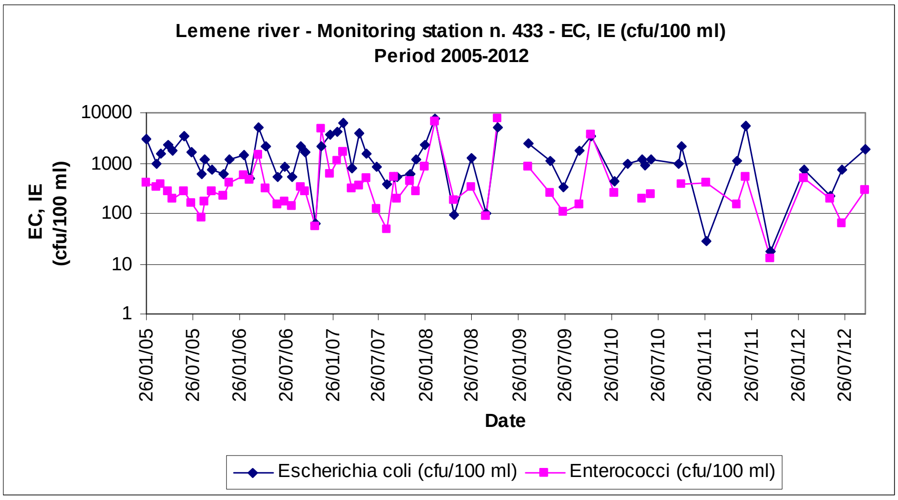
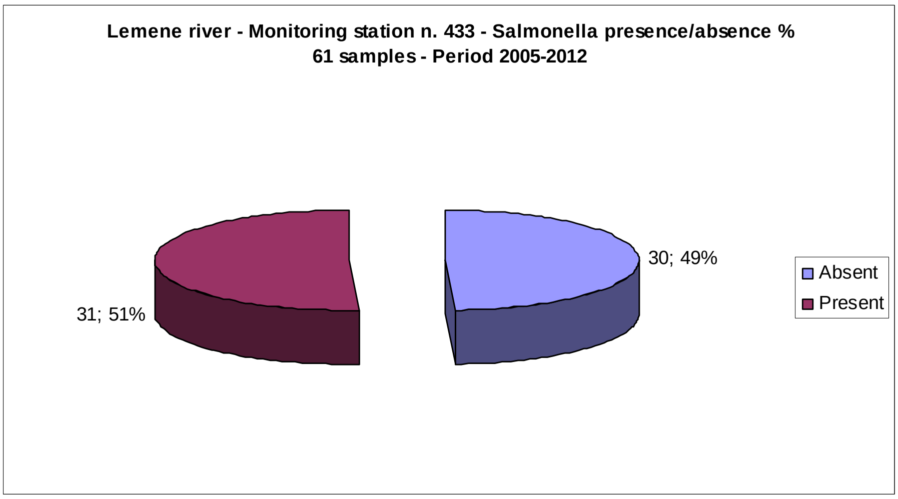


Figure 10.12 *– Lemene river*



Station n. 76 (Caorle near river mouth)

Table 10.16 *– Station 76*

Station 76	Escherichia coli (cfu/100 ml)	Enterococci (cfu/100 ml)
Mean	460	139
75° PERC	343	120
MIN	3	8
MAX	5300	850
STD DEV	1063	192

***Figure 10.13** –Lemene river*

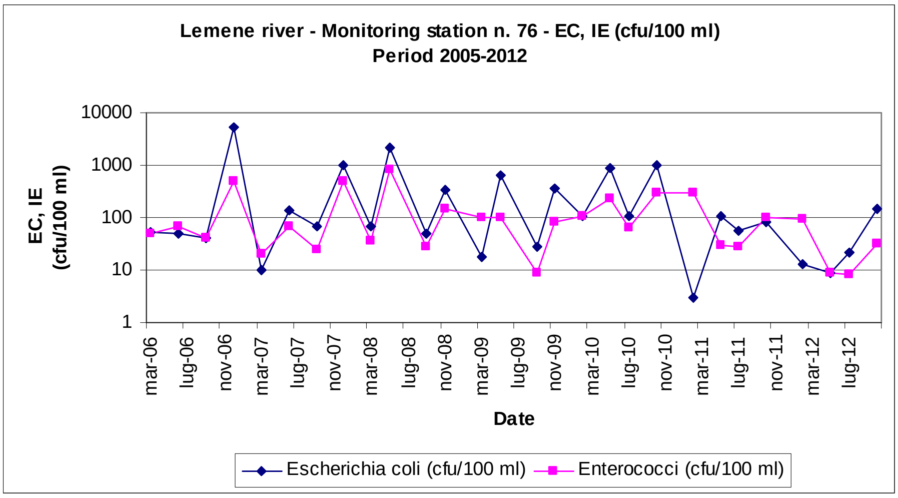
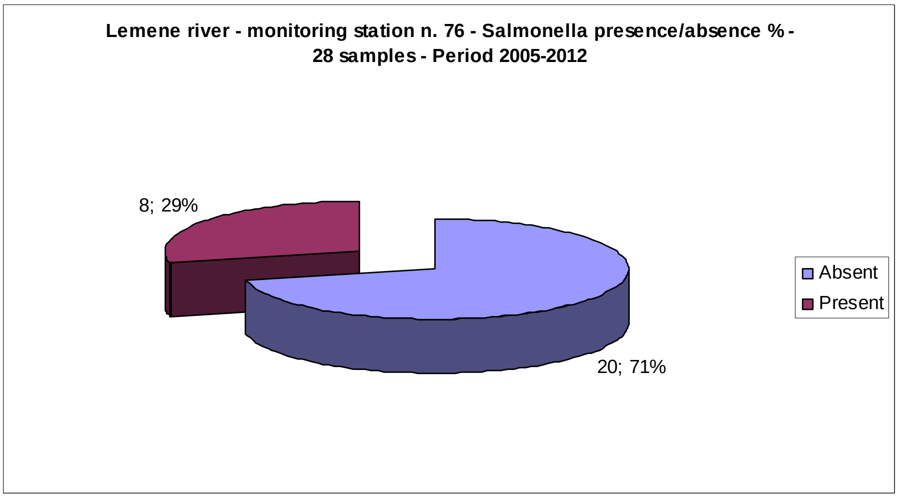


***Figure 10.14** – Lemene river*



Livenza river

For river Livenza two monitoring stations have been considered: n. 61 in Motta di Livenza still in the province of Treviso to assess the contamination level before the province of Venice and n. 72 in Torre di Mosto (VE).

***Table 10.17** – Station 72*

Station 72	Escherichia coli (cfu/100 ml)	Enterococci (cfu/100 ml)
Mean	979	363
75° PERC	1025	310
MIN	5	7
MAX	8200	5500
STD DEV	1245	758

Figure 10.15 *– Livenza river*

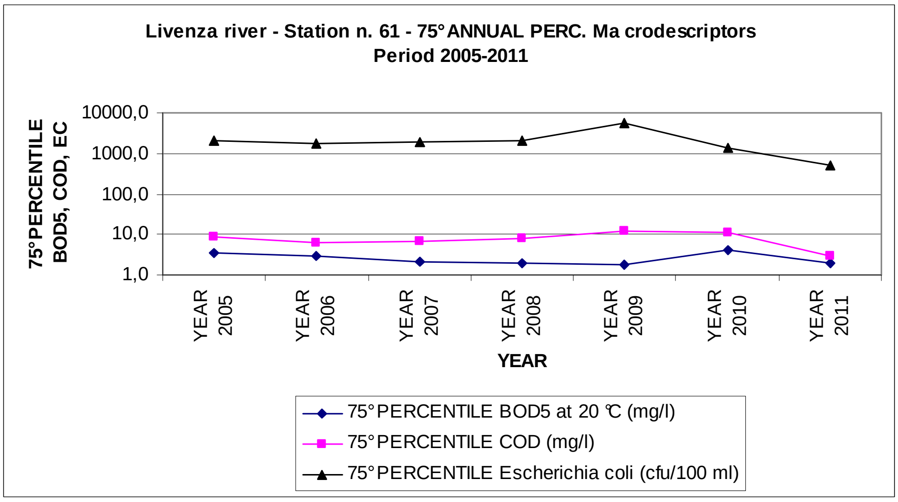


Figure 10.16 *– Livenza riverr*

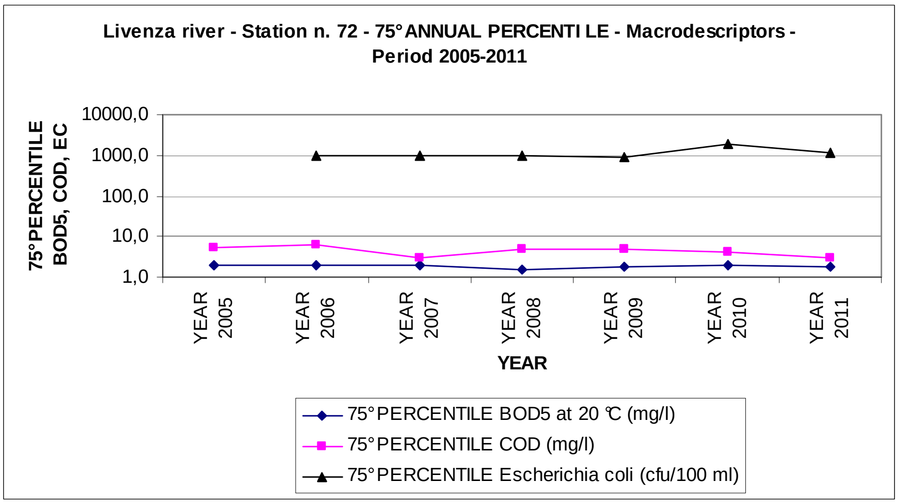


Figure 10.17 *– Livenza river*

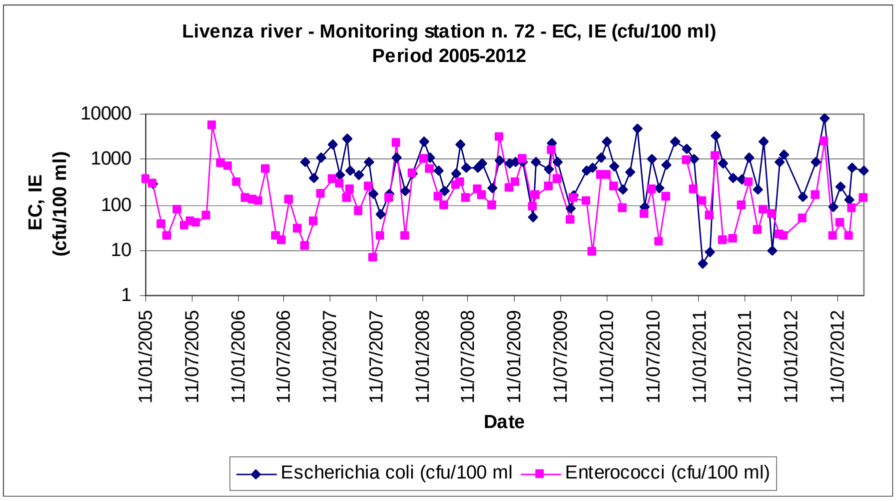
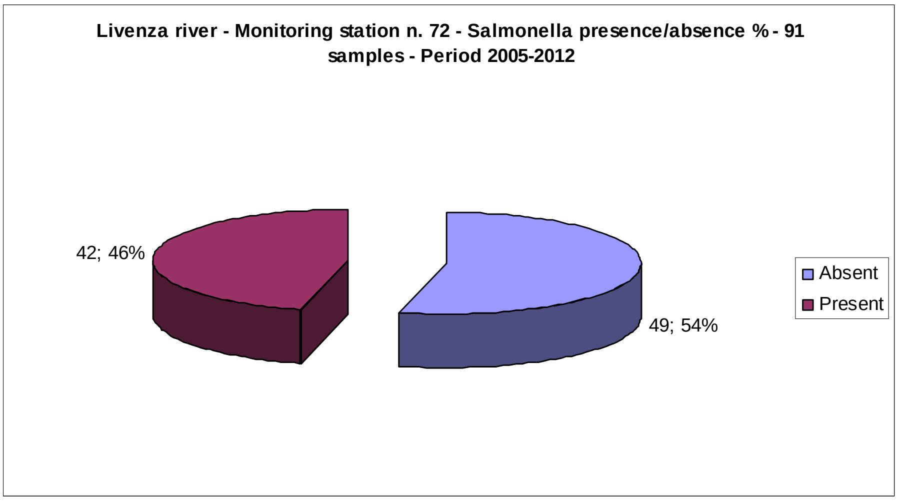


***Figure 10.18** – Livenza river*



Piave-Livenza Plain

Only the station n. 435 is available for this basin.

***Figure 10.19** – Piave-Livenza plain*

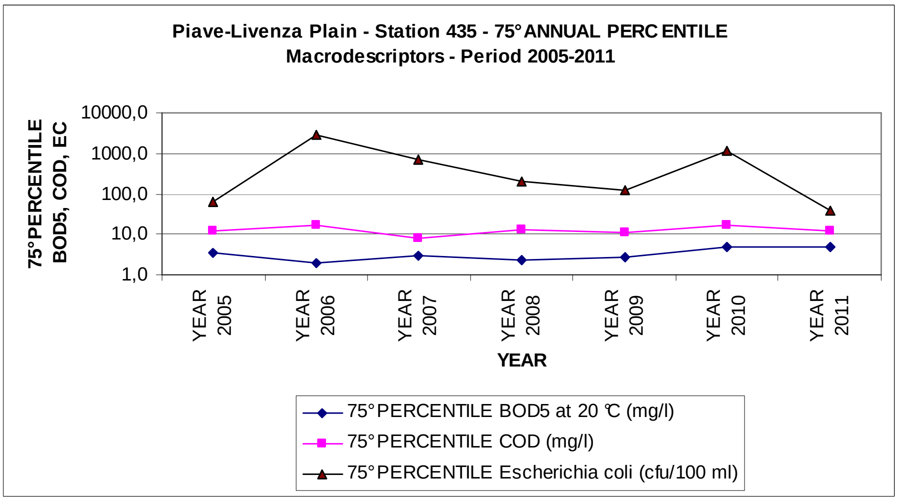


***Table 10.18** – Station 435*

Station 435	Escherichia coli (cfu/100 ml)	Enterococci (cfu/100 ml)
Mean	554	306
75° PERC	230	100
MIN	0	0
MAX	6300	4000
STD DEV	1414	874

Figure 10.20 *– Piave-Livenza plain*

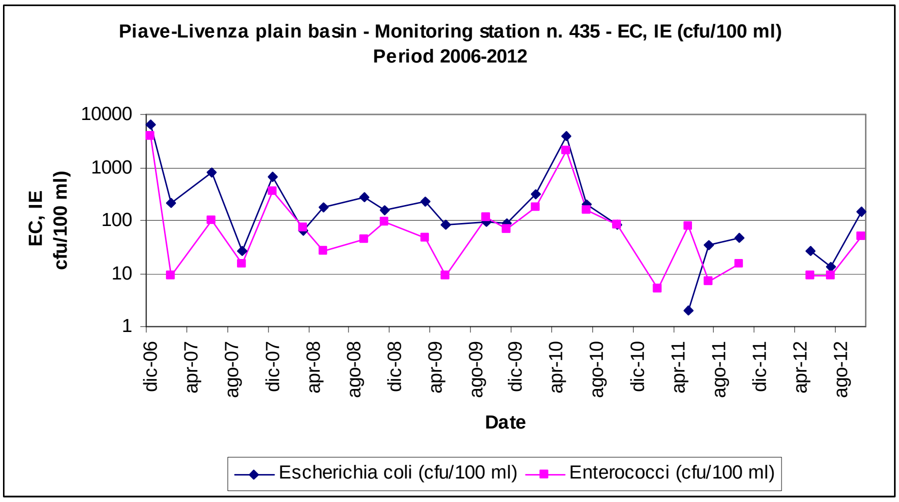
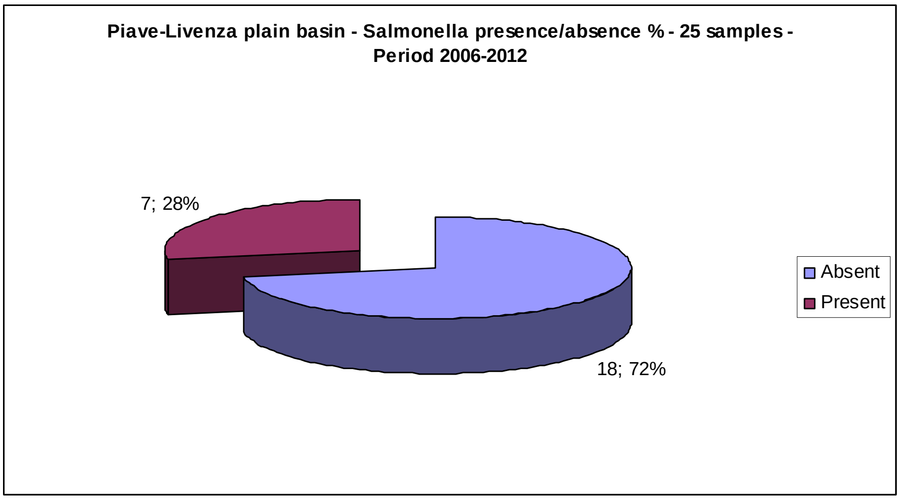


Figure 10.21 *– Tagliamento river*



Piave river

To follow the water quality of the Piave river in its final stretch three stations have been chosen: n. 304 Susegana in the Province of Treviso and n. 65 in Fossalta di Piave Province of Venice.

Table 10.19 *– Station 65*

Station 65	Escherichia coli (cfu/100 ml)	Enterococci (cfu/100 ml)
Mean	427	306
75° PERC	260	123
MIN	0	0
MAX	6200	10000
STD DEV	1053	1120

Figure 10.22 *– Piave river*

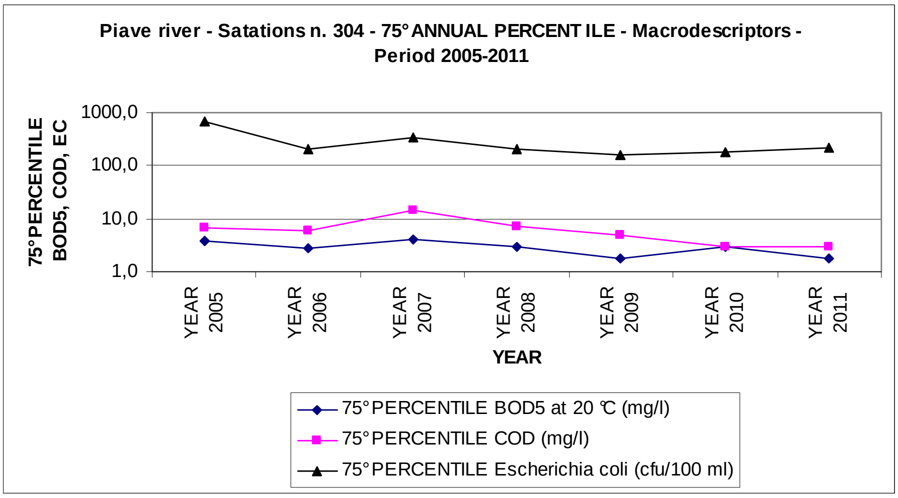


Figure 10.23 *– Piave river*

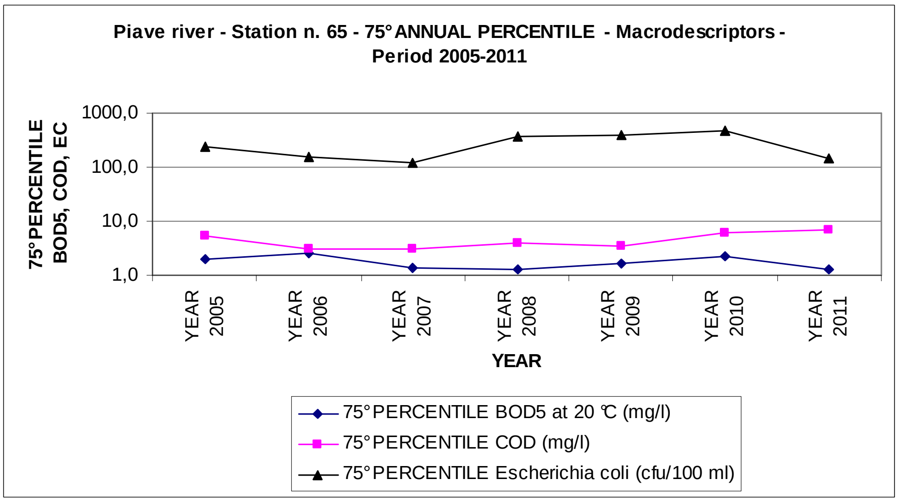


Figure 10.24 *– Piave river*

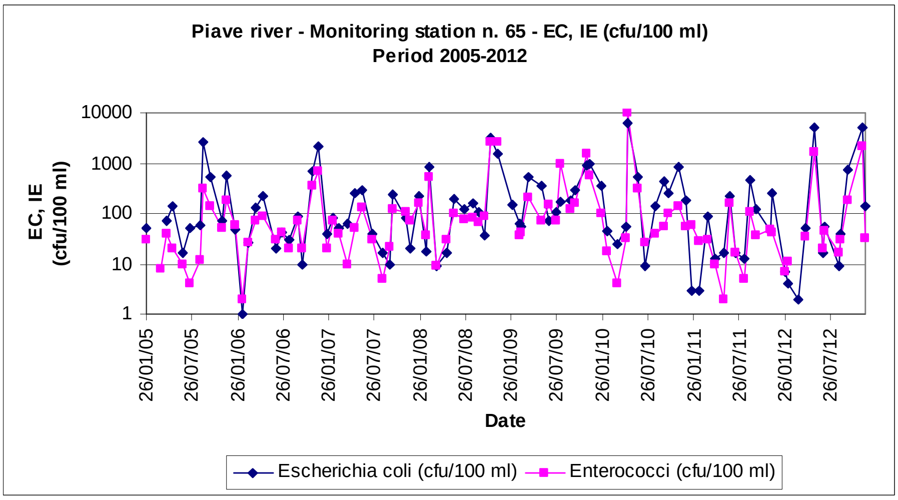
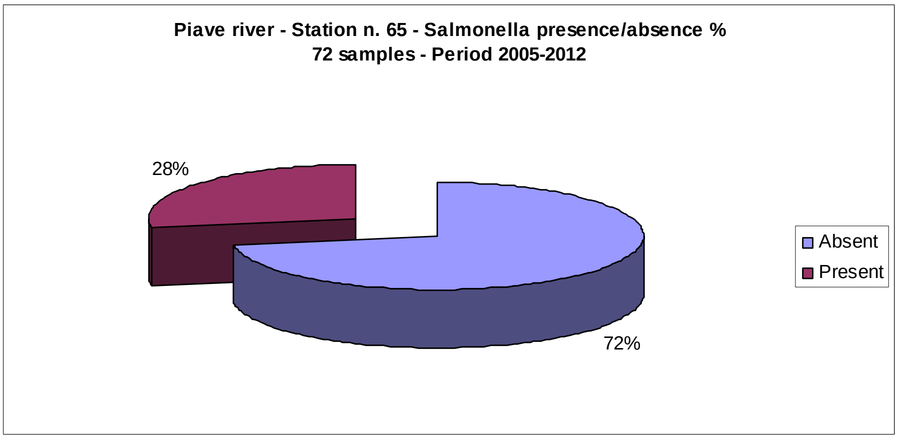


Figure 10.25 – *Piave river*



Sile river

Figure 10.26 –*Sile river*

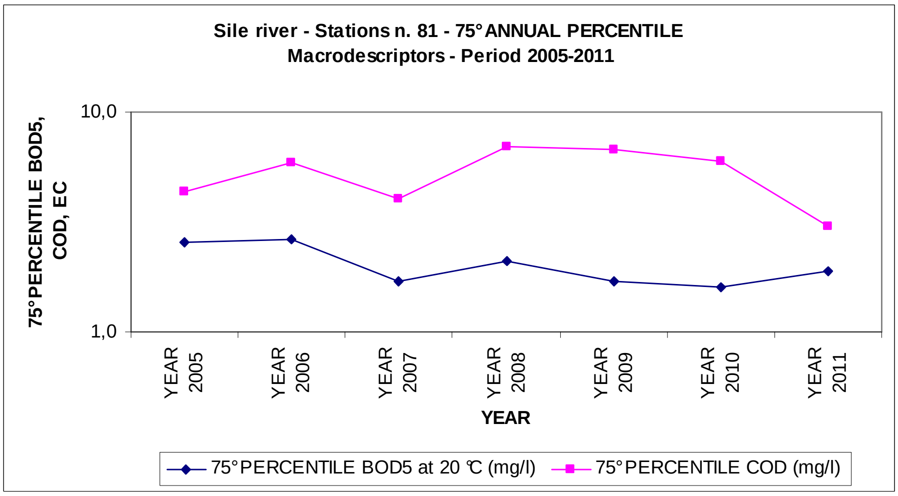
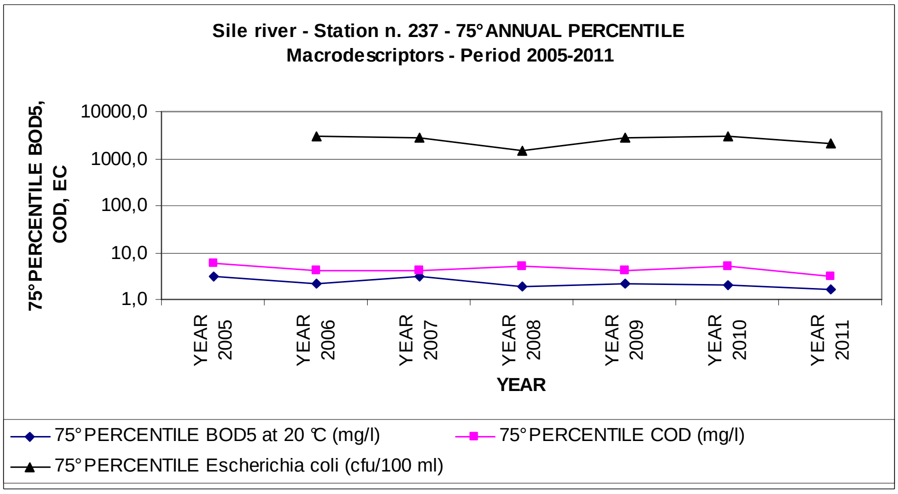


Figure 10.27 – *Sile river*



For Sile river four water quality monitoring stations have been considered (two upward: one in the province of Treviso n. 81, and one in the province of Venice n. 237). One more station just before the Jesolo WWTP's disharge point (station n. 238) and one just downward (station n. 148).

Figure 10.28 *– Sile river river*

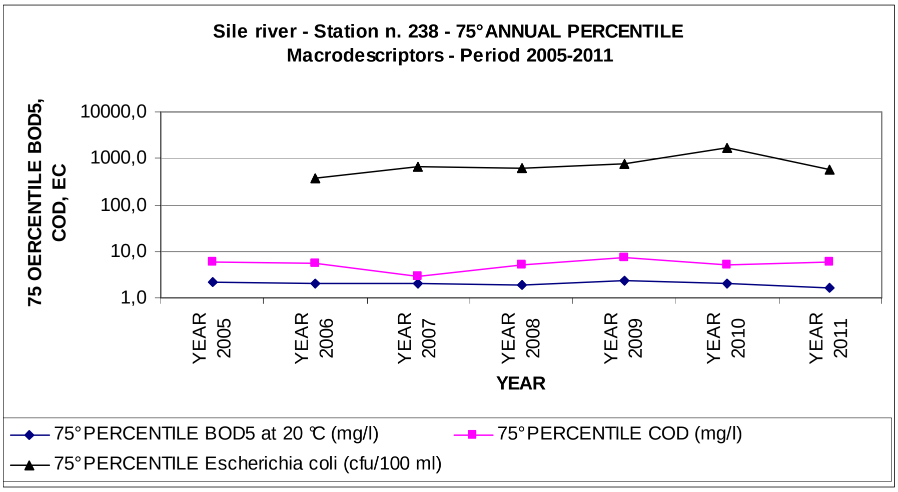
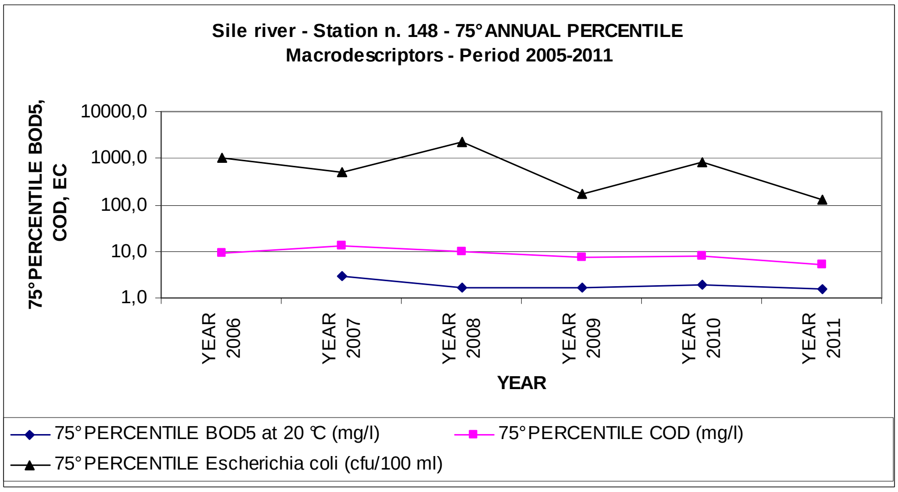


Figure 10.29 *– Sile river*



From the last fig. and the previous one it is evident that the impact of Jesolo plant (with disinfection system active) is not significant.

Table 10.20 *– Station 238*

Station 238	Escherichia coli (cfu/100 ml)	Enterococci (cfu/100 ml)	Faecal coliphorms (cfu/100 ml)	Total coliphorms (cfu/100 ml)
Mean	648	181	982	5114
75° PERC	690	220	900	5000
MIN	0	0	55	150
MAX	5600	2500	8700	51000
STD DEV	900	294	1471	8141

***Figure 10.30** – Sile river*

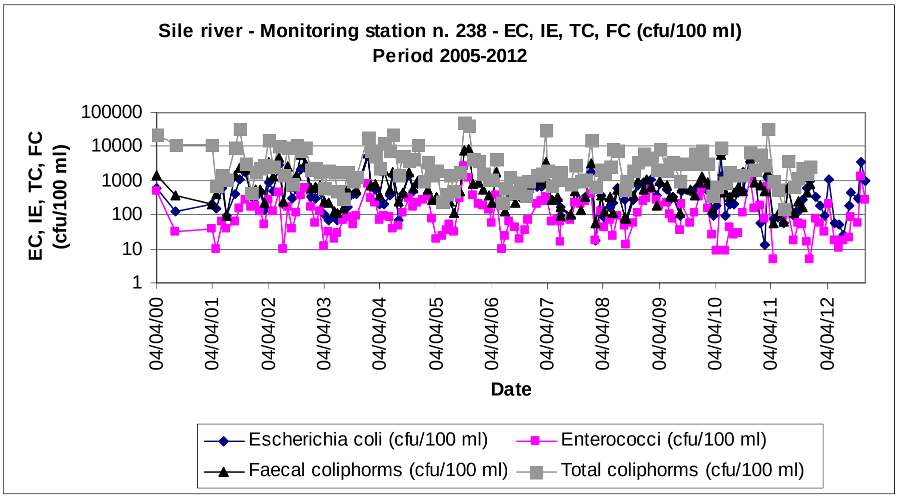
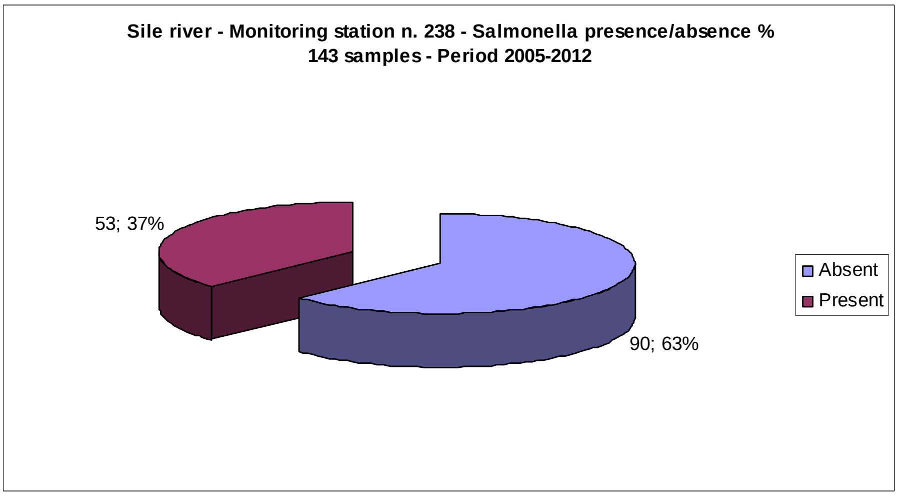


***Figure 10.31** – Sile river*



Station n. 148 (Jesolo)

***Table 10.21** – Station 148*

Station 148	Escherichia coli (cfu/100 ml)	Enterococci (cfu/100 ml)
Mean	590	304
75° PERC	490	173
MIN	5	10
MAX	4300	2800
STD DEV	1029	639

***Figure 10.32** – Sile river*

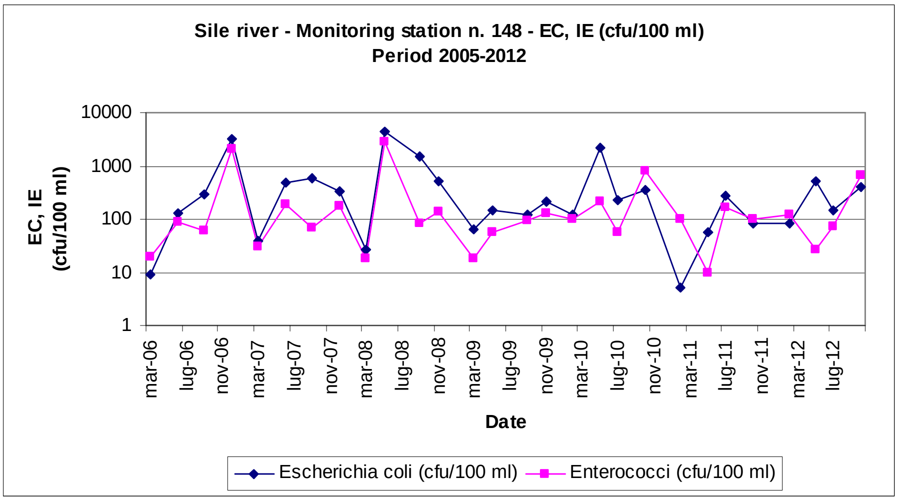
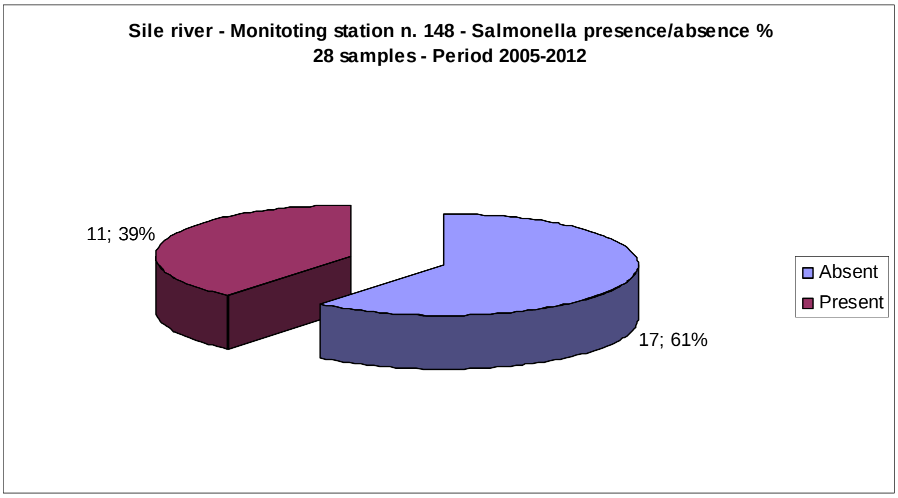


***Figure 10.33** – Sile river*

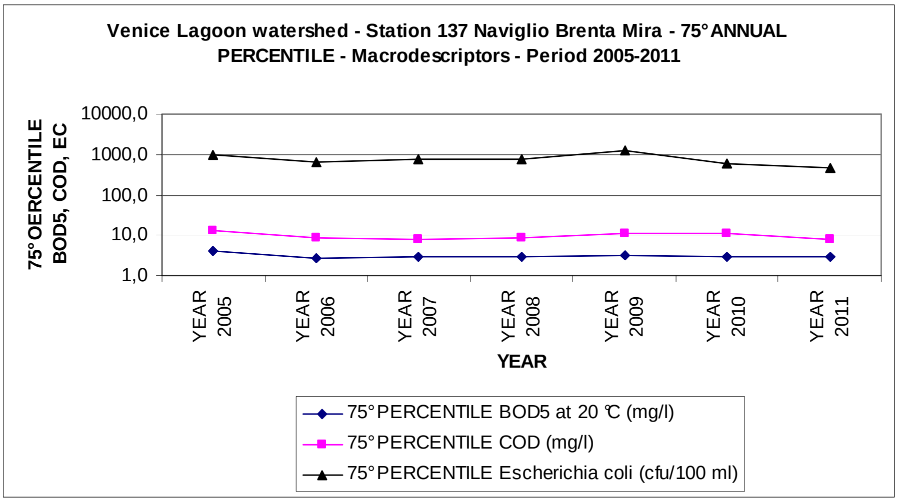


Venice Lagoon watershed

In the following a specific characterization of the main rivers of this basin are detailed (Naviglio Brenta, Zero river, Dese river, Marzenego river).

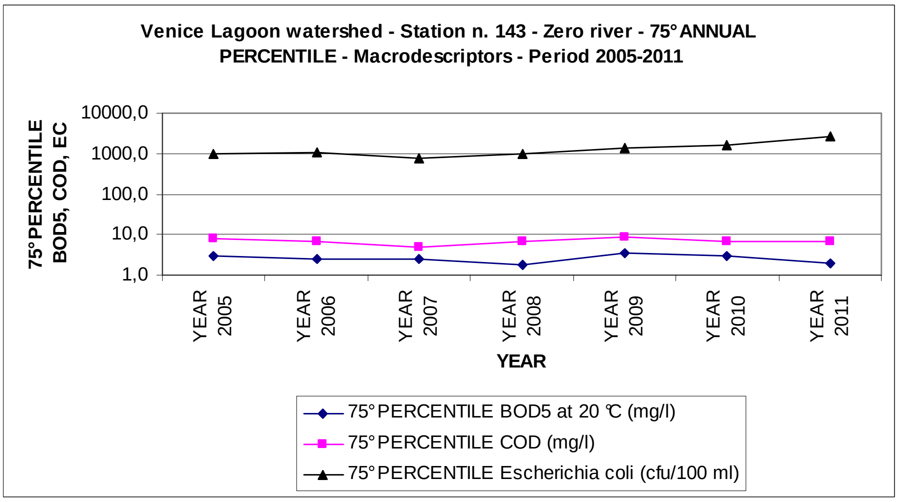
<u>Naviglio Brenta</u>

Figure 10.34 *–Naviglio Brenta*



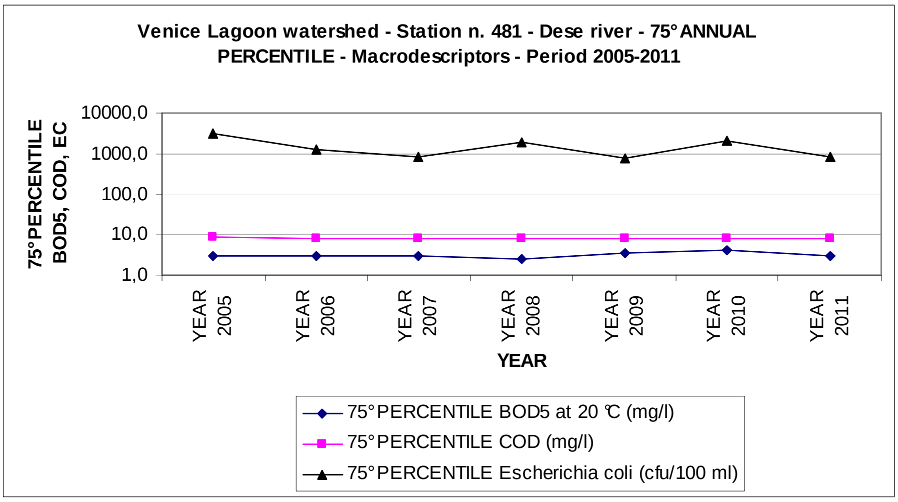
Zero river

Figure 10.35 *– Zero river*



Dese river

Figure 10.36 *–Dese river*



Marzenego-Osellino river

This monitoring station is located upward with reference to the Campalto WWTP's discharge point.

Figure 10.37 *– Marzenego river*

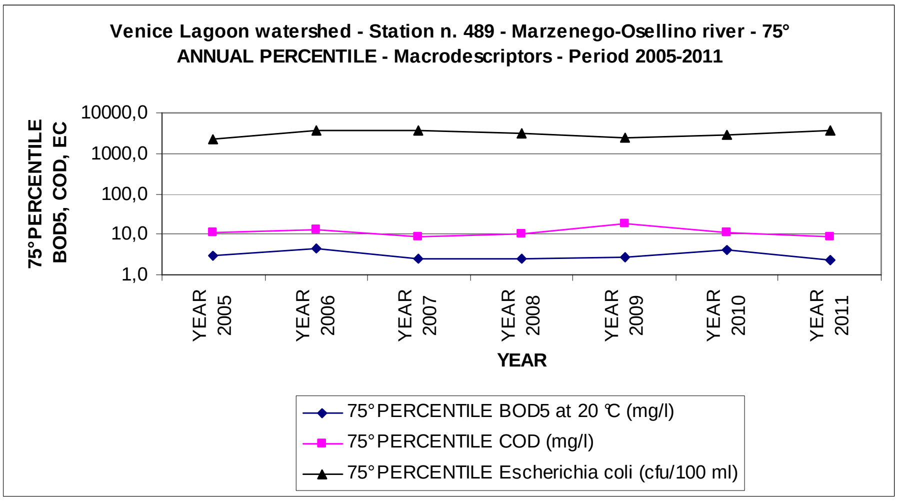


Table 10.22 *– Station 489*

Station 489	Escherichia coli (cfu100 ml)	Enterococci (cfu/100 ml)
Mean	4973	514
75° PERC	2900	595
MIN	13	12
MAX	218000	2400
STD DEV	22855	501

Figure 10.38 *– Marzenego river*

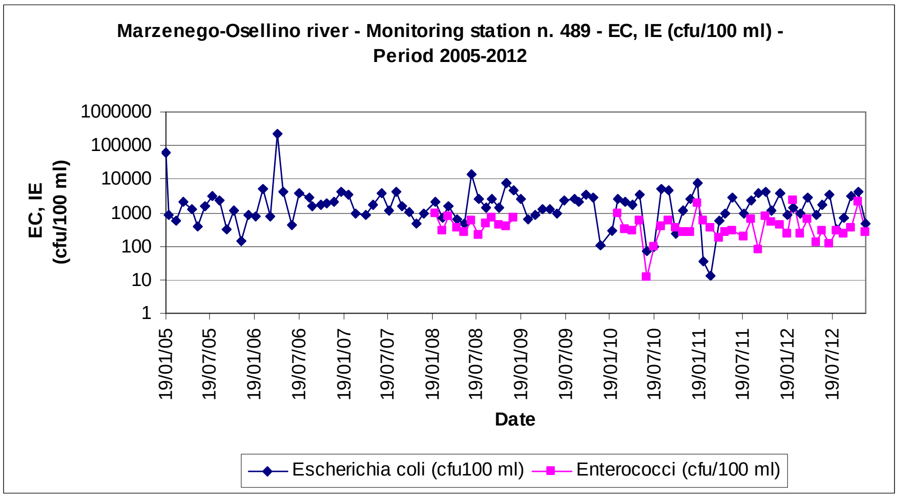
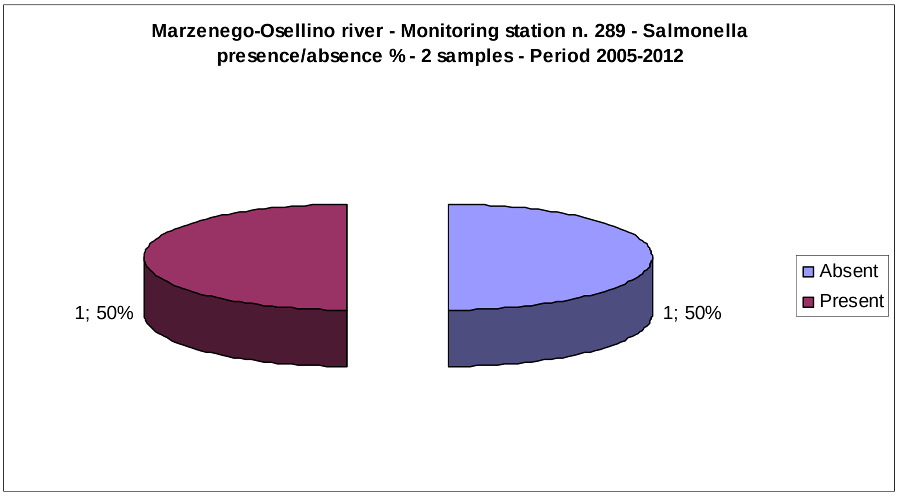


Figure 10.39 *– Marzenego river*



Brenta river

For Brenta river three stations have been considered: n. 118 just near Padova, n. 212 near Chioggia after the conjunction of Bacchiglione anf Fratta.Gorzone rivers and n. 436 near the river mouth.

Figure 10.40 *– Brenta river*

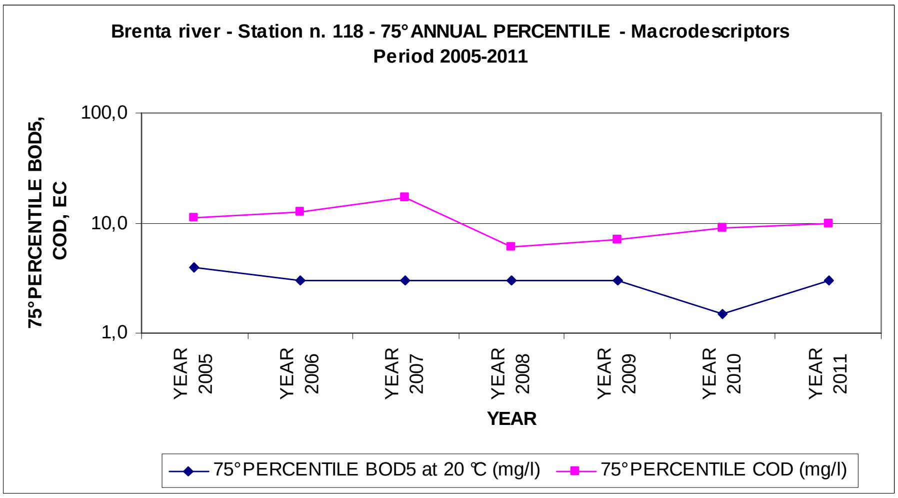


Table 10.23 *– Station 212*

Station 212	Escherichia coli (cfu/100 ml)	Enterococci (cfu/100 ml)
Mean	847	216
75° PERC	755	125
MIN	18	10
MAX	6100	2100
STD DEV	1432	473

Figure 10.41 *– Brenta river*

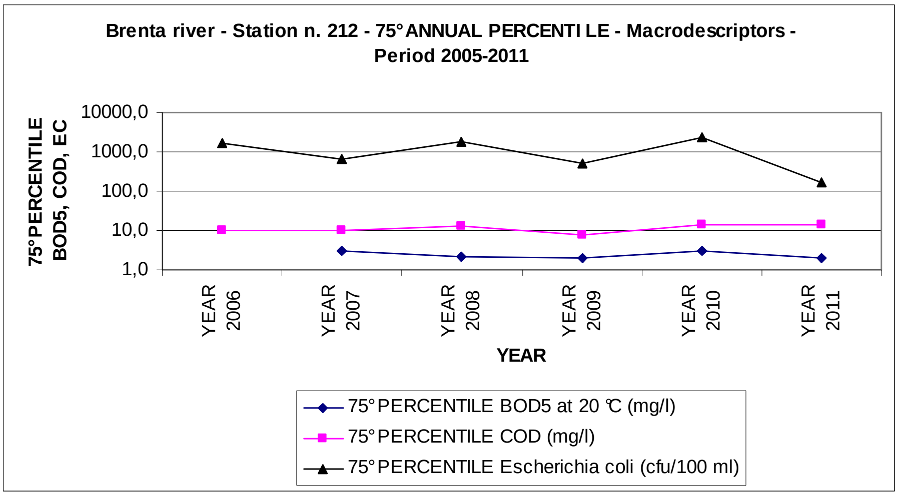


Figure 10.42 *– Brenta river*

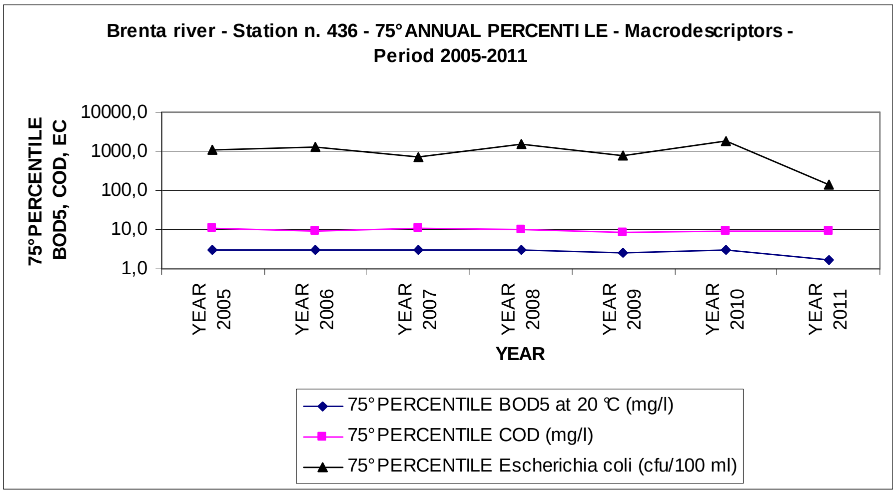


Figure 10.43 *– Brenta river*

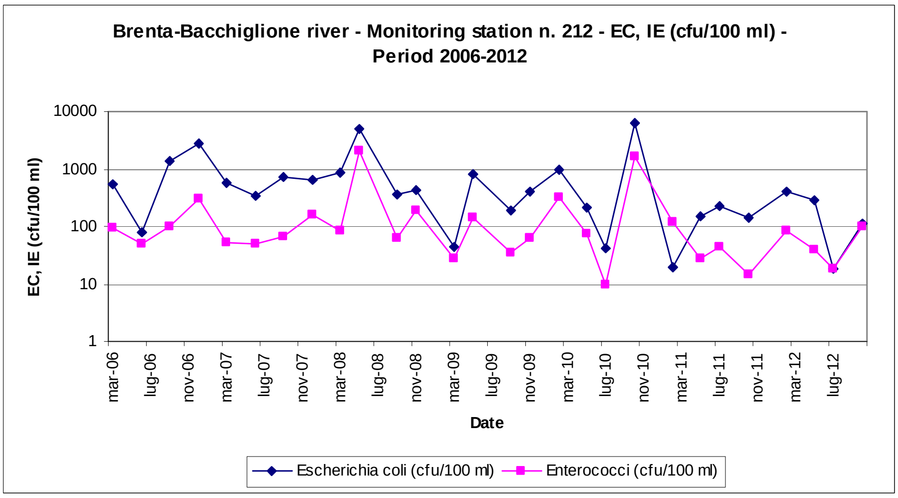
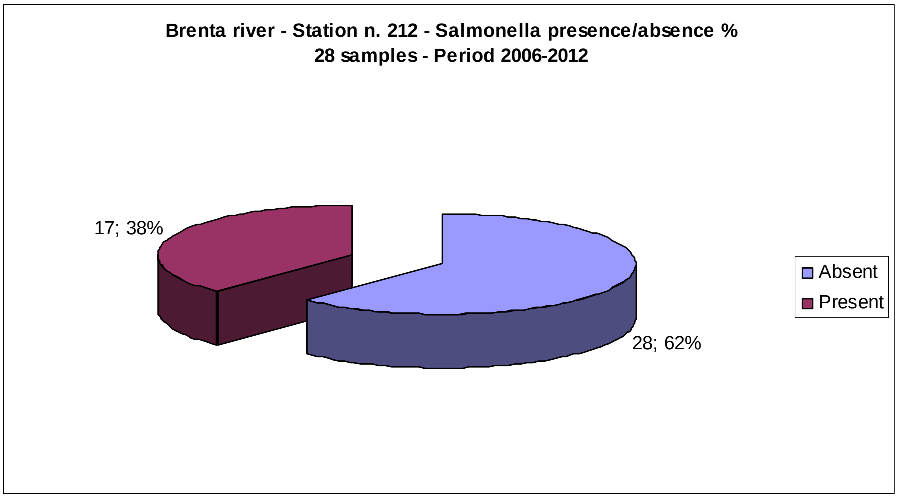


Figure 10.44 *– Brenta river*



Bacchiglione river

For Bacchiglione river the two stations of n. 174 Ponte S. Nicolò and n. 181 Pontelongo have been considered.

Figure 10.45 *– Bacchiglione river*

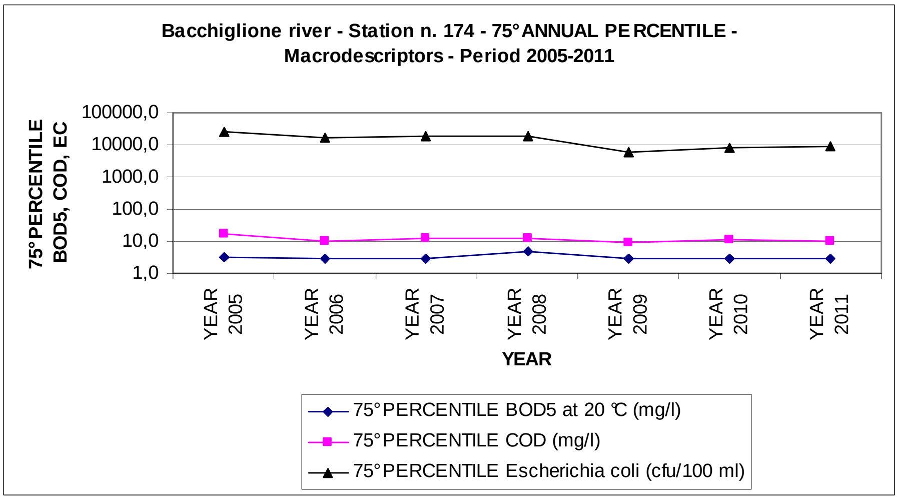


Table 10.24 *– Station 181*

Station 181	Escherichia coli (cfu/100 ml)	Enterococci (cfu/100 ml)
Mean	3945	1241
75° PERC	5925	1800
MIN	130	12
MAX	20000	13000
STD DEV	3881	1837

Figure 10.46 *– Bacchiglione river*

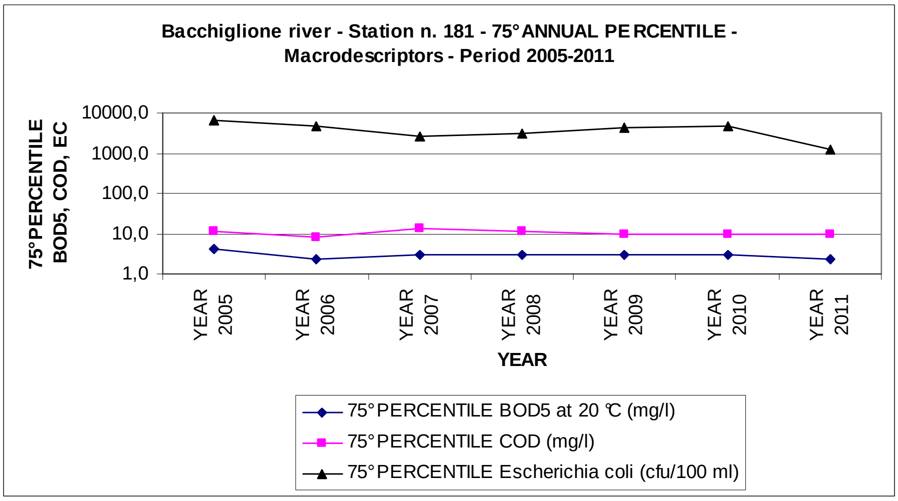


Figure 10.47 *– Bacchiglione river*

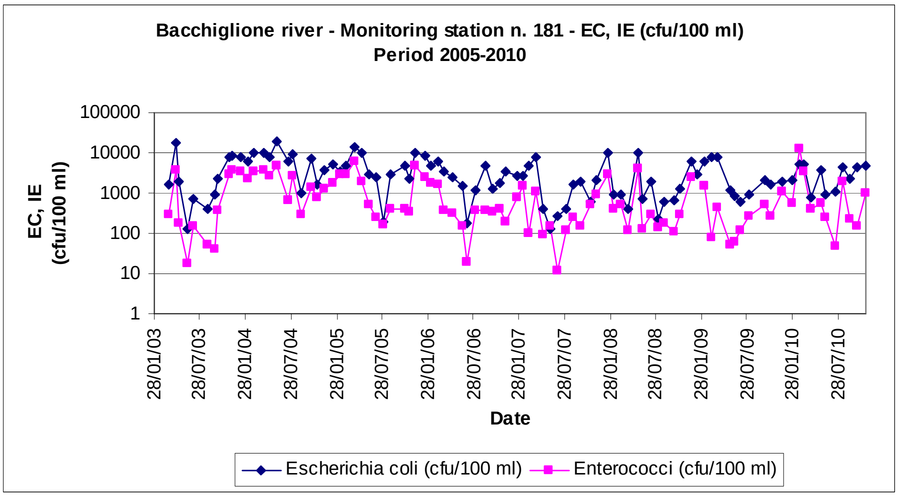
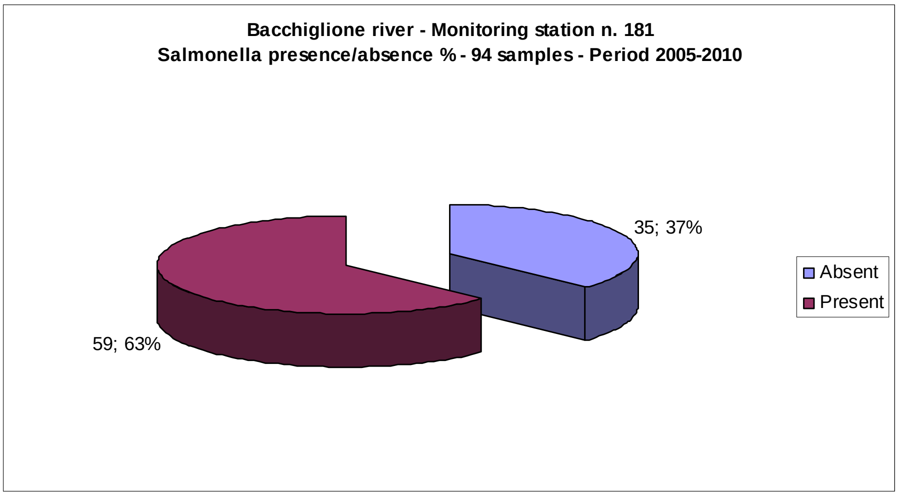


Figure 10.48 *– Bacchiglione river*



Fratta-Gorzone river

Stations n. 201 (Stanghella, Province of Padova) and n. 437 (Cavarzere, Province of Venice) have been considered.

Figure 10.49 *– Fratta-Gorzone river*

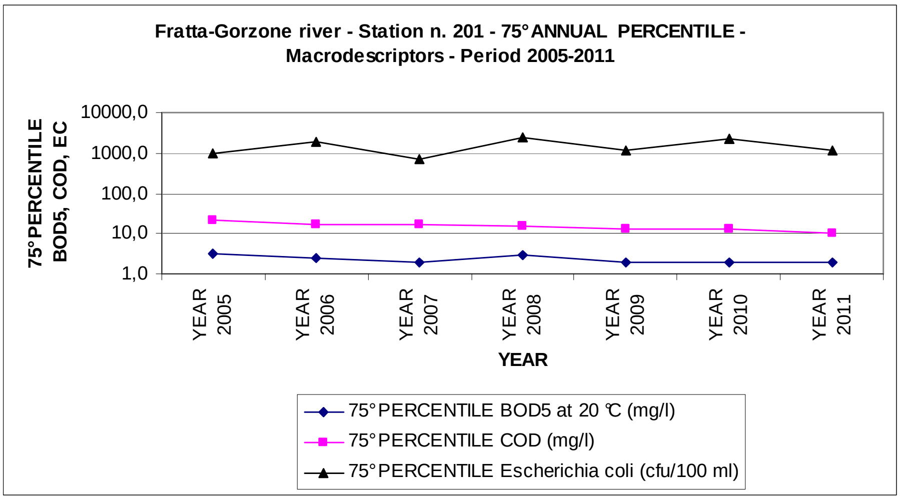


Figure 10.50 *– Fratta-Gorzone river*

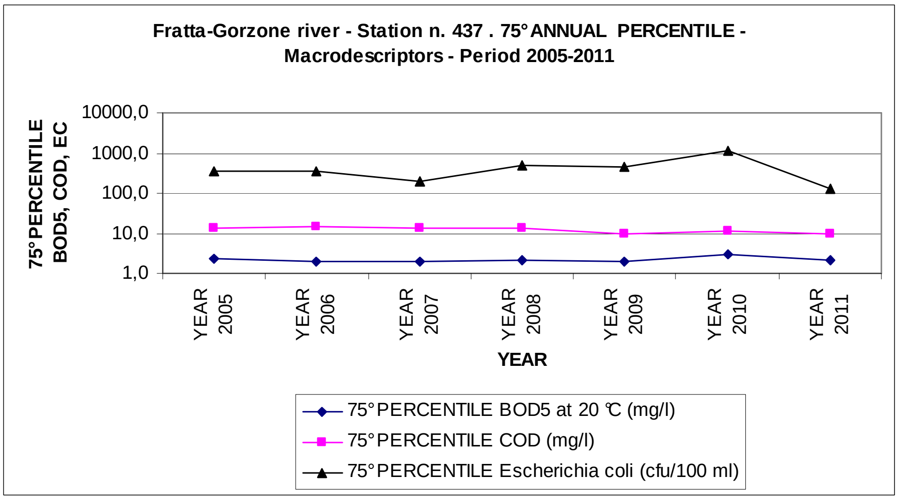


Table 10.25 *– Station 437*

Station 437	Escherichia coli (cfu/100 ml)	Enterococci (cfu/100 ml)
Mean	472	180
75° PERC	340	151
MIN	5	0
MAX	7300	2900
STD DEV	1063	394

Figure 10.51 *– Fratta-Gorzone river*

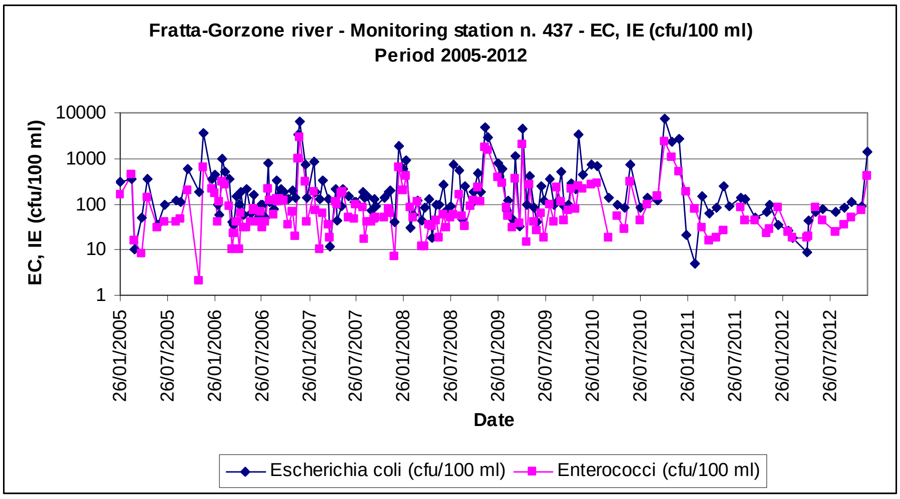
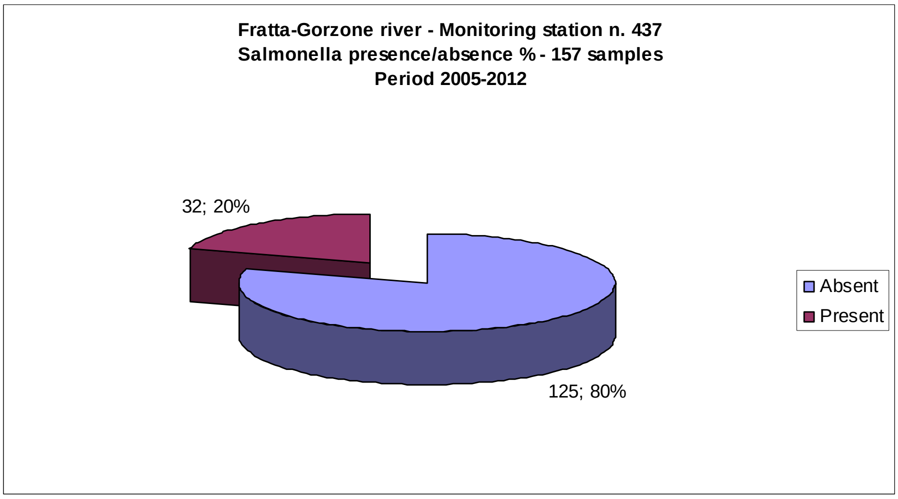


Figure 10.52 *– Fratta-Gorzone river*



Adige river

For Adige river the monitoring stations n. 221 (Rosolina, province of Rovigo) and n. 222 (Sottomarina-Chioggia, province of Venice) have been considered.

Table 10.26 *– Station 222*

Station n. 222	Escherichia coli (cfu/100 ml)	Enterococci (cfu/100 ml)
Mean	602	227
75° PERC	275	123
MIN	0	0
MAX	21000	4300
STD DEV	2470	653

***Figure 10.53** – Fratta-Gorzone river*

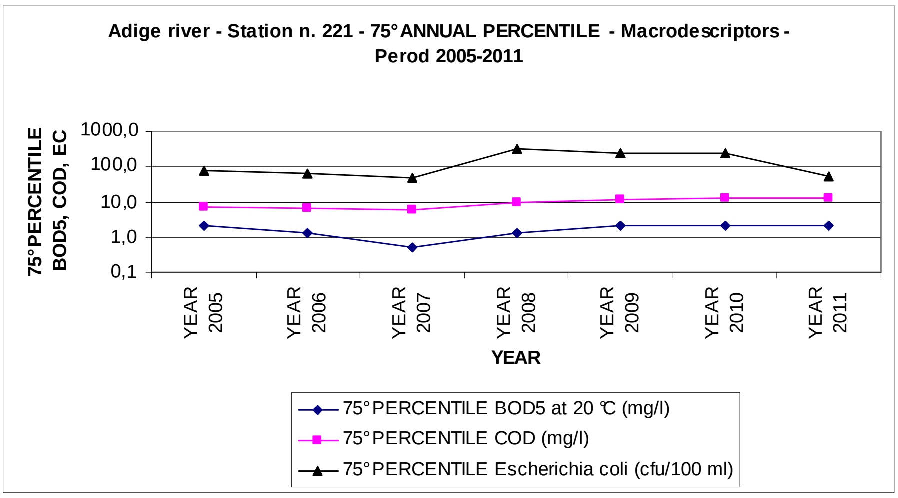


***Figure 10.54** – Adige river*

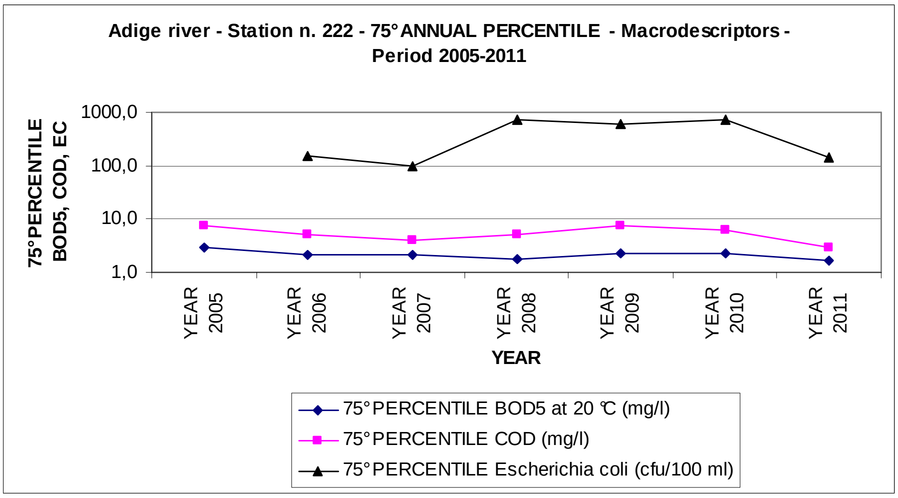


***Figure 10.55** – Adige river*

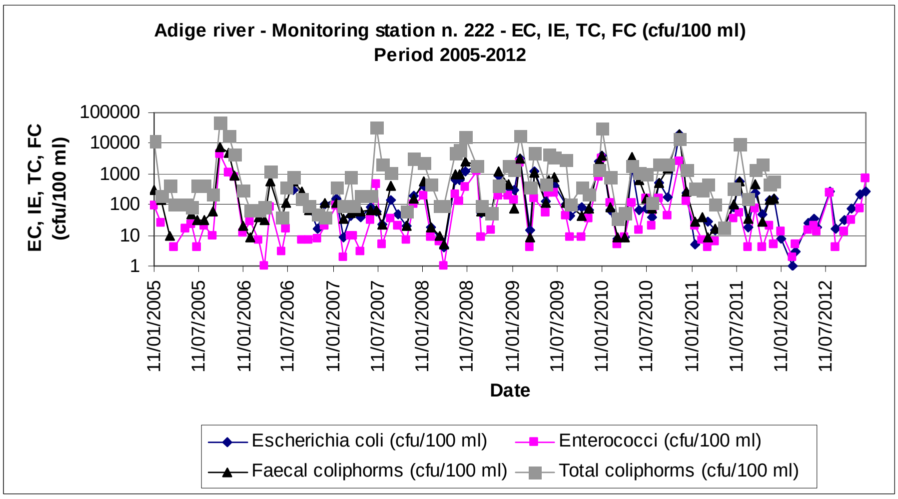
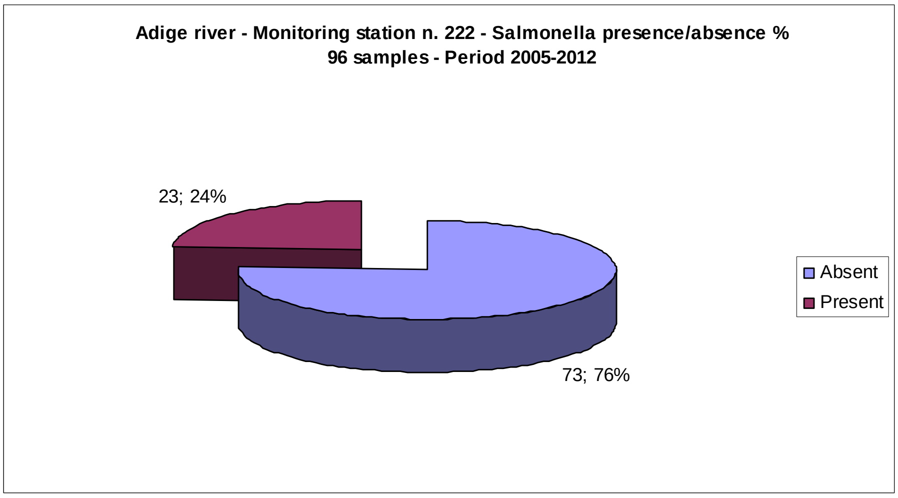


***Figure 10.56** – Fratta-Gorzone river*



10.3.2 Water classification according to Decree n. 152/1999

In **tab. 10.27** the environmental status classification defined with technical criteria of decree n. 152/1999 for the selected monitoring stations described before for the perio 2005-2010 is reported (not in alla stations the classification was possible). It must be observed that microbiological parameters influence onlu the PLM for the definition of the Ecological status. Critical situations can be observed in the Venice lagoon catchment and in the Brenta-Bacchiglione-Fratta-Gorzone basin.

***Table 10.27** – Environmental status of monoitoring stations 2005-210*

Monit station	Year	Water body	Environmental status
432	2005	TAGLIAMENTO	
432	2006	TAGLIAMENTO	
432	2007	TAGLIAMENTO	
432	2008	TAGLIAMENTO	
433	2005	LEMENE	
433	2006	LEMENE	
433	2007	LEMENE	
433	2008	LEMENE	
61	2005	LIVENZA	
61	2006	LIVENZA	
61	2007	LIVENZA	
61	2008	LIVENZA	
72	2006	LIVENZA	
72	2007	LIVENZA	
72	2008	LIVENZA	
435	2005	C. BRIAN TAGLIO	
435	2006	C. BRIAN TAGLIO	
435	2007	C. BRIAN TAGLIO	
435	2008	C. BRIAN TAGLIO	

Monit station	Year	Water body	Environmental status
65	2005	PIAVE	
65	2006	PIAVE	
65	2007	PIAVE	
65	2008	PIAVE	
238	2006	SILE	
238	2007	SILE	
238	2008	SILE	
137	2005	NAVIGLIO BRENTA	
137	2006	NAVIGLIO BRENTA	
137	2007	NAVIGLIO BRENTA	
137	2008	NAVIGLIO BRENTA	
143	2000	ZERO	
143	2001	ZERO	
143	2002	ZERO	
143	2003	ZERO	
143	2004	ZERO	
143	2005	ZERO	
143	2006	ZERO	
143	2007	ZERO	
143	2008	ZERO	
481	2002	DESE	
481	2003	DESE	
481	2004	DESE	
481	2005	DESE	
481	2006	DESE	
481	2007	DESE	
481	2008	DESE	
118	2000	BRENTA	
118	2001	BRENTA	
118	2002	BRENTA	
118	2003	BRENTA	
118	2004	BRENTA	
118	2005	BRENTA	
118	2006	BRENTA	
118	2007	BRENTA	
118	2008	BRENTA	
174	2000	BACCHIGLIONE	
174	2001	BACCHIGLIONE	
174	2003	BACCHIGLIONE	
174	2006	BACCHIGLIONE	
174	2007	BACCHIGLIONE	
174	2008	BACCHIGLIONE	
181	2000	BACCHIGLIONE	
181	2001	BACCHIGLIONE	
181	2002	BACCHIGLIONE	
181	2003	BACCHIGLIONE	

Monit station	Year	Water body	Environmental status
181	2004	BACCHIGLIONE	[yellow]
181	2005	BACCHIGLIONE	[yellow]
181	2006	BACCHIGLIONE	[orange]
181	2007	BACCHIGLIONE	[yellow]
181	2008	BACCHIGLIONE	[orange]
201	2000	GORZONE	[yellow]
201	2001	GORZONE	[yellow]
201	2002	GORZONE	[orange]
201	2003	GORZONE	[orange]
201	2004	GORZONE	[yellow]
201	2005	GORZONE	[orange]
201	2006	GORZONE	[yellow]
201	2007	GORZONE	[yellow]
201	2008	GORZONE	[yellow]
437	2000	GORZONE	[yellow]
437	2001	GORZONE	[orange]
437	2002	GORZONE	[orange]
437	2003	GORZONE	[orange]
437	2004	GORZONE	[yellow]
437	2005	GORZONE	[orange]
437	2006	GORZONE	[orange]
437	2007	GORZONE	[orange]
437	2008	GORZONE	[orange]
Legenda			
[blue]	HIGH		
[light green]	GOOD		
[yellow]	FAIR		
[orange]	POOR		
[pink]	WORST		

10.4 Bathing waters monitoring on the coastal belt

10.4.1 Bathing waters monitoring data

Specific station have been chosen for bathing water quality according to the integrated analysis (2000-2006), the tide general circulation and historical data.

To verify the general microbiological impact along the coast, on the basis of the integrated analysis 2000-2006, as already reported, and on the basis of the marine water circulation of the Northern Adriatic sea, specific bathing water monitoring station have been chosen and data elaborated. According to the changes in the monitoring network, and the implementation of the new Italian regulation on bathing waters (transposition of the Directive 2006/7/EC), for each river mouth and for the stretches with no rivers one or two monitoring stations have been chosen; for these stations microbiological data in the period 2010-2012 have been elaborated and assessed.

In **tab. 10.28** the chosen bathing monitoring stations for the assessment of the microbiological impact in the period 2005-2012 are reported. In **tab. 10.29** the station localities are reported.

Table 10.28 *– Specific bathing waters monitoring stations for microbiological impact analysis*

Stretch	Reference river mouth	WWTP (provincial code and name)	Available bathing monitoring stations	Chosen station 2010-2012
I	Tagliamento river	Bibione	517, 002, 003, 004, 005, 518, 007	**2**
II	Lemene river	Portogruaro	008, 009, 519, 010, 011, 012	**9, 10**
III	Livenza river	Caorle	013,014,520, 521, 015, 498, 016, 017	**14, 15**
IV	Piave river	Eraclea mare	018, 019, 020, 499, 021, 022, 023, 024, 025, 026	**21, 22**
V	Sile river, Sile-old Piave river	Quarto d'Altino, Jesolo	027, 028, 029, 030, 032, 033, 034, 035, 036, 075, 037, 500	**32, 34**
VI	Venice Lagoon San Nicolò mouth (no river)	Lido, Cavallino	038, 039, 040, 041, 526, 042, 043, 044, 045, 046, 047, 048, 049	**49**
VII	Venice Lagoon Malamocco mouth (no river)		501, 502, 050, 051, 052, 053, 054, 055	**54**
VIII A	Brenta and Adige mouth	Chioggia	503, 056, 057, 058, 059, 060, 061, 522, 523, 063, 064	**62, 64**
VIII B	Adige	-	065, 066, 524, 528, 529	**66**

Table 10.29 *– Localities of the chosen bathing monitoring stations 2010-2012*

Station number	Locality
2	S. MICHELE AL TAGLIAMENTO - BIBIONE - VIA DELFINO
9	CAORLE - BRUSSA - SPONDA SINISTRA FOCE CANALE NICESOLO
10	CAORLE - SPIAGGIA LEVANTE - VIA TORINO
14	CAORLE - SPIAGGIA PONENTE - PIAZZA MARCO POLO
15	CAORLE - PORTO S.MARGHERITA - PIAZZALE PORTESIN
21	JESOLO - LAGUNA DEL MORTO- SPONDA SINISTRA FOCE FIUME PIAVE
22	JESOLO - JESOLO LIDO- SPONDA DESTRA FOCE FIUME PIAVE
32	CAVALLINO-TREPORTI - CAVALLINO- VIA FARO CIV. 12
49	VENEZIA - VENEZIA LIDO- LUNGOMARE G. MARCONI CIV. 61
54	VENEZIA - PELLESTRINA- SPIAGGIA S.ANTONIO
62	CHIOGGIA - SOTTOMARINA-4600 METRI A SUD INIZIO DIGA S.FELICE
64	CHIOGGIA - ISOLA VERDE-1100 METRI SUD INIZIO DIGA DESTRA FOCE FIUME BRENTA
66	CHIOGGIA - ISOLA VERDE-500 M. NORD INIZIO DIGA SINISTRA FOCE FIUME ADIGE

It must be observed (see the integrated coastal analysis 2000-2006 **§ 10.1**) that till 2005 in WWTP discharges, surface and bathing waters all TC, FC, FS were monitored while EC only on discharges. Since 2006 TC, FC, FS were no more monitored in WWTPs' discharges while they were monitored in bathing waters till the end of 2009.

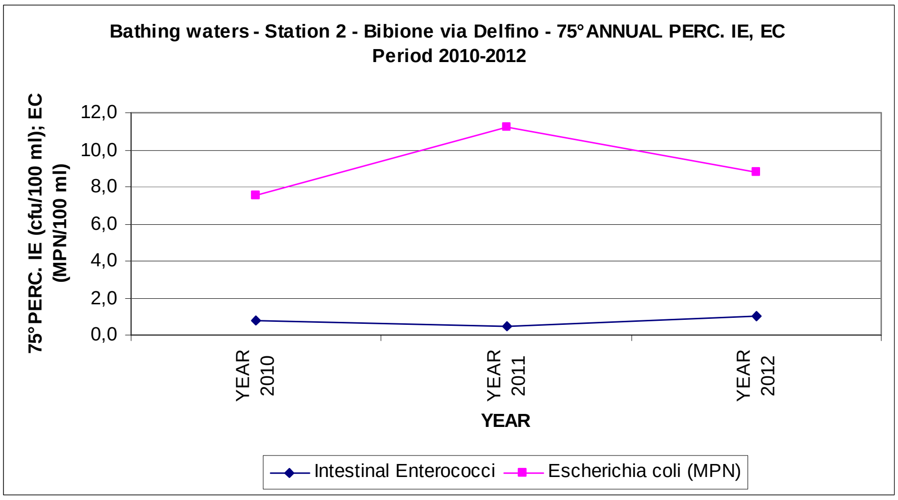
For homogeneity reasons here we consider the two indicators EC and IE, Therefore discharges, rivers and bathing waters qualities are compared with reference to these parameters (where available). The period considered for the analysis of single stations in bathing waters is 2010-2012 when data on EC and IE are available, according to the implementation of directive 2006/7/EC. Bathing water network has been lightly integrated in the period 2000-2009, while sine 2010 sampling and classifications rules have been changed according to the Italian Decree n. 116/2008 which transposed the Directive 2006/7/EC on bathing waters.

Data from monitoring of bathing waters

According to the official monitoring network for bathing waters the 75 perc. of the annual values measured during bathing season (1st April-30th September) have been calculated and reported. The stations have been chosen according the historical knowledge of pollution cases and according to the results of the integrated analysis for the period 2000-2006.

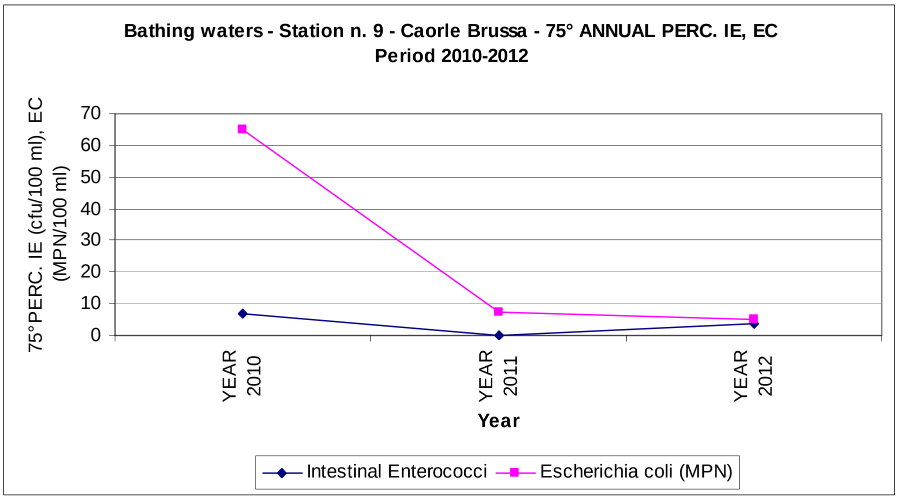
Station n. 2	Enterococchi	Escherichia coli (MPN)
	cfu/100 ml	MPN/100 ml
Mean	2	18
75° PERC	1	9
MIN	0	5
MAX	24	144
STD DEV	5	32

Figure 10.57 *–Station n. 2*



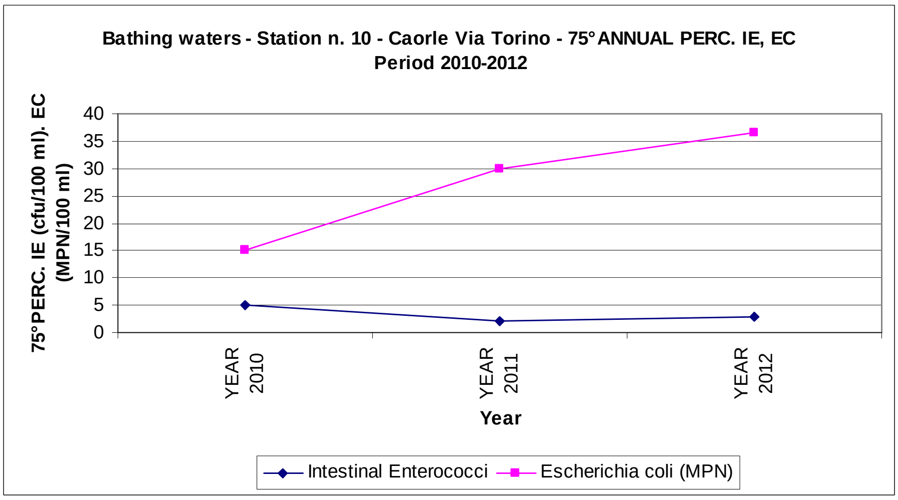
Station n. 9	Intestinal Enterococcii	Escherichia coli (MPN)
	cfu/100 ml	MPN/100 ml
Mean	8	276
75° PERC	4	23
MIN	0	5
MAX	120	3564
STD DEV	26	870

Figure 10.58 *– Station n. 9*



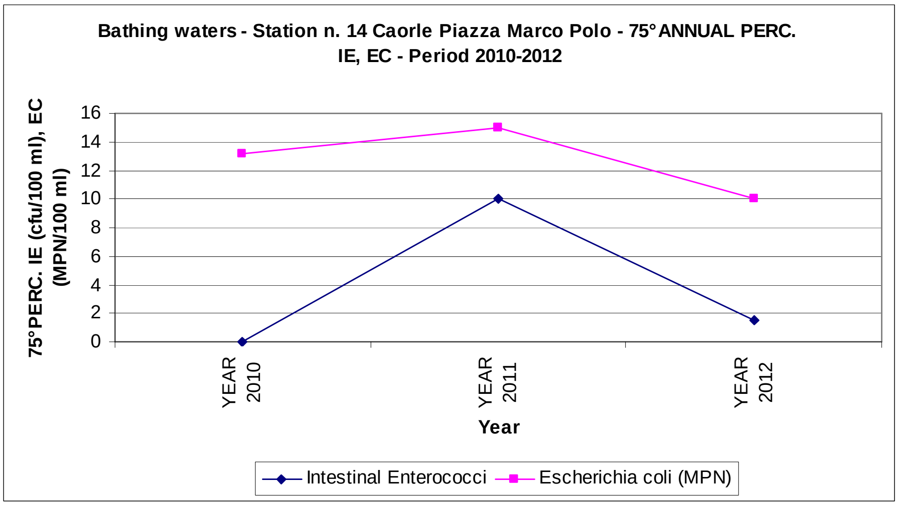
Station n.10	Intestinal Enterococci	Escherichia coli (MPN)
	cfu/100 ml	MPN/100 ml
Mean	5	39
75° PERC	3	30
MIN	0	5
MAX	44	226
STD DEV	12	66

Figure 10.59 *– Station n. 10*



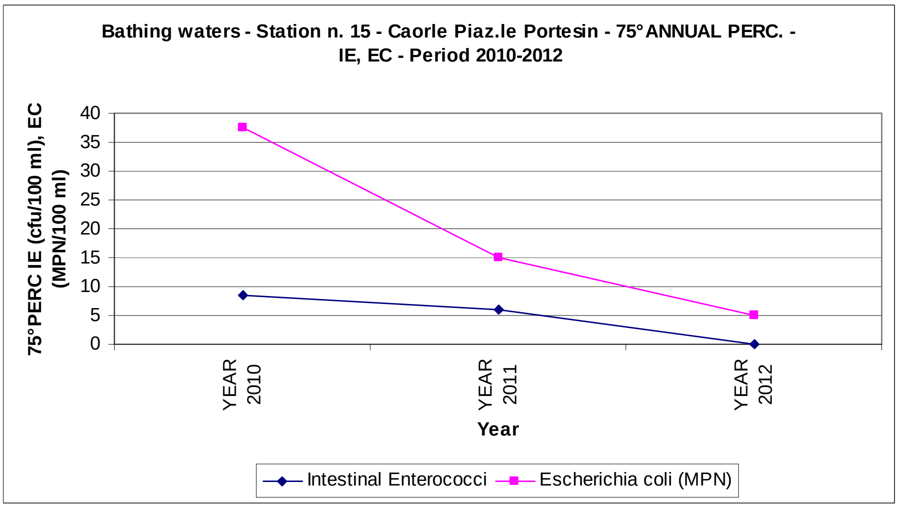
Station n. 14	Intestinal Enterococci	Escherichia coli (MPN)
	cfu/100 ml	MPN/100 ml
Mean	7	25
75° PERC	2	15
MIN	0	5
MAX	64	215
STD DEV	17	49

Figure 10.60 *– Station n. 14*



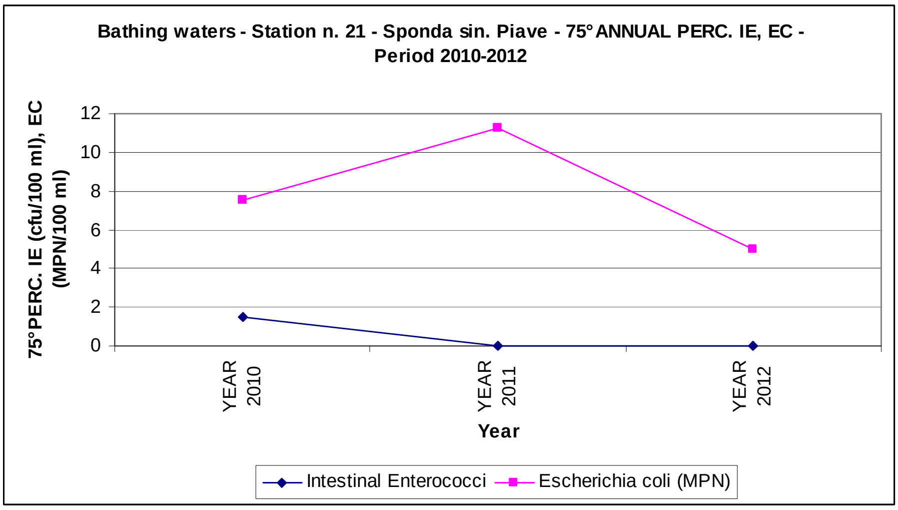
Station n. 15	Intestinal Enterococci	Escherichia coli (MPN)
	cfu/100 ml	MPN/100 ml
Mean	8	26
75° PERC	5	15
MIN	0	5
MAX	94	234
STD DEV	22	53

Figure 10.61 *– Station n. 15*



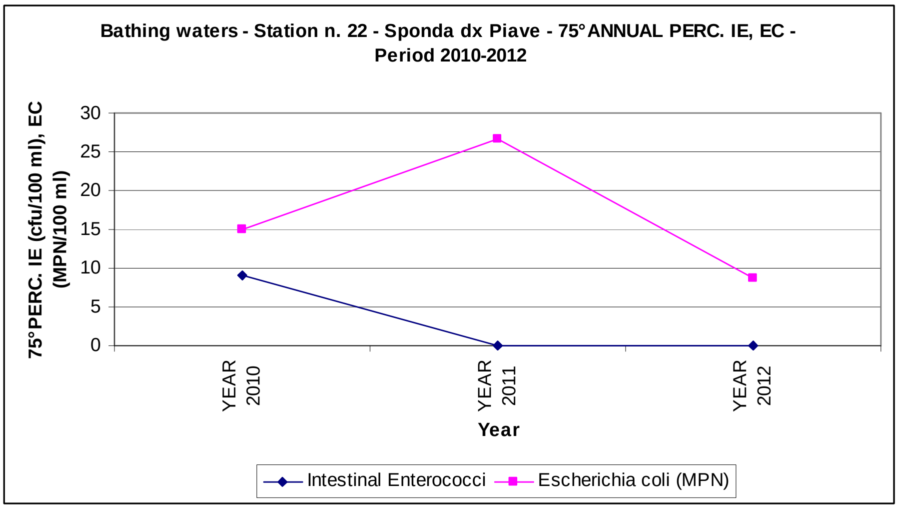
Station n. 21	Intstinal Enterococci	Escherichia coli (MPN)
	cfu/100 ml	MPN/100 ml
Mean	2	17
75° PERC	0	8
MIN	0	5
MAX	28	179
STD DEV	6	40

***Figure 10.62** – Station n. 21*



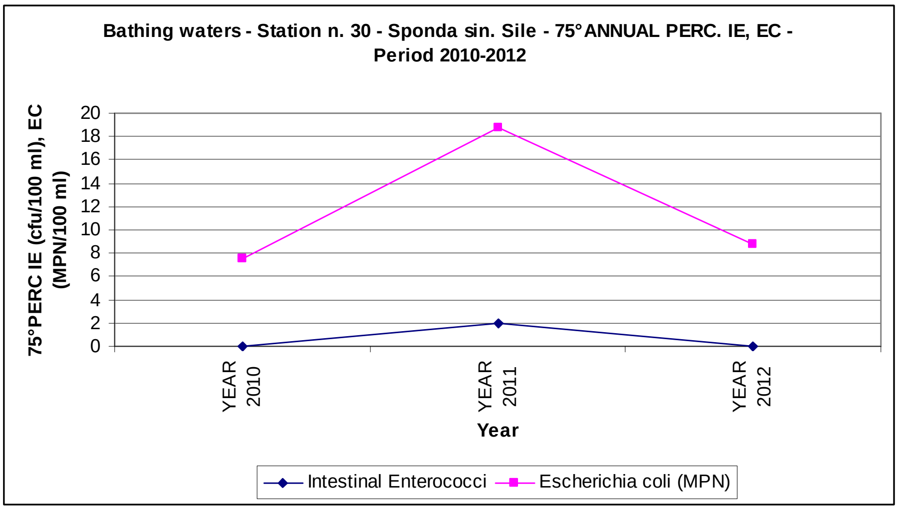
Station n. 22	Intestinal Enterococci	Escherichia coli (MPN)
	cfu/100 ml	MPN/100ml
Mean	5	33
75° PERC	3	15
MIN	0	5
MAX	72	397
STD DEV	16	89

***Figure 10.63** – Station n. 22*



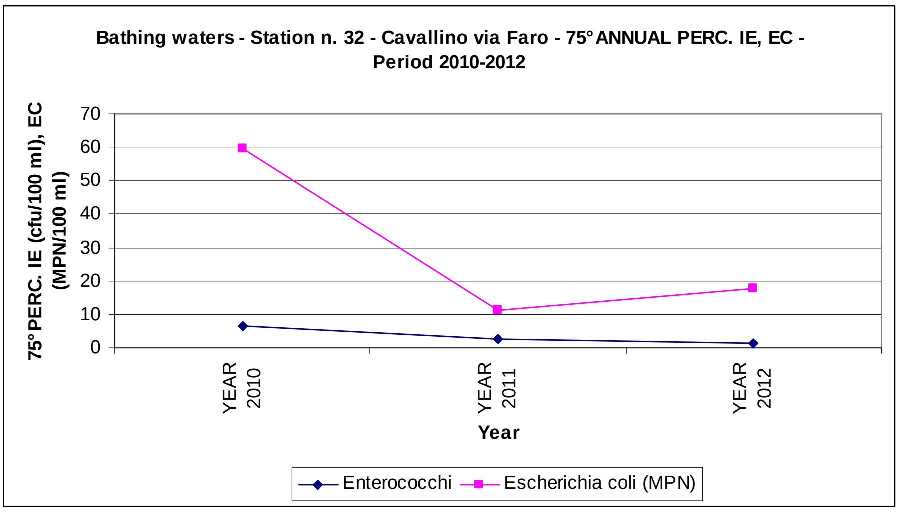
Station n. 30	Intestinal Enterococci	Escherichia coli (MPN)
	cfu/100 ml	MPN/100 ml
Mean	1	12
75° PERC	1	9
MIN	0	5
MAX	4	46
STD DEV	1	13

Figure 10.64 *– Station n. 30*



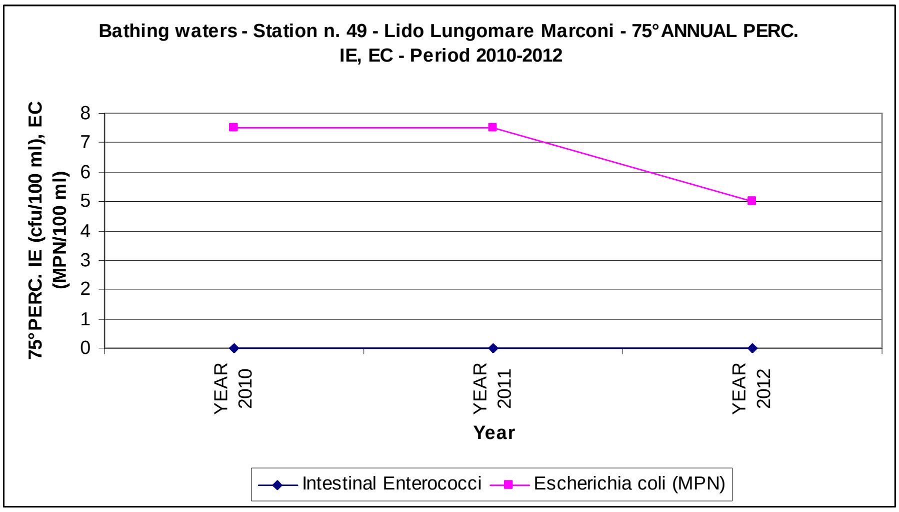
Station n. 32	Intestinal Enterococci	Escherichia coli (MPN)
	cfu/100 ml	MPN/100ml
Mean	2	27
75° PERC	3	18
MIN	0	5
MAX	8	161
STD DEV	3	43

Figure 10.65 *– Station n. 32*



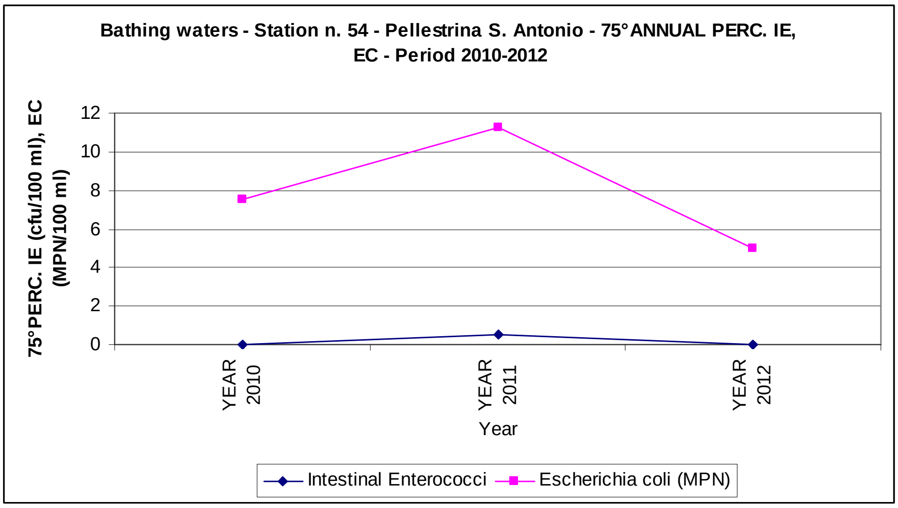
Station n. 49	Intestinal Enterococci	Escherichia coli (MPN)
	cfu/100 ml	MPN/100 ml
Mean	0	8
75° PERC	0	8
MIN	0	5
MAX	2	30
STD DEV	0	5

Figure 10.66 *– Station n. 49*



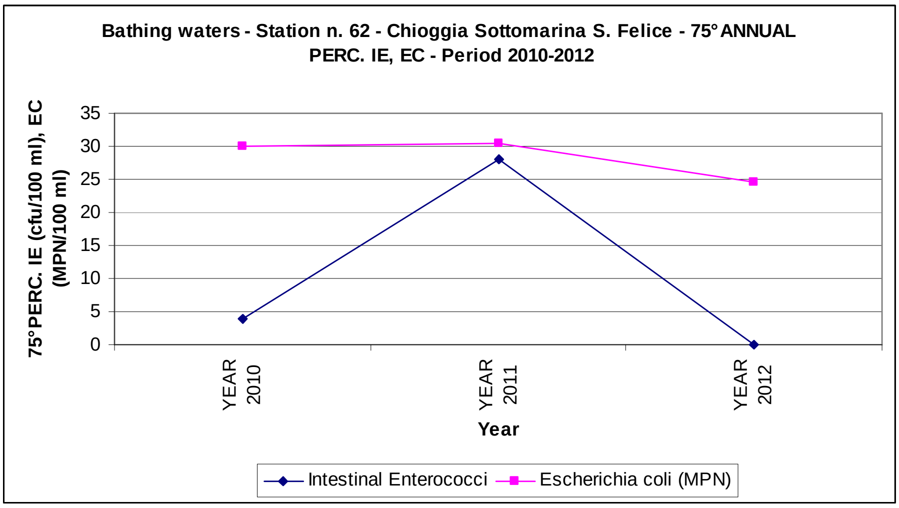
Station n. 54	Intestinal Enterococci	Escherichia coli (MPN)
	cfu/100 ml	MPN/100 ml
Mean	0	15
75° PERC	0	8
MIN	0	5
MAX	4	143
STD DEV	1	31

Figure 10.67 *– Station n. 54*



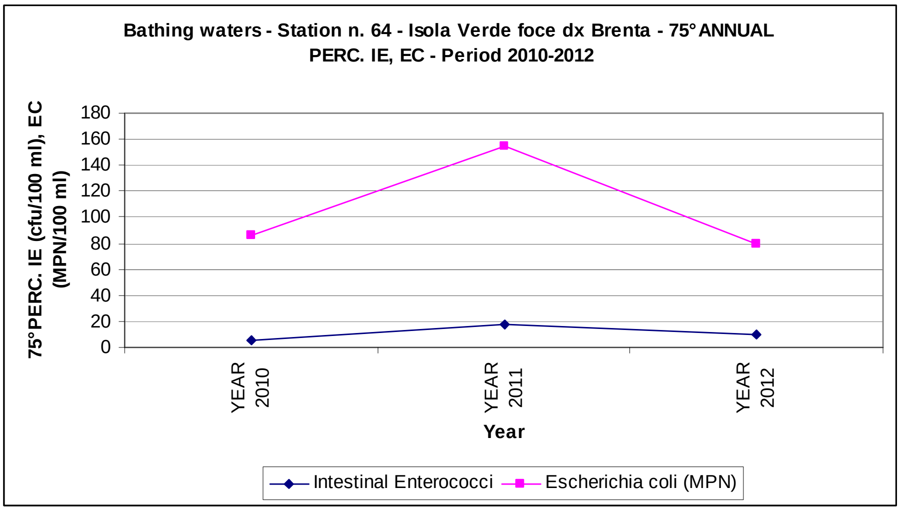
Station n. 62	Intestinal Enterococci	Escherichia coli (MPN)
	cfu/100 ml	MPN/100 ml
Mean	9	62
75° PERC	6	30
MIN	0	5
MAX	50	480
STD DEV	17	132

Figure 10.68 *– Station n. 62*



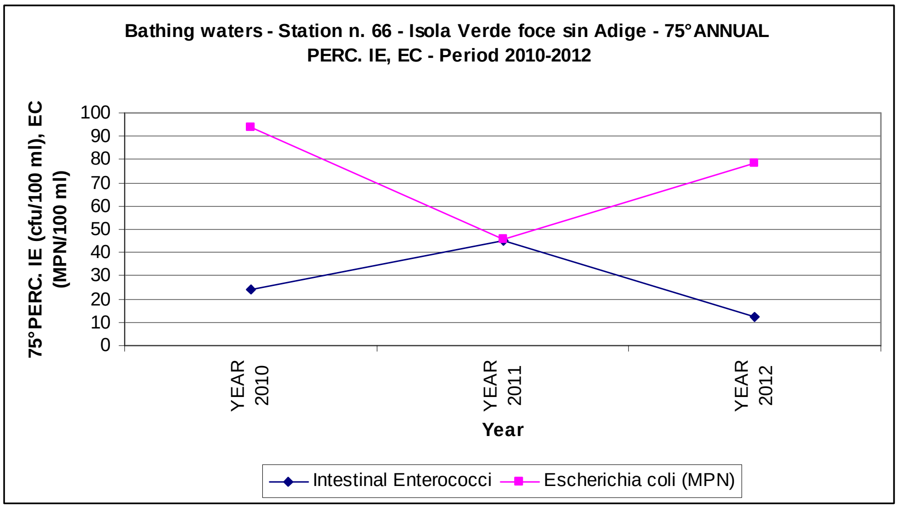
Station n. 64	Intestinal Enterococci	Escherichia coli (MPN)
	cfu/100 ml	MPN/100 ml
Mean	14	155
75° PERC	9	119
MIN	0	5
MAX	144	2005
STD DEV	30	390

Figure 10.69 *– Station n. 64*



Station n. 66	Intestinal Enterococci	Escherichia coli (MPN)
	cfu/100 ml	MPN/100 ml
Mean	17	165
75° PERC	26	94
MIN	0	5
MAX	110	2005
STD DEV	29	413

Figure 10.70 *– Station n. 66*



10.4.2 Comments on bathing waters monitoring data

The most critical situations are located **near the river mouths**. In particular for the Adige, Brenta-Bacchiglione rivers and near the Tagliamento mouth situations of local contamination were found.

The pollution level of the rivers is confirmed by data on river monitoring presented in the beginning of this chapter. Disinfection is therefore still necessary to guarantee the uses of the water bodies. In the integrated analysis data on different water matrices have been assessed together.

10.4.3 Bathing water monitoring classification

According to Legislative Decree n. 116/2008 the classification of the selected bathing water monitoring stations is reported for the period 2007-2010 in he **tab. 10.30**.

From bathing water classification the worst situations are identified near Chioggia where Adige and Brenta-Bacchiglione mouths are localized.

Table 10.30 *– Bathing waters classification according to Decree n. 116/2008 – 2007-2010*

WATER BODY	STATION	N° SAMPLES	95 PERC. E.Coli	90 PERC. E.Coli	CLASSIF	95 PERC. Entero	90PERC. Entero	CLASS	FINAL QUALITY CLASS
ADRIATIC SEA									
SAN MICHELE AL TAGLIAMENTO	2	42	14.84	9.71	HIGH	4.48	3.47	HIGH	HIGH
CAORLE	9	42	16.29	10.39	HIGH	4.65	3.65	HIGH	HIGH
CAORLE	10	42	63.74	37.54	HIGH	17.33	11.26	HIGH	HIGH
CAORLE	14	45	58.49	35.67	HIGH	20.96	13.68	HIGH	HIGH
CAORLE	15	42	69.56	39.11	HIGH	19.54	12.31	HIGH	HIGH
JESOLO	21	42	21.75	13.24	HIGH	6.58	4.86	HIGH	HIGH
JESOLO	22	42	38.11	22.77	HIGH	8.98	6.37	HIGH	HIGH
CAVALLINO - TREPORTI	32	42	36.56	21.93	HIGH	6.19	4.79	HIGH	HIGH
CAVALLINO - TREPORTI	34	42	27.65	17.87	HIGH	6.60	5.00	HIGH	HIGH
VENEZIA	49	42	8.24	5.68	HIGH	1.82	1.62	HIGH	HIGH
VENEZIA	54	42	13.79	8.70	HIGH	2.13	1.82	HIGH	HIGH
CHIOGGIA	62	52	590.56	234.38	FAIR	11.68	8.10	HIGH	FAIR
CHIOGGIA	64	52	882.74	363.64	FAIR	16.86	11.08	HIGH	FAIR
CHIOGGIA	66	51	717.99	297.17	FAIR	18.29	12.31	HIGH	FAIR

CONCLUSIONS

The wastewater disinfection can be an effective intervention as long as its use is decided on the basis of specific requirements of protections defined with respect to real sanitary and environmental risks. Disinfection is necessary to reduce or stop the pathogen microorganisms' growth (bacteria, virus, protozoa, etc.) and to sensibly reduce the diffusion of deseases. In the choice of a specific disinfection system different factors must be considered beyond the water quality objectives: plant costs, operative costs, residual toxicity of DBPs.

Disinfection systems – in their installation – are now compulsory in Italy in wastewater treatment plants (WWTP) larger than 2,000 Population Equivalents (PE). From one side a satisfactory abatement percentage for microbiological parameters must be guaranteed when the receiving water body is subject to specific human uses, while from the other very low levels of chemical pollutants from disinfection (DBPs) must be obtained in the final discharge to achieve Environmental Quality Standards (EQS) in the water body (Directive 2000/60/EC). Since December 2012, chlorine and its compounds have been prohibited for disinfection in the Veneto region in compliance with the 2009 Regional Water Protection Plan.

In this study the WWTPs of the province of Venice with potentiality higher than 10,000 PE and with different disinfection systems (with the addition of Paese WWTP as it applies ozone disinfection) have been considered; the discharge control data produced by the the Veneto Environmental Regional Protection Agency (ARPAV) have been recovered and assessed for the period 2005-2012 for microbiological pollution and for DBPs reaseach. A specific set of WWTPs (n. 7 plants) of the total set has been selected: on these plants the functionality verification at mean loads was performed and the managers data have been used to determine the abatement efficiencies.

Functionality verification appears a support for the knowledge of the plants but also to understand if specific classes of DBPs can be aspected (for example HNMs in case of not complete nitrification). Morover it is a support for the control Authorities to define frequency of controls and to assess the control delegation (annex V Decree n. 152/2005 Part III) performing integrated controls. The DBPs have been investigated according to the analytical panel normally executed by ARPAV with routinary methods (classes of phenols and chlorophnols, organohalogenated compounds comprehensive of Trihalomethanes-THMs). THMs have been found at values higher than LODs especially for chlorine disinfection systems, but the values detected appeared to be always at values lower than discharge limit values but also quality standards for wastewater resuse.

Specific laboratory and full scale trials on the correct doses of chlorine able to allow an acceptable level of THMs in the final discharge have been performed by one of the involved plant managers; the main results have been presented and discussed showing the efficiency of chlorine and the low level of produced THMs, always under drinking water limit value.

Due to the prohibition of chlorine and compounds (defined in 2004 and effective since December 2012) by the Veneto region, the same plant manager experimented since 2005 the Performic acid (PFA) in wastewater disinfection. ARPAV partecipated with integrative samples for DBPs identification during 2012. The analyses were quantitative for the main classes of

DBPs, while for other classes only qualitative. No evidence of particular DBPs have been pointed out. PFA appears very interesting: high efficiency and low level of by-products. More sperimentation is in any case necessary on the mid to long-time scale.

From the assessment of the disinfection systems performed in this study it can be said that, with differences among the WWTPs, the abatement efficiencies were good and that satisfactory results have been achieved except for ozone; the DBPs have been detected but always at acceptable levels. It must be observed that many classes of emerging pollutants (Halonitromethanes, Haloacetic acids, Haloaldehydes, Haloketones, etc.) are not investigated neither regulations give specific indication on limit or standard values.

The tendency to form THMs grows with high concentration of chlorine (Cl_2 = 50 mg/l) and contact time of 24 h. The involved plant manager did not find HAAs as well as N-nitrosodimethylamine (NDMA) in all the analysis performed in 2012. In systems with a complete nitrification controlled application of chlorine and compound in disinfection produces acceptable THMs (at level for drinking water).

With the support of institutional control data from ARPAV and the results of laboratory and full-scale trials on the chosen WWTPs the chlorine prohibition for medium size plants appears to be excessive and in particular for non critical areas like the Venice lagoon watershed. We can suggest to define with particular care the real necessity of disinfection according to the specific use of the receiving water body, considering the really necessary period of activation too.

Peracetic acid (PAA) is a largely experimented alternative to chlorine. But from experimental data, in the Jesolo plant increasing efficiency was determined passing from PAA to hypochlorite. The cost and the risks for PAA storage are negative aspects. The case study with UV (Fusina plant) showed very high efficiency in microbiological abatement, costs lower than the PAA; the system requires ultrafiltration pre-treatment to reduce shadow effects.

The WWTP at Paese (province of Treviso – Veneto region) has been presented as a case study for ozone; the plant is characterized with a large section for the treatment of liquid wastes too. From available microbiological data supplied by the plant manager, concerning waters entering and exiting the disinfection system and according to the criterion applied, good but not completely satisfactory abatement efficiency (more than 99% in most cases but not equal to 99.99%) has been observed. However, in various cases the inflow to the disinfection system revealed very high microbiological levels in the outlet and the ozone disinfection system was not used regularly. Disinfection functionality should be verified with additional data. From data available regarding the final discharge and performed by ARPAV for the period 2002-2011, most of the organic micro-pollutants are lower than the available LODs. The analytic panel must, however, be improved.

From the *integrated analysis* along the costal belt for biological parameters relevant for bathing water quality in the period 2000-2006 for the identified homogeneous stretches a preliminary *bathing water profile* as requested by Directive 2006/7/EC was developed. The results highlight that in some cases there is a high level of mean faecal contamination along the coast; the most critical situation is coastal stretch n. VIII (beaches of Ca' Roman, Sottomarina-Chioggia and Isola Verde) and these results are widely imputable to the pressures created by the Brenta-Bacchiglione and Adige rivers. The best situations are observed where no river mouth is present and the WWTPs’ effluents are discharged through submarine outfalls (stretches n. VI and n. VII). It is evident that the problem of microbiological impact must be studied following a river basin-approach according to the influence of river loads on coastal areas. In the case of the province of Venice the bathing water control appears strategic also for the economical consequences of closures of the beaches during summer time.

From the preliminary analysis of the sea water quality observed, submarine outfalls appear to be a good solution in guaranteeing the quality of bathing water along the coast, as proved with support of a 3D modelling tool. More investigation through complementary studies, in particular, modelling assessments, is needed. Nevertheless, this solution cannot ignore the possible impact of the discharges on sea waters intended for specific uses, such as mussel farms with reference to coastal hydrodynamics.

The surface water classification according to WFD 2000/60/EC and to the Italian Decree n. 260/2010 does not give a determining information to decide about acceptability of microbiological pollution. Therefore it is here proposed to maintain *Escherchia coli* and Salmonella monitoring for surface water as well as for discharge controls. At analytical level the LODs of the applied methods should be lowered for routinary uses; emerging DBPs should be researched implementing the analytical techniques.

The river and bathing waters monitoring stations data as well as the treatment plants discharges quality data confirmed the need to continue disinfection of wastewaters; for river impacts along the coast a river basin approach must be applied according to DPSIR scheme.

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List of equations

ANNEXES

Annex I: Discharge limit values

Table I.1 *– Discharge limit values for industrial wastewaters into surface waters*

Parameter number	SUBSTANCES	Units of measure	Discharge into surface watersi	Discharge into public sewers
1	pH		5.5-9.5	5.5-9.5
2	Temperature	°C	(1)	(1)
3	Color		Not identifieblewith dilution of 1:20	Not identifieble with dilution of 1:40
4	Odor		No malodors	No malodors
5	Coarse materials		absent	absent
6	Total sospende solids	mg/L	≤ 80	≤ 200
7	BOD_5 (as O_2)	mg/L	≤ 40	≤ 250
8	COD (as O_2)	mg/L	≤ 160	≤ 500
9	Al	mg/L	≤ 1	≤ 2.0
10	As	mg/L	≤ 0.5	≤ 0.5
11	Ba	mg/L	≤ 20	-
12	B	mg/L	≤ 2	≤ 4
13	Cd	mg/L	≤ 0.02	≤ 0.02
14	Total Cr	mg/L	≤ 2	≤ 4
15	Cr VI	mg/L	≤ 0.2	≤ 0.20
16	Fe	mg/L	≤ 2	≤ 4
17	Mn	mg/L	≤ 2	≤ 4
18	Hg	mg/L	≤ 0.005	≤ 0.005
19	Ni	mg/L	≤ 2	≤ 4
20	Pb	mg/L	≤ 0.2	≤ 0.3
21	Cu	mg/L	≤ 0.1	≤ 0.4
22	Se	mg/L	≤ 0.03	≤ 0.03
23	Sn	mg/L	≤ 10	
24	Zn	mg/L	≤ 0.5	≤ 1.0
25	Total CN (as CN)	mg/L	≤ 0.5	≤ 1.0
26	Free active Chlorine	mg/L	≤ 0.2	≤ 0.3
27	Solphurs (as S)	mg/L	≤ 1	≤ 2
28	Solfiti (as SO_2)	mg/L	≤ 1	≤ 2
29	Solphites (as SO_3)	mg/L	≤ 1000	≤ 1000
30	Chlorides	mg/L	≤ 1200	≤ 1200
31	Fluorides	mg/L	≤ 6	≤ 12
32	Total P (as P)	mg/L	≤ 10	≤ 10
33	N-NH4 (as NH_4)	mg /L	≤ 15	≤ 30

Parameter number	SUBSTANCES	Units of measure	Discharge into surface watersi	Discharge into public sewers
34	N-NO2 (as N)	mg/L	≤ 0.6	≤ 0.6
35	N-NO3 (as N)	mg /L	≤ 20	≤ 30
36	Grease and animal/vegetal oils	mg/L	≤ 20	≤ 40
37	Total hydrocarbons	mg/L	≤ 5	≤ 10
38	Phenols	mg/L	≤ 0,5	≤ 1
39	Aldehydes	mg/L	≤ 1	≤ 2
40	Aromatic organic solvents	mg/L	≤ 0.2	≤ 0.4
41	Nitrogen organic solvents	mg/L	≤ 0.1	≤ 0.2
42	Total surfactants	mg/L	≤ 2	≤ 4
43	P pesticides	mg/L	≤ 0.10	≤ 0.10
44	Total pesticides (excluded with P) as:	mg/L	≤ 0.05	≤ 0.05
45	- aldrin	mg/L	≤ 0.01	≤ 0.01
46	- dieldrin	mg/L	≤ 0.01	≤ 0.01
47	- endrin	mg/L	≤ 0.002	≤ 0.002
48	- isodrin	mg/L	≤ 0.002	≤ 0.002
49	Chlorinated solvents	mg/L	≤ 1	≤ 2
50	*Escherichia coli* (6)	UFC/100mL	Nota	
51	Acute toxicity essay		Not acceptable after 24 hours and the number of immobile organisms is ≥ 50% of the total	Not acceptable after 24 hours and the number of immobile organisms is ≥ 8% of the total

Annex II: WWTPs in the Province of Venice

In the following table the list of the WWTPs active (without Imhoff tanks) in the Province of Venice at the date of March 2013 is reported; the potentiality, the adopted disinfection system and the period of their activation are reported. The data source is the Province of Venice – Servizio Ambiente.

Commune	**WWTP's manager**	*Locality*	*Address*	*Max Pot. (PE)*	*Emission limits (column WPP)*	*Disinfection*
Annone Veneto	Acque del Basso Livenza S.p.A.	Capoluogo	Via Lorenzaga	2.000	C	D (*) (2)
Caorle	Azienda Servizi Integrati S.p.A. di San Donà di Piave	Capoluogo	Via Tràghete	120.000	C + P_{tot}	D (^) (3)
Caorle	Azienda Servizi Integrati S.p.A. di San Donà di Piave	San Giorgio di Livenza	Via Strada Nuova	3.000	C	d (3)
Cavarzere	Polesine Acque S.p.A.	Capoluogo	Via Piantazza	20.000	C + P_{tot}	D (^) (2)
Ceggia	Azienda Servizi Integrati S.p.A. di San Donà di Piave	Capoluogo	Via I Maggio	5.000	C	d (3)
Chioggia	V.E.R.I.T.A.S. S.p.A.	Capoluogo	Val da Rio	160.000	C + P_{tot}	D (*) (1)
Cona	AcegasAps S.p.A.	Pegolotte	Via Tasso	6.000	Tab. A Decree 30/07/1999	D (*) (1)
Concordia Sagittaria	Acque del Basso Livenza S.p.A.	Capoluogo	Via Basse	3.000	C	D (*) (2)
Concordia Sagittaria	Acque del Basso Livenza S.p.A.	Capoluogo	Via Gabriela	3.000	C	D (*) (2)
Eraclea	Azienda Servizi Integrati S.p.A. di San Donà di Piave	Ponte Crepaldo	Via Leonardo da Vinci	4.700	C	d (3)
Eraclea Mare	Azienda Servizi Integrati S.p.A. di San Donà di Piave	Eraclea Mare	Via dei Pioppi	32.000	C + P_{tot}	D (^) (3)
Fossalta di Piave	Azienda Servizi Integrati S.p.A. di San Donà di Piave	Capoluogo	Via Cadorna	3.600	C	d (3)
Fossalta di Portogruaro	Comune	Capoluogo	Via Europa	3.000	C	D (*) (2)
Jesolo	Azienda Servizi Integrati S.p.A. di San Donà di Piave	Capoluogo	Via Aleardi	185.000	C + P_{tot}	D (^) (3)
Meolo	Azienda Servizi Pubblici Sile-Piave S.p.A.	Capoluogo	Via Marteggia	9.000	C	d (2)
Musile di Piave	Azienda Servizi Integrati S.p.A.di San Donà di Piave	Capoluogo	Via Rovigo	10.000	C	D (^) (3)

Commune	WWTP's manager	*Locality*	*Address*	*Max Pot. (PE)*	*Emission limits (column WPP)*	*Disinfection*
Noventa di Piave	Azienda Servizi Integrati S.p.A. di San Donà di Piave	Capoluogo	Via Torino	4.500	C	d (3)
Portogruaro	Acque del Basso Livenza S.p.A.	loc. Destra Reghena	Viale Venezia	8.400	C + P_{tot}	D (*) (2)
Pramaggiore	Acque del Basso Livenza S.p.A.	Blessaglia	Via Blessaglia	4.500	C	D (*) (2)
Quarto d'Altino	Azienda Servizi Pubblici Sile -Piave S.p.A.	Capoluogo	Via Marconi	50.000	C + P_{tot}	D (*) (2)
San Donà di Piave	Azienda Servizi Integrati S.p.A. di San Donà di Piave	Capoluogo	Via Tronco	45.000	C + P_{tot}	D (^) (3)
San Michele al Tagliamento	Comune	Capoluogo	Via Aldo Moro	8.000	C	D (*) (2)
San Michele al Tagliamento	Comune	Bibione	Via Parenzo	150.000	C + P_{tot}	D (^) (3)
Santo Stino di Livenza	Acque del Basso Livenza S.p.A.	Capoluogo	Via Canaletta	10.000	C	D (*) (2)
Santo Stino di Livenza	Acque del Basso Livenza S.p.A.	La Salute di Livenza	Via Leonardo da Vinci	2.500	C	D (*) (2)
Torre di Mosto	Azienda Servizi Integrati S.p.A. di San Donà di Piave	Capoluogo	Via Xola (MBR)	3.000	C	D (*) (3)
Venezia	V.E.R.I.T.A.S. S.p.A.	Campalto	Via brigadiere Scantamburlo	130.000	Tab. A Decree 30/07/1999 with As ≤ 10 μg/l	D (*) (1)
Cavallino - Treporti	V.E.R.I.T.A.S. S.p.A.	Cavallino	Via Fausta	105.000	E + P_{tot}	D (^) (2)
Venezia	V.E.R.I.T.A.S. S.p.A.	Malamocco	Via Galba	30.000	E + P_{tot}	D (^) (2)
Venezia	V.E.R.I.T.A.S. S.p.A.	Fusina	Via dei Cantieri	400.000	L_2 del P.R.R.A.	D (*) (1)

Legenda:
d = with disinfection installed
D = with disinfection active: (*) all the year (^) 15/03- 30/09

Disinfection systems: (1) UV - (2) PAA - (3) PFA

Annex III: Reference dangerous substances values from Italian regulations

In the following table discharge limit values, wastewater reuse limits, EQSs and drinking water required values from Italian regulations are detailed. Italian regulations for EQSs and for drinking waters transpose respectively the Directives 2008/105/EC and 98/83/EEC.

		Total phenols	Dichlorophenols	PCP (PP)	Residual Chlorine	Chlorinated organic solvents^	tetrachloromethane	Chlorophorm (P)	1,2 Dichloroethane (P)	Trichloroethilene	Tetrachloroethilene	THMs	Total Aldehydes	Sum terea and trichloroethilene
Law/Regulation	Reference value	μg/l	μg/l	μg/l	mg/l	mg/l	μg/l	μg/l	μg/l	μg/l	μg/l	mg/l	mg/l	mg/l
DM 30/07/1999	limt values for discharges for Venice Lagoon and its watershed	50	50	50	0.02	0.4								
DM 28/04/1998	EQS for Venice lagoon and its watershed are*	5	0.4	0.3			0.25	5.7	0.4	2.7	0.8			
Decree n. 152/2006 Annex 1 Part III	Std value for Chemical status of water bodies			0.4				12		10	10			
DM 185/2003	Water reuse limits	0.1		0.003		0.04						0.03	0.5	0.01
Decree n. 31/2001	Drinking water std								3			0.03		0.01

^Sum of Tetracloromethane, Chlorophorm, 1,2-Dichloroethane, Trichloroethilene, Tetrachlorethilene, Trichlorobenzene, Esachlorobutadiene, Tetrachlorobenzene

*Compulsory value for the lagoon

Annex IV: ARPAV laboratory's test lists for DBPs

In the following table the test list forWWTP for the reasearched DBPs is reported.

Substance	Unit of measure	LOD	Analytical technique
Chlorophorm	mg/l	<0.001	Rapporto ISTISAN 2000/14
1,1,1 Trichloroethane	µg/l	<0.001	Notiziario IRSA n. 1 (2005) Ed. on line
1,1,1 Trichloroethane	mg/l	<0.0005	Rapporto ISTISAN 2000/14
1,1 Dicloroethane	µg/l	<0.05	Notiziario IRSA n. 1 (2005) Ed. on line
1,2 Dichloroethane	µg/l	<0.05	Notiziario IRSA n. 1 (2005) Ed. on line
Trichloroethilene (C2HCl3)	mg/l	<0.0005	Rapporto ISTISAN 2000/14
Trichlorofluorometane	mg/l	<0.0005	Rapporto ISTISAN 2000/14
Bromophorm (Tribromomethane)	mg/l	<0.001	Rapporto ISTISAN 2000/14
Dibromochloromethane	mg/l	<0.001	Rapporto ISTISAN 2000/14
Dichlorobromomethane	mg/l	<0.001	Rapporto ISTISAN 2000/14
Tetrachloroethilene (C2Cl4)	mg/l	<0.0005	Rapporto ISTISAN 2000/14
Tetrachloromethane CCl4	mg/l	<0.0005	Rapporto ISTISAN 2000/14
Total organohalogenated solvents	mg/l	<0.001	Rapporto ISTISAN 2000/14
1,1 Dichloroethilene	µg/l	<0.5	Notiziario IRSA n. 1 (2005) Ed. on line
1,1,1 Trichloroethane	mg/l	<0.0005	Rapporto ISTISAN 2000/14
1,1,2 Trichloroethane	µg/l	<0.5	Notiziario IRSA n. 1 (2005) Ed. on line
1,1,2,2 Tetrachloroethane	µg/l	<0.5	Notiziario IRSA n. 1 (2005) Ed. on line
1,2 Dibromoethane	µg/l	<0.5	Notiziario IRSA n. 1 (2005) Ed. on line
1,2 Dicloroethilene cis	µg/l	<0.5	Notiziario IRSA n. 1 (2005) Ed. on line
1,2 Dicloroethilene trans	µg/l	<0.5	Notiziario IRSA n. 1 (2005) Ed. on line
1,2 Dichloropropane	µg/l	<0.5	Notiziario IRSA n. 1 (2005) Ed. on line
1,2,3 Trichloropropane	µg/l	<0.5	Notiziario IRSA n. 1 (2005) Ed. on line
Esachlorobutadiene (HCBD)	µg/l	<0.5	Notiziario IRSA n. 1 (2005) Ed. on line
Phenols	mg/l	<0.004	APAT CNR IRSA n. 29/2003
Aldehydes	mg/l	<0.17	APAT CNR IRSA n. 29/2003
Phenol sum	µg/l	<0.2	APAT CNR IRSA n. 29/2003
Phenol	µg/l	<0.2	APAT CNR IRSA n. 29/2003
2,4,6-Trichlorophenol	µg/l	<1	APAT CNR IRSA n. 29/2003
2-Chlorophenol	µg/l	<0.4	APAT CNR IRSA n. 29/2003
4-Chlorophenol	µg/l	<0.4	APAT CNR IRSA n. 29/2003
3-Chlorophenol	µg/l	<0.4	APAT CNR IRSA n. 29/2003
PCP	µg/l	<1	APAT CNR IRSA n. 29/2003
2,4-Chlorophenol	µg/l	<1	APAT CNR IRSA n. 29/2003
Sum of organohalogenated compounds	µg/l	<1	Notiziario IRSA n. 1 (2005) Ed. on line
Tribromomethane	µg/l	<0.3	Notiziario IRSA n. 1 (2005) Ed. on line
Trichloromethane	µg/l	<0.1	Notiziario IRSA n. 1 (2005) Ed. on line
Dibromochloromethane	µg/l	<0.1	Notiziario IRSA n. 1 (2005) Ed. on line
Bromodichloromethane	µg/l	<0.1	Notiziario IRSA n. 1 (2005) Ed. on line
Trichoroethilene	µg/l	<0.05	Notiziario IRSA n. 1 (2005) Ed. on line
Tetrachloroethilene	µg/l	<0.05	Notiziario IRSA n. 1 (2005) Ed. on line
Vynil-chloride	µg/l	<0.05	Notiziario IRSA n. 1 (2005) Ed. on line
1,2-dichloroethane	µg/l	<0.03	Notiziario IRSA n. 1 (2005) Ed. on line
1,1,2 Trichloethane	µg/l	<0.1	Notiziario IRSA n. 1 (2005) Ed. on line
1,1-Dichloroethilene	µg/l	<0.03	Notiziario IRSA n. 1 (2005) Ed. on line
1,2-dichloroethilene cis	µg/l	<0.05	Notiziario IRSA n. 1 (2005) Ed. on line
1,2-dichloroethilene trans	µg/l	<0.05	Notiziario IRSA n. 1 (2005) Ed. on line

1,2-dichloropropane	µg/l	<0.05	Notiziario IRSA n. 1 (2005) Ed. on line
1,1-dichloroethane	µg/l	<0.05	Notiziario IRSA n. 1 (2005) Ed. on line
1,2-dibromoethane	µg/l	<0.03	Notiziario IRSA n. 1 (2005) Ed. on line
1,2,3-trichloropropane	µg/l	<0.03	Notiziario IRSA n. 1 (2005) Ed. on line
Esachlorobutadiene	µg/l	<0.05	Notiziario IRSA n. 1 (2005) Ed. on line
Benzene	µg/l	<0.03	Notiziario IRSA n. 1 (2005) Ed. on line
Toluene	µg/l	<0.03	Notiziario IRSA n. 1 (2005) Ed. on line
Ethilbenzene	µg/l	<0.03	Notiziario IRSA n. 1 (2005) Ed. on line
Xylenes (o+m+p)	µg/l	<0.03	Notiziario IRSA n. 1 (2005) Ed. on line
Styrene	µg/l	<0.03	Notiziario IRSA n. 1 (2005) Ed. on line

Annex V: Biological wastewater treatment processes

The characterization of COD of typical **urban wastewater** is reported in **fig. V.1** (Masotti, 1999). The various types of solids, according to Masotti (1999), can be classified into the classes reported in **fig. V.2**.

Figure V.1 *– COD characterization*

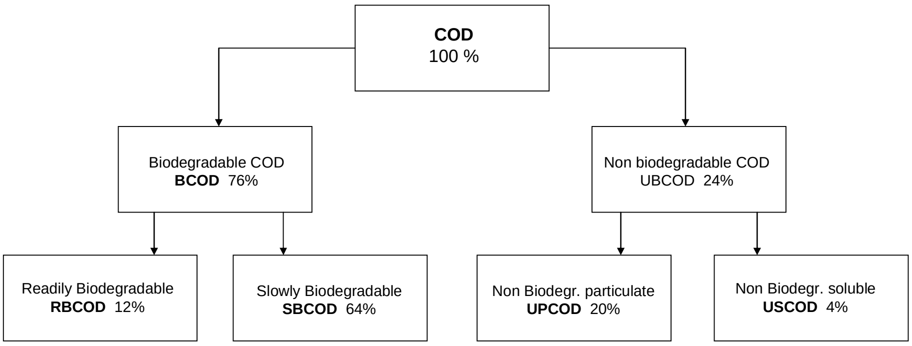
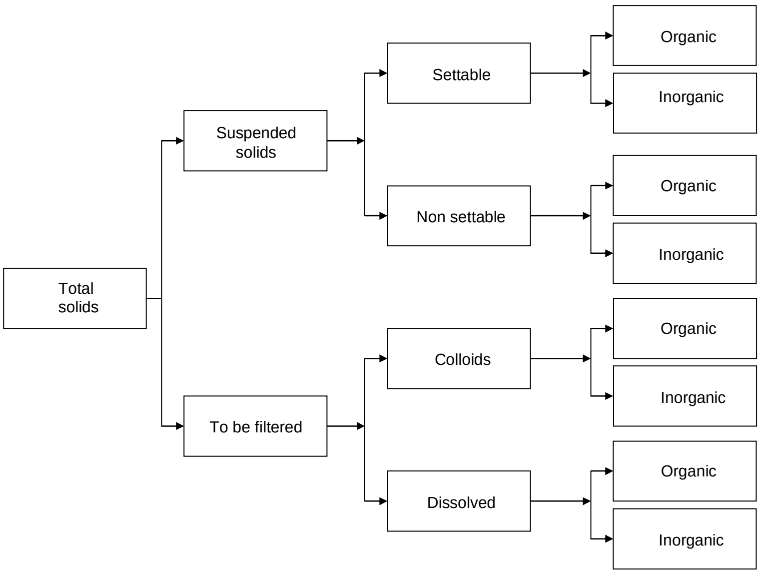


Figure V.2 *– Types of solids in the WW*



V.1 Biological processes: denitrification, nitrification and oxidation

After the primary treatments the WW is sent to the denitrification process for Nitrogen removal and to the biological nitrification-oxidation phase for the removal of dissolved and colloidal organic materials. With the primary treatment we remove suspended solids according to physical processes like sedimentation due to gravity and uprising with floatation. Remaining organic materials are removed till the concentrations allowed for the discharge limits are satisfied in the biological treatment section.

Microorganisms follow a growth path according to the following five phases (Masotti, 1999; Metlcalf & Eddy, 2010): adaptation phase; lag phase; log phase; maturation phase; endogenous phase.

According to the ratio F/M = food/mass (Masotti, 1999), the biological system can be classified in different ways:

- WWTP with high organic load;

- WWTP with low organic load.

Extended aeration (total oxidation) plants
In these plants no primary sedimentation is designed and the hydraulic retention time (HRT) is very high. In this condition the re-circulated sludge undergoes an aerobic digestion (stabilization) or mineralization. In this type of plant the sludge stabilization is performed at the same time of the aeration phase (Masotti, 1999). We define the **organic load factor** (Masotti, 1999) as:

$$F_c = \frac{f}{m*t}$$

Eq. 12: Organic load factor

where f/t is the food flow and m the mass of microorganism (heteotrophic organisms).

Moreover we define (Masotti, 1999):

$$F_c* = \frac{F}{M*t}$$ F_c* (kg BOD_5/kg SSVxd).

Eq. 13: Organic load factor according to SSV

M* is the mass of total volatile suspended solids. We can assume a mean ratio of volatile and total SS for low load phase as 0.7: F_c = 0.7 F_c* (Masotti, 1999). The organic sludge production aims to make possible the sedimentation of organic load (dissolved and colloidal) in order to remove it with a sedimentation process (secondary sedimentation). We have to choose the value of F_c in order to produce a biological sludge with better sedimentation characteristics.

The F/M typical values from literature are reported in **tab. V.1**. If a plant is located in the first case (extended aeration) ther are high retention times and high volumes.

Table V.1 *– F/M typical values and ranges*

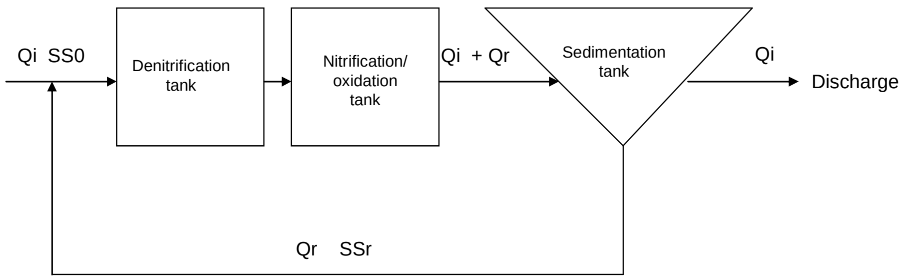
Biological process	***Typical values***	***range***
Extended aeration	**0.075**	(0.06÷0.09)
Nitrification (according T)	**0.15**	(0.12÷0.18)
Carbon removal only (h =85-90%)	**0.25**	(0.2÷0.35)

The choice of the **organic sludge load** (Vismara & Butelli, 1999) determines in which bacteria growing phase is located the plant: high values shows big availability of organic substance with reference to the biomass and therefore a quick growing of the active sludge; low values shows limited availability of organic substance which is highly stabilized. The obtainable depuration efficincy is tied to the sludge load: the higher efficacies are obtained with the lower values of the organic load. According to the value of the adopted F_c there are different types of processes as indicated in **tab. V.2**. In **fig. V.3** the extended aeratoion plant scheme is reported.

***Table V.2** – Bilogical depuration processes at different values of the sludge organic load*

F_c value	Process type	Process description
F_c < 0,08	Sludge stabilization (extended oxidation)	Non putrescibile excess sludge Nitrification with very high performances
0,08< F_c <0,15	Low load	Nitrification with very high performances
0,15< F_c <0,3	Middle load	Oxidative processes
F_c >0,3	High load	Enhanced oxidative processes

***Figure V.3** – Extended aeration plant*



The sludge sedimentation characteristics can be measured with the SVI (*sludge volume index*):
SVI = % of volume of settable sludge (cm^3/1000 cm^3)/% of weight of the dried residual (g/1000 cm^3).
Eq. 14: Sludge Volume Index

The parameters to be regulated for the biological process are the *sludge recirculation*, the *HRT* in order to control the MLSS concentration and the *sludge age*:

Sludge age = E = M/ΔX = whole sludge quantity (g SS)/g SS produced*d
Eq. 15: Sludge age

$$E = \frac{V * C_a}{Q_s * C_s}$$

Eq. 16: Sludge age and concentrations

where:
V = volume of the aeration tank
Q_s = flow of the excess sludge recirculated
C_s = concentration of solids in the recirculated sludged
C_a = concentration in the aerated WW.

We assume the mixed liquor sludge concentration in the range 3-5 mg/l (kg/m^3); with values higher than 5 the sludge has settling problems; with values lower than 2 there are problems with foam production. In the plant design we start with fixing the F_c value; from F_c we have the indications of the type of plant we choose (see **tab. V.4**). For C_a we choose 4 mg/l and the Kozani WWTP Fc value is 0.075. When C_a and F_c are fixed the Cr is influenced by the C_a value.

V.2 Predenitrification

As represented a predenitrification process is performed just after primary treatment and directly before nitrification and oxidation in order to guarantee the availability of a high organic content as denitrificatioin bacteria are heterotrophic organisms that require anoxic conditions; in aerobic conditions the aerobic microorganisms are favoured and the denitrification cannot start (Metcalf & Eddy, 2010). In biological plant sizing the ratio COD/BOD and BOD/TKN (or COD/TKN) are reference parameters. In denitrification it is necessary an entering organic load to remove Nitrogen according to the specific microorganisms that make the process possible. According to literature data (Metcalf & Eddy, 2010) we assume:

- 3 kg BOD_5/kg($N\text{-}NO_3$)DEN when sizing oxidation;
- 4 kg BOD_5/kg($N\text{-}NO_3$)DEN when sizing post-denitrification.

The **Nitrogen balance** can be represented as:

$$TKN_{IN}+(N\text{-}NO_2)_{in}+(N\text{-}NO_3)_{IN} = TKN_{SED}+(N\text{-}NO_3)_{DEN}+TKN_{OX}+TKN_{OUT}+(N\text{-}NO_2)_{OUT}+(N\text{-}NO_3)_{OUT}$$

Eq. 17: Nitrogen balance

where:

TKN_{IN} = inlet Nitrogen (organic and ammonia);
$(N\text{-}NO_2)_{IN}$ = inlet Nitrogen (nitrite); generally absent;
$(N\text{-}NO_3)_{IN}$ = inlet Nitrogen (nitrate); present only in industrial wastewater;
TKN_{SED} = organic Nitrogen removed in primary sedimentation: 10÷15% TKN_{IN};
$TKN_{IN}(N\text{-}NO_3)_{DEN}$ = nitrogen to remove by denitrification;
TKNox = TKN removed by bacterial metabolism (5% BOD removed in biological treatment = 0.05 ($BOD_{IN\ DEN}$ – BOD_{OUT});
TKN_{OUT} = outflow Nitrogen (organic ed ammonia) - assume: 1 mg/l;
$(N\text{-}NO_2)_{OUT}$ = outflow Nitrogen (nitrite) – negligible;
$(N\text{-}NO_3)_{OUT}$ = outflow Nitrogen (nitrate) - project requirement(10÷15 mg/l).

Normally it is not possible to find at the same time significant values of $(N\text{-}NH_3)_{OUT}$ and of $(N\text{-}NO_3)_{OUT}$. For municipal effluents the denitrification velocity can be calculated with the following formula:

$$(v_D)_T = (v_D)_{20} * \theta^{T-20}$$

Eq. 18: Denitrification velocity

where:

$(v_D)_T$ [g $N\text{-}NO_3$/kgVSS*d] = Denitrification velocity:actual operative conditions (temperature = T);
$(v_D)_{20}$ [g $N\text{-}NO_3$/kgVSS*d] = Denitrification velocity: max value at T = 20 °C, without any limiting factor;
θ = Temperature correction coefficient (higher value, higher T dependence)

Moreover for the denitrification process the velocity, detailing the $(v_D)_{20}$ factor, is given by the following expression:

$$v_{den}(T) = v_{max}' \frac{S_n}{k_n + S_n} \frac{S_c}{k_c + S_c} \theta^{(T-20)}$$

Eq. 19: Denitrification velocity

The values of the denitrification process paremeters are detailed in **tab. V.3**.

Tab. V.3 *– Denitrification parameters (Vismara & Butelli, 1999)*

Process parameter	Symbol	Measure Unit	Value	Reference
Max denitrification velocity	$(\nu_D)_{20}$	g $N\text{-}NO_3$/kg VSS*d	**80 ÷100**	Ekama - Beccari
Temperature correction factor	θ	-	**1.06 ÷ 1.08** **1.06 ÷ 1.1**	Ekama – Beccari Vismara - Butelli

For the denitrification volume the following calculation has been used:

$$V = \frac{(N - NO_3)_{DEN}}{(\nu_D)_T * X}$$

Eq. 20: Denitrification tank volume

where:

V [m^3] = minimum design denitrification volume

T [°C] = minimum design temperature

$(N\text{-}NO_3)_{DEN}$ [kg $N\text{-}NO_3$/d] = nitrogen to remove by denitrification

X [kg SSV/m^3] = Volatile Suspended Solids concentration in biological basins (Denitrification – Nitrification)

Considering active sludge recirculation, after the nitrification section, the mixed liquor to recycle can be calculated as:

$$Q_{ML} = \frac{1000 * (N - NO_3)_{DEN}}{24 * (N - NO_3)_{OUT}} * Q_R$$

Eq. 21: Mixed liquor to recycle

where:

Q_{ML} [m^3/h] = flowrate of recirculated Mixed Liquor

Q_R [m^3/h] = return sludge flowrate

$(N\text{-}NO_3)_{DEN}$ [kg $N\text{-}NO_3$/d] = nitrogen to remove by denitrification

$(N\text{-}NO_3)_{OUT}$ [g/m^3] = concentration of nitrogen in outlet stream (design value)

1000 = conversion factor (kg $\rightarrow$ g)

24 = conversion factor (d $\rightarrow$ h)

It must be observed that from literature and experimental activities it can be useful to assure a minimum residential time of 3÷4 h at the maximum flow, to give to mixed liquor enough time to reduce its O_2 content (DO concentration of 0.5 mg/l reduce denitrification efficiency to 10%).

V.3 Nitrification and oxidation processes

For the nitrification process the velocity can be calculated from the following equation (Vismara & Butelli, 1999):

$$v_{nitr}(T) = v_{\max} \frac{S_n}{k_n + S_n} \frac{DO}{k_0 + DO} \theta^{(T-20)} [1 - 0.833(7 - 2pH)]$$ (Vismara & Butelli, 1999)

Eq. 22: Nitrification velocity with temperature and pH

Normally the factor that takes care of the pH is considered equal to 1. The S_n represents the TKN. The relationship takes care of the temperature and the pH too.

$$(v_n) = (\bar{v}_n)_{20} \frac{TKN}{k_{TKN} + TKN} * \frac{DO}{k_0 + DO} \theta^{T-20}$$ (Scaunich, University lecture slides, 2011)

Eq. 23: Nitrification velocity with temperature

The reference data for the parameters of the previous equations are reported in **tab. V.4**.

Table V.4 *– Nitrification process data*

Symbol	Measure Unit	Value at 20 °C	Refrence
$\bar{v}_n$	g TKN/kg SSV*d	5000	Bonomo (2008)
k_0	mg O_2/l	0.4	Andreottola (2005)
k_{TKN}	mg TKN/l	1	Bonomo (2008, Andreottola (2005)
TKN	mg TKN/l	1	-
D.O.	mg O_2/l	2	-
θ	l	1.12	Bonomo (1983), Andreottola (2005)

where:

$(v_n)_T$ = Nitrification velocity: actual operative conditions (temperature = T [gTKN/kgSSV/d];

$(v_n)_{20}$ = Nitrification velocity: max value at T = 20 °C, without any limiting factor; [gTKN/kgSSV/d];

q = Temperature correction coefficient;

k_{TKN}, K_O = semisaturation constants, relating to TKN and DO [mg/l];

TKN, O.D.= TKN and Oxygen concentrations in biological basins [mg/l]

The **nitrification bacteria fraction** is given by the following expression:

$$f = \frac{1}{1 + \frac{y * (S_0 - S_e)}{y_N * (TKN_0 - TKN_e)}}$$

Eq. 24: Nitrification bacteria fraction

where:

y_N = nitrificant bacteria cellular yield coefficient [kgSSV/kg/TKN]

y = heterotrophic bacteria cellular yield coefficient [gSSV/gBOD]

S_0 = inlet organic matter [mg/l]

S_e = outlet organic matter [mg/l]

TKN_0 = inlet TKN [mg/l]

TKN_e = outlet TKN [mg/l]

y/y_N = 4.72 (Bonomo, 2008)

For the calculation of the nitrification volume we use the following expression:

$$V = \frac{X_n}{x}$$

Eq. 25: Nitrification volume

and:

$$X_n = \frac{Q * [TKN_0 - TKN_e - 0.05 * (S_0 - S_e)]}{f * (\nu_n)_T}$$

Eq. 26: Total nitrificant bacteria

where:

x = Total Suspended Solids concentration in biological basins [kg SST/m^3]

X_N = Total nitrificant bacteria in nitrification basins [kg SST]

Oxidation design and return sludge flowrate

The MLSS in the aeration tank is not arbitrary or casual; it is established and regulated according to the required sedimentation characteristics of the sludge.

The maximum concentration of the sludge in the aeration tank is regulated with the maximum concentration of solids in the recirculated sludge and with the recirculation flow. For calculation the mass balance is essential. For the aerated tank the **mass balance** is:

$$(Q_r + Q_i) * MLSS = Q_r * SS_r$$

Eq. 27: Mass balance in the depuration biological process

where:

Q_i = flow of the entering WW.

Q_r = recirculated flow.

SS_0 = entering concentration.

MLSS = SS concentration in the aeration tank.

SS_r = SS concentration in recirculated sludge.

and therefore:

$$MLSS = \frac{Q_i * SS_r}{Q_i + Q_r}$$

Eq. 28: Sludge concentration

The calculation of the **return sludge flowrate** is made with the following equation:

$$Q_r = \frac{Q * x}{x_r - x}$$

Eq. 29: Return sludge flowrate

where:

x_r = Total Suspended Solids concentration in return sludge [kg TSS/m^3]

The **sludge volume** can be determined with the Imhoff cone:

$$\left(Q+Q_r\right)*V_a=Q_r*V_r$$

Eq. 30: Mass balance with volumes.

In the aeration tank the food/mass ratio is:

$$\frac{F}{M}=\frac{S_0*Q}{V*X}=\frac{S_0}{HRT*X}$$

Eq. 31: Food/Sludge ratio

The **hydraulic retention time** is:

HRT = V/Q

Eq. 32: Hydraulic Ritention time

SRT = sludge age = $\dfrac{V*X}{[(Q_s*X_s)+(Q_e*X_e)]}$

Eq. 33: Sludge Ritention Time

where:

Q_e = exiting flow.

Q_s = flow from sedimentation tank.

Moreover (Vismara & Butelli, 1999) the volume of the biological treatment tank is given by:

$$V=\frac{Q_i*S_0}{F_c*MLSS}\ \text{m}^3$$

Eq. 34: Volume of the aeration tank

$$F_c=\frac{Q_i*S_0}{V*MLSS}\ \text{(kg BOD}_5\text{/kg SS*d)}$$

Eq. 35: The organic load factor

where:

V = volume of the aeration tank (m^3).

Q_i = entering flow (m_3/d).

S_0 = mean concentration opf the biodegradable entering WW (kg BOD_5/m_3).

F_c = organic load factor (kg BOD_5/kg SS*d).

MLSS = active sludge conc. (kg SS/m^3).

For the oxidation preliminary sizing, the **volume of the nitrification-oxidation tank** can be calculated as:

$$V=\frac{BOD_{IN}}{X*F/M}$$

Eq. 36: Nitrification-Oxidation dimensioning

where:

BOD_{IN} [kg BOD_5/d] = Inlet BOD_5, coming from Denitrification;

X [kg SST/m3] = Total Suspended Solids concentration in biological basins (Denitrification – Nitrification); values = 4÷6;
SSV/SST = Organic fraction: typical = 0.7;
F/M [kg BOD/kg SST*d] = Ratio Food/Mass.

We can estimate the excess sludge production as follows:

$\Delta X = [(aF - bM_d) + S_i] - xS_{tot}$
Eq. 37: Excess sludge production

where:
ΔX = daily excess sludge
F = food, that is BOD_5 entering the system (kg BOD_5/d).
a = coefficient for sludge synthesis.
M_d = total mass of microorganisms present in the system (kg SST or SSV).
b = coefficient of endogenous respiration (t^{-1}).
S_i = mass of inert solids entering the system (kg/d).
S_{tot} = mass of total solids entering the system (kg/d).
x = fraction of S_{tot} escaping the system.

Oxygen need is given from the following equation:

$O = I + a'F_a + b'M_d + 4.6*mNH_3$ (N)
Eq. 38: Oxygen demand

The Oxygen need for the carbonaceous fraction is:

$F_o = O/F_a$ kg O_2/kg BOD_5
Eq. 39: Oxygen need

F_a is the transformed organic substance eliminated in the plant from the water and expressed as kg BOD_5. We can distinguish according to the aeration and organic load the factors F_0 as in **tab. V.5**. The designed plant is located in the second range (total depuration with nitrification). The lower is the organic load F_c the higher is the Oxygen quantity to be supplied, that is the higher is the sludge age. The higher is the sludge age and the lower is F_c, the higher is the oxidation degree of the entering organic substances.

Tab. V.5 *– F_0 factor value*

Type of plant	F_o = OC/Load kg OC/kg BOD_5
Prolonged aeration (sludge mineralization)	2.0 – 2.5
Total depuration with nitrification	1.8 – 2.5
Total depuration	1.2 – 2
Partial depuration	1 or < 1

The oxygen need is expressed by the **actual oxygen requirements** (AOR) and the **standard oxygen requirements** (SOR) as follows:

$$AOR = a*Q*(S_0 - S_e) + b*V*x + 4.57*N_{to\_nitrificate}$$ [kg O_2/d]

Eq. 40: Actual Oxygen Requirement

where:
a = Carbon removal coefficient = 0.5 kg O_2/kg BOD_5
b = Endogenous respiration coefficient = 0.08 kg O_2/kg SST/d
N to remove in nitrification [kgN-NH_4/d]
Oxygen recovery = 2.86 kg O_2/kg N_{DEN}

The relationship between SOR and AOR is given as follows:

$$\frac{SOR}{AOR} = \frac{1}{\alpha \bullet \frac{\left[\left(\beta \bullet C_{s,T} - C_{w,T}\right)\right]}{C_s^*} \bullet 1,024^{T-20}} \qquad SOR = AOR \bullet \left\{ \max\left[\frac{SOR}{AOR}\right]_{T\max}, \left[\frac{SOR}{AOR}\right]_{T\min} \right\}, \text{ [kgO2/d]}$$

Eq. 41: SOR and AOR

where:
α = ratio between the transferring coefficient for real liquid at 20 °C and that of standard conditions fixed at 0.7;
β = ratio between the oxygen concentration at saturation in the real liquid in operating conditions and that in clean water in exercise conditions;
$C_{s,T}$ = concentration of oxygen at saturation in clean water at the opeative conditions at temperature T;
$C_{w,T}$ = concentration of oxygen in the real liquid at the operative conditions, fixed as 2 mg/l;
C_s* = saturation concentration in clean water in standard conditions (20 °C);
T = exercise temperature.

The **air demand** is:

$$Q_{air} = \frac{SOR}{24 * 0.28 * \eta} \text{ [m}^3\text{/h]}$$

Eq. 42: Air demand

where:
24 = 24 hours (1 day);
0.28 = kg O_2/m^3 air in standard conditions (20°C – 0 m a.s.l.);
η = transfer efficiency O_2 = 5%/m depth.

The **excess sludge flowrate** to be sent to sedimentation is calculated from:

$$Q_S = Q_{S,OX} + Q_{S,DEN}$$

Eq. 43: Excess sludge

$$Q_{S,OX} = 0.75 \frac{kgTSS}{kgBODrim} * BOD_{to\_remove\_in\_ox}$$

Eq. 44: Excess sludge from oxidation

$$Q_{S,OXtot} = 0.6 \frac{kgTSS}{kgBODrim} * BOD_{to\_remove\_in\_ox\_tot}$$

Eq. 45: exess sludge from total oxidation

$$Q_{S,DEN} = 0.3 \frac{kgTSS}{kgBODrim} * BOD_{to\_remove\_in\_DEN}$$

Eq. 46: Excess sludge from denitrification

V.4 Secondary sedimentation

In a WWTP with activated sludge the sedimentation tank is necessary for the separation of the liquid phase which will overflow as water after treatment and the biological sludges, which are recovered on the bottom of the sedimentation tank. Sedimentation has the following functions: cleaning function; sludge thickening function; storage of transferred sludges because of peak flows.
Activated sludges are characterized with behaviour typical of floating flakes; the flakes have the tendency to aggregate in larger and havier ones; the sedimentation characteristics are:

- sludge volume;
- sludge volume index;
- settling velocity.

Among the settling tanks available in technical literature we can remember: circular and rectangular settlers; among the circular settlers we can remember: upflowing settler (Dortmund type, Candy type, Spaulding type, Centrifloc type) radial flow settler, horizontal settler (Masotti, 1999; Metcalf & Eddy, 2010). For the process control the Hazen theory is applied (Bianucci & Ribaldone, 1998). For the Kozani WWTP we propose the realization of two circular sedimentation tanks of the same type and volume. The bottom is realized horizontally and this solution reduces the turbulence and the consequent resuspention phenomena. The height of the top of the walls (with a free space from the max WW free surface level inside) must be at maximum be 1.4 m out of earth level in order to allow the technical personnel of the plant to see inside for a visual verification of the plant. In fact problems of bulking, rising, pin-point and foaming are particularly evident in the secondary sedimentation tank, considered the most vulnerable part of the WWTP.

The dimensioning criteria of the sedimentation tank are the following:

- **C_i**: hydraulic surface load (m^3/m^2*h);
- **C_s**: solid materials surface load (kg SS/m^2*l);
- **F**: overflow from weirs (m^3/m*h);
- **H**: height of the tank (m).

The **hydraulic load** is calculated from:

$$C_i = \frac{Q_i}{A}$$

Eq. 47: Hydraulic load

The solid material **surface load** is given by:

$$C_S = \frac{(Q_i + Q_r)_{MLSS}}{A}$$

Eq. 48: Solid material surface load

The **weir overflow** (portata allo stramazzo) is:

$$F = \frac{Q_i}{L}$$

Eq. 49: Weir overflow

where:

Q_i = overflow without ricirculation (m^3/d)
L = length of the overflow.

The sedimentation process is governed by the Stokes' law:

$$v_s = \frac{g * (\rho_s - \rho) * d^2}{18 * 10^6 * \mu}$$

Eq. 50: Stokes' law

where:

v_s = sedimentation velocity (m/s);

ρ_s = density of the solid particles (kg/m^3);

d = particle dimensions (mm);

μ = water viscosity.

In **tab. V.6** the details of the sedimentation tank (Masotti, 1999, Metcalf & Eddy, 2010).

Tab. V.6 *– Secondary sedimentation design details*

Parameter	Symbol	Value – Range	Data
Hudraulic head	C_i = Q/A	0.2 – 0.3	Q (m^3/h), flowrate A (m^2), area
Solid load (kg SST /m^2*d)	C_s = G/A	< 5 at Q_{24} < 9 at Q_{max}	G (kg SST/d), solid flowrate = 2.5Q_r*X X (kg SST/m^3), activated sludge concentration Q_r (m^3/h), return sludge flowrate = 1 – 1.5*Q_{24}
Height (m)	≥ 3m		
Bridge	Suction bridge		

Annex VI: Functionality verification and discharge control delegation procedure

VI.1 The WWTP control protocol and functionality verification

The protocol (PCFP) of the WWTPs' control has been prepared by an ARPAV inter-departmental working group of experts; the document has been subjected to the assessment of the experts from all of the provinces of the Veneto region; subsequently the document has been applied to WWTPs for an experimental campaign in all ARPAV Provincial Departments. In this document specific parameters and conditions have been used to distinguish the application field of the different controls, and are detailed as follows:

- WWTPs potentiality class (annex 5 Italian Decree n. 152/2006);
- possible type of treated waste (in case of treatment from a third subjects; dangerous and non-dangerous waste);
- plants which are subject, or not, to the IPPC Directive 96/61/EC (it depends on the waste treatment by the same plant);
- operative phases: test and ordinary phase.

To determine modalities (documentary, technical, management controls) and frequencies of control, the following aspects have to be considered: the potentiality class of the WWTP (annex 5 Italian Decree n. 152/2006, in application of the Directive 91/271/EEC); the control activities without delegation (control performed by ARPAV) or with control delegation (self-monitoring of WWTP manager according to specific conditions and methodologies).

Therefore, on the basis of the present legal and methodological framework, the protocol takes into consideration four typologies of WWTPs classified with potentiality: 1) < 2000 EI; 2) ≥ 2000 EI and < 10000 EI; 3) ≥ 10000 EI without control delegation; 4) ≥ 10000 EI with control delegation.

The control is performed by:

- compiling the control check-list;
- compiling the synthetic schedule regarding compliance and omission, giving full motivation according to the assessment;
- compiling the minutes of the inspection visit and providing the samples (where applicable);
- discharge sampling and where there are other matrices (wastes, sludge) the consequent analytic determination.

The documentary, technical and management controls must be performed with a prefixed frequency, in relation to the complexity of the WWTPs. For WWTPs with a potentiality of < 2000 EI, documental and a technical control (plant functioning and structures control) is sufficient once every 4 years; on the other hand the verification of the management system due to the plant dimension is not necessary. The frequency of controls progressively increases to one control per year as a function of the plant potentiality for all of the three control typologies (analytic control excluded).

The Italian technical regulation (Annex 5 of the Italian Decree n. 152/2006) fixes the minimum number of samples for the parameters COD, BOD_5, SS, N_{tot} and P_{tot} according to the plant dimension (potentiality in EI). The samples must be made by the competent Authority or by the plant manager guaranteeing data reports and a transmission system of samples to the Control Authority at regular time intervals during the year.

The *documentary control* considers the authorization and the organization framework of the plant with reference to the sector regulations, the discharge limits and of the presence, compliance and updating of the technical and administrative documents in the plant.

The *technical control* is performed through:

- assessment of technical data gathered with the manager's report (input loads, plant potentiality, energy and resource consumption, characteristics of the discharged wastewaters, waste treatment for other external subjects) and the documentary control;
- technical visit (evident problems discovered; malfunctioning; process parameters).

The *management control* is conducted by verifying managerial procedures (audit) performed by the plant manager regarding: control of depuration process, control of industrial discharges received by the plant through the sewer pipe, controls in case of liquid waste received by the plant, control of the produced sludge, self-certification of maintenance, environmental management and quality assurance systems.

Where part of the analytical controls are delegated to the WWTP manager, the following conditions must be applied:

1. the delegation is considered, in the first instance as possible only for WWTPs with potentiality ≥ 10000 PE;
2. the frequency of technical and management controls is increased;
3. **t**he environmental protection Agency must guarantee a number of samples for the analysis of the parameters COD, BOD_5, SS (table 1 Annex 5 Italian Decree n. 152/2006), N_{tot} and P_{tot} (table 2 Annex 5) equal to the minimum amount of frequencies stipulated for verifications of table 3 (chemical parameters) of Annex 5 of Decree n. 152/2006, as the delegation of control of the tab. 3 parameters is not allowed by law.

For public WWTPs the preparation of the Protocol PCFP in the hierarchical assessment of environmental controls according to legal obligations (minimum compulsory frequencies) concluded with the proposed approach for WWTPs with the two scenarios "without delegation" and "with delegation" reported in **tabs VI.1** and **VI.2**.

In Fig. 6 the framework of the executed controls on WWTP is reported (year 2007) and is distributed according to the typology (documentary, technical, management and analytic controls) at both regional and provincial level, according to the potentiality.

Table VI.1 *Frequencies of documentary, technical, management and analytic controls of WWTPs in the scenario without control delegation*

Eq. Inhabitants		Type and frequency control (number/year)						
					Analytic			
		Documentary	Technical	Management	discharges tabs 1 and 2 (ann. 5)	discharges tab. 3 (ann. 5) or PTA	sludges	RADIOACTIVITY ON WASTEWATERS and on sludges
< 2.000*		0.25^	0.25	-	0.5^^	0.5	-	-
2.000 - 10.000		1	0.25	0.25	4 (+10%)	1	if requested	-
≥ 10.000	**10.000 – 50.000**	1	0.25	0.25	12	3	0.5	12
	≥ 50.000				24	6	1	

* priority is given to WWTPs with potentiality > S, dimensional threshold indicated in the *Water Protection Plan* (PTA) corresponding to the number of inhabitants for each specific zone in which the Veneto region is divided.
^ 0.25= 1 control/4 years.
^^ 0.5= 1 control/2 years.

VI.2 Proposal of a procedure for discharge control delegation to plant managers

The choice of the plants where controls may be delegated is under the competence of the Province. This is done on the basis of the identification made by the Provincial Department of the Regional Environmental Protection Agency according to the available information on these plants, the territory, the processes held by the plant and the problems connected to the plant. More specifically, it refers to the following aspects:

- reliability in respecting discharge limit values on the basis of the past data (information regarding the history of the discharge quality of the WWTP, overtaking of limit values fixed by law, etc.);
- good structural and management functionality of the WWTP (through the functionality verification);
- the availability of an effective support laboratory with quality assurance;
- the existence of an authorized data transmission system from the plant's manager to the Province and to the Regional Environmental Agency.

Table VI.2 *Frequencies of documentary, technical, management and analytic controls of WWTPs in the scenario with control delegation*

<table>
<tr><th rowspan="3" colspan="2">Eq. Inhabitants</th><th colspan="7">Type and frequency control (number/year)</th></tr>
<tr><th rowspan="2">Documentary</th><th rowspan="2">Technical</th><th rowspan="2">Management</th><th colspan="4">Analytic</th></tr>
<tr><th>discharges tabs 1 and 2 (ann. 5)</th><th>discharges tab. 3 (ann. 5) or PTA</th><th>sludges</th><th>RADIOACTIVITY ON WASTEWATERS AND ON SLUDGES</th></tr>
<tr><td colspan="2">< 2.000*</td><td>0.25^</td><td>0.25</td><td>-</td><td>0.5</td><td>0.5^^</td><td>-</td><td>-</td></tr>
<tr><td colspan="2">2.000 - 10.000</td><td>1</td><td>0.25</td><td>0.25</td><td>4 (+10%)</td><td>1</td><td>if requested</td><td>-</td></tr>
<tr><td rowspan="2">≥ 10.000</td><td>10.000 – 50.000</td><td rowspan="2">1</td><td rowspan="2">1</td><td rowspan="2">1</td><td colspan="2">3</td><td>0.5</td><td rowspan="2">to be assessed</td></tr>
<tr><td>≥ 50.000</td><td colspan="2">6</td><td>1</td></tr>
</table>

* priority is given to WWTPs with potentiality > S. dimensional threshold indicated in the *Water Protection Plan* (PTA) corresponding to the number of inhabitants for each specific zone in which the Veneto region is divided.
^ 0.25= 1 control/4 years.
^^ 0.5= 1 control/2 years.

On the basis of the protocol, a procedure for the delegation of discharge controls was proposed comprehensive of the documentary, technical, management and analytical controls and of the functionality verification, according to the following phases:

- the Regional Environmental Agency, in accordance with the competent provincial Administration (responsible for the discharge authorization), plans and carries out the integrated controls to be executed on the WWTPs, according to the procedures and frequencies established in the control protocol, annually, using the *operative check-list* prepared for this purpose;
- at the same time the functional assessment is carried out on some plants of potentiality ≥ 10000 EI;
- to ensure the completion of the previous points, the Agency analyses the WWTPs using data supplied from the Environmental Regional Informative System (SIRAV in Veneto region); the control data on the discharge must refer to a period of at least two years (in one year there can be no regular trends), with monthly or with higher frequency sampling carried out by the control Authority or by the plant manager (provided that they are made with the same modalities and with a sample mean and weighted on 24 hours). The data assessment must allow, when the limit values are significantly overtaken, to understand the reasons for this, and where appropriate, corrective interventions must be adopted to avoid repetition of the phenomenon. No specific criteria of assessment are given as this comprehensive assessment must be carried out by the Province and the Provincial Department of the Environmental Agency, who have the past knowledge regarding the plants;
- the Regional Environmental Protection Agency assesses the suitability of the laboratory (for the delegated controls) on the basis of the quality assurance procedure followed, and of the sampling and analysis methods, which should be used for the legal controls;
- when the plants considered suitable for control delegation are identified, it is possible to subscribe an agreement between the Province, the Regional Environmental Protection Agency and the plant manager’s company in order to regulate the execution of the delegated controls with the indication of the procedures, and the frequency of samples, the analytical aspects, the reference laboratory and the data transmission system for self-monitoring results;
- beyond the legal analytical controls, which must be performed on the delegated plants, the Regional Environmental Protection Agency must carry out documental, technical and management controls and verify the plant functionality annually.

Annex VII: Functionality verification sheets for chosen set of WWTPs

For the selected set of WWTP the functionality verifications have been performed and are here below reported (n. 7 plants: n. 6 in the Province of Venice – Fusina, Jesolo, Eraclea mare, San Donà di Piave, Musile di Piave, Caorle; n. 1 in the Province of Treviso – Paese).

Legenda:	
(pink)	Data recovered from the sheets of functionality verification (field data)
(light blue)	Values assumed for the theoretical functionality verification
(orange)	Values already assumed in previous control activities
(white)	Calculated values
(yellow)	Values already calculated and here recalled and re-used

VII.1. Caorle WWTP

Theoretical verification at the mean received loads and mass balances	**Unit of measure (U.M.)**	**Values**
Estimation of the received loads to the WWTP		
Hydraulic Population Equivalents (civil + industrial)	PE	79945
Organic Population Equivalents (civil + industrial)	PE	70085
Hydraulic specific load	l/PE*d	200.0
Organic specific load	$gBOD_5/PE*d$	60.0
Daily hydraulic mean load	**m^3/d**	**15989**
Mean flow (Q_m)	m^3/h	666
Peak flow ($Q_p = 1.5*Q_m$)	m^3/h	999
Max flow ($Q_{max} = 2*Q_m$)	m^3/h	1332
Mean BOD_5 IN load	**$gBOD_5/m^3$**	**263**
Organic load (BOD_5)	$kgBOD_5/d$	4205
Mean COD IN concentration	**$gCOD/m^3$**	**553**
Organic load (COD)	kgCOD/d	8842
Mean SS IN concentration	**gSS/m^3**	**360**
Suspended solids load (SS)	kgSS/d	5756
Mean TKN IN concentration	**gN/m^3**	**48**
TKN load	kgN/d	767
Mean concentration of NO_3^- IN	**gN/m^3**	**0**
Nitric Nitrogen load	kgN/d	0
Mean P IN concentration	**gP/m^3**	**8.8**
P load	kgP/d	141
Organic matter load balance		
Organic load	$kgBOD_5/d$	4205
% abatement of BOD_5 in the primary sedimentation unit	%	10
BOD_5 removed in the primary sedimentation unit	$kgBOD_5/d$	421
BOD_5 IN at secondary treatment units	$kgBOD_5/d$	3785
BOD_5 concentration at the final discharge	$gBOD_5/m^3$	15
BOD_5 load at the final discharge	$kgBOD_5/d$	240
BOD_5 abatement in the secondary treatment unit (ΔBOD_5)	$kgBOD_5/d$	3545
Efficiency of the secondary treatment for BOD_5	%	94

Nitrogen mass balance

TKN load	kgN/d	767
N nitric load entering the WWTP	kgN/d	0
TKN abatement in the primary sedimentation unit	%	7.5
TKN abatement in the primary sedimentation unit	kgN/d	57.56
TKN entering the secondary treatment	kgN/d	710
N-NH4 concentration in the final discharge	gN/m^3	1
N-NH4 load in the final discharge	kgN/d	15.99
N-NO3 concentration in the final discharge	gN/m^3	6,9
N-NO3 load in the final discharge azoto nitrico allo scarico	kgN/d	110.32
N-NO2 concentration in the final discharge	gN/m^3	0.1
N-NO2 load in the final discharge	kgN/d	1.60
Organic N concentration in the final discharge	gN/m^3	2
Organic N load in the final discharge	kgN/d	31.98
N removed with BOD_5	%	4
N removed with BOD_5 (% of BOD_5)	kgN/d	141.79
N to undergo to the nitrification process	kgN/d	518.56
N to undergo to the dnitrification process	kgN/d	408.23
Efficiency of the secondary treatment on N	%	79

Phosphorous mass balance

Total Phosphorous load	kgP/d	141
P removed in the primary sedimentation unit	%	5
P load removed in the primary sedimentation unit	kgP/d	7
P total concentration in the final discharge	gP/m^3	1
P total load at the final discharge	kgP/d	15.99
P removed with BOD_5	%	1
P removed with BOD_5 (% of BOD_5)	kgP/d	35.45
P total to be removed	kgP/d	82.23

Theoretical verification at the mean loads. Functional parameters.	**Unit of measure (U.M.)**	**Values**

Functional parameters of the primary sedimentation station

Number of units	-	2
Diameter	m	14
Height at the periphery	m	2
Useful height	m	2.3
Surface	m^2	981,2
Total volume	m^3	2946.0
Uprising velocy at Q_m	m/h	0.68
Uprising velocity at Q_p	m/h	1.02
Uprising velocity at Q_{max}	m/h	1.36
Retention time at Q_m	min	265
Retention time at Q_p	min	177
Retention time at Q_{max}	min	133
Abatement of BOD_5	%	10
Abatement of TKN	%	7.5
Abatement of P	%	5
Hydraulic load discharged after primary sedimentation (overflow)	m^3/d	

Functional parameters of the pre-de-nitrification station

Hydraulic load entering the secondary treatment unit	m^3/d	15989
Mean flow Q_m	m^3/h	666
Peak flow Q_p	m^3/h	999
Max flow Q_{max}	m^3/h	1332
Organic load IN secondary treatment	$kgBOD_5/d$	3785

Sludge recirculation ratio	-	0,89
Recirculation sludge from secondary sedimentation unit Q_r	m^3/h	592.93
N-NO_3 concentration in the final discharge	gN/m^3	6,9
NO_3 supply with sludge re-circulation	kgN/d	98,19
Re-circulated mixed liquor ratio	-	0.00
Re-circulated mixed liquor flow Q_{ml}	m^3/h	0,00
N-NO_3 concentration in the mixed liquor	gN/m^3	6.9
NO_3 supply with mixed liquor recirculation	kgN/d	0,00
NO_3 supply at pre-denitrification $Q_m + Q_r + Q_{ml}$	kgN/d	98.19
Entering flow at the pre-denitrification with $Q_m + Q_r + Q_{ml}$	m^3/h	1259.13
Number of units or compartments	-	3
Total volume	m^3	2000
Suspended Solids concentration (SS)	$kgSS/m^3$	5,8
VSS/SS	kgSSV/kgSS	0,69
Temperature	°C	15
De-nitrification specific velocity	kgN/kgSSV*d	0,036
Nitrogen to undergo de-nitrification	kgN/d	98.19
De-nitrification capacity of the basin	kgN/d	288.14
Removed N in pre-denitrification	kgN/d	98.19
BOD_5 removed in pre-denitrification	$kgBOD_5/kgN$	2
BOD_5 removed in pre-denitrification	$kgBOD_5/d$	196.38
Retention time	h	1.59
Mixing specific power	W/m^3	10.00

Theoretical verification at the mean loads. Functional parameters.	**Unit of measure (U.M.)**	**Values**
Functional parameters of the biologic oxidation and nitrification station		
Number of units/compartments	-	3
Total volume	m^3	4350
Organic load after pre-denitrification	$kgBOD_5/d$	3588
Volumic load c_V	$kgBOD_5/m^3*d$	0,82
Suspended Solids load (SS)	$kgSS/m^3$	5,8
Sludge load c_F	**$kgBOD_5/kgSS*d$**	**0,14**
Removed BOD_5 (oxidation. + denitr.: ΔBOD_5)	$kgBOD_5/d$	3545
Removed BOD_5 in oxidation	$kgBOD_5/d$	3348
BOD_5 removal (oxidation + de-nitrification)	%	93,7
Growth index	$kgSS/kgBOD_{5,aat}$	0,75
Production of removal (supero) sludges F_S (oxidation + de-nitrification)	kgSS/d	2659
Sludge age	**d**	**9**
Theorethical oxigen demand	kgO_2/d	6567
Exercise temperature	C	15
Saturation concentration	gO_2/m^3	9,8
Oxygen residual concentration	gO_2/m^3	2,4
Effective oxygen request	kgO_2/d	10814
Mean efficiency of the insufflation system	%	16
Air request/need	m^3/d	237993
Oxygenation capacity of blowers	m^3/d	341760
Oxygenation capacity of surface aerators	kgO_2/d	
Nitrification velocity (safe value)	$kgN\text{-}NH_4^+/kgSS*d$	0.05
Nitrification capacity	kgN/d	1262
N to be nitrified	kgN/d	519
N produce in nitrification	kgN/d	519
Retention time	h	3,45

Functional parameters of the post-de-nitrification station

Number of units	-	0
Total volume	m^3	0
Concetration of Suspended Solids (SS)	$kgSS/m^3$	5.8
VSS/SS	kgSSV/kgSS	0.69
Temperature	C	15
De-nitrification specific velocity	kgN/kgSSV*d	0.036
N to be de-nitrified	kgN/d	310,04
De-nitrification capacity of the basin	kgN/d	0.00
N removed in pre-denitrification	kgN/d	0,00
BOD_5 removed in post-denitrification	$kgBOD_5/kgN$	0
BOD_5 removed in post-denitrification	$kgBOD_5/d$	0.00
External supply of readily bio-degradable organic substances	$kgBOD_5/d$	0.00
N associated to the external source of Carbon	kgN/d	0
$N-NO_3$ supply to post-denitrification	kgN/d	420.37
Entering flow to post-denitrification $Q_m + Q_r$	m^3/h	1259.13
Ritention time	h	0.00
Mixing specific power	W/m^3	

Functional parameters for the secondary sedimentation station

Number of units	-	5
Diameter	m	25
Mean depth	m	3
Total surface of the station	m^2	2070
Total volume of the station	m^3	5847
Overflow length	m	393
Hydraulic load at the overflow at Q_m	$m^3/m*h$	1.70
Uprising velocity at Q_m	m/h	0.32
Uprising velocity at Q_p	m/h	0.48
Uprising velocity at Q_{max}	m/h	0.64
Retention time at Q_m	h	8.78
Retention time at Q_p	h	5.85
Retention time at Q_{max}	h	4.39
Recirculation ratio according to influent	-	0.89
Surface load of SS at Q_m	$kgSS/m^2*h$	3.53
SS concentration in the re-circulated flow	$kgSS/m^3$	12.32

Comments:

According to Masotti (1999) the plant can be classified in the present condition as a "**extended aeration**" (total oxidation) plant. With the mean values of the hydraulic daily load (15,989 m^3/d) and organic load (263 $gBOD/m^3$) it can be observed that the hydraulic dimensioning (79,945 PE) can match with the organic dimensioning (70,085 PE).

The organic substances mass balance shows a depurarion efficiency for BOD_5 of 94%, very good if compared with the aspected data from literature of about 85-95%. Lightly lower data (79%) are found for the massa balance of N, in any case satisfactory.

VII.2. Eraclea mare WWTP

This plant has been assessed in the two conditions: high season and low season asset.

Theoretical verification at the mean received loads and mass balances	Unit of measure (U.M.)	Values HIGH SEASON	Values LOW SEASON
Estimation of the received loads to the WWTP			
Hydraulic Population Equivalents	PE	**19725**	**14340**
Organic Population Equivalents	PE	**11506**	**3967**
Nitrogen load Population Equivalents	PE	**17095**	**7648**
Hydraulic specific load	l/PE*d	200.00	200.00
Organic specific load	$gBOD_5/PE*d$	60.00	60.00
Niterogen	gN/PE*d	12.00	12.00
Daily hydraulic mean load	m^3/d	**3945**	**2868**
Mean flow (Q_m)	m^3/h	164	120
Peak flow ($Q_p = 1.5*Q_m$)	m^3/h	247	179
Max flow ($Q_{max} = 2*Q_m$)	m^3/h	329	239
Mean BOD_5 IN load	$gBOD5/m^3$	**175**	**83**
Organic load (BOD_5)	$kgBOD_5/d$	690	238
Mean COD IN concentration	$gCOD/m^3$	**367**	**170**
Organic load (COD)	kgCOD/d	1448	488
Mean SS IN concentration	gSS/m^3	**220**	**120**
Suspended solids load (SS)	kgSS/d	868	344
Mean N Total IN concentration	gN/m^3	**52**	**32**
Ntot load	kgN/d	205	92
Mean concentration of NO_3^- IN	gN/m^3	**0**	**0**
Nitric Nitrogen load	kgN/d	0	0
Mean P IN concentration	gP/m^3	**10**	**10**
P load	kgP/d	39	29
Organic matter load balance			
Organic load	$kgBOD_5/d$	690	238
% abatement of BOD_5 in the primary sedimentation unit*	**%**	**0**	**0**
BOD_5 removed in the primary sedimentation unit*	$kgBOD_5/d$	0	0
BOD_5 IN at secondary treatment units	$kgBOD_5/d$	690	238
BOD_5 concentration at the final discharge	**$gBOD_5/m^3$**	**7**	**5**
BOD_5 load at the final discharge	$kgBOD_5/d$	**28**	**14**
BOD_5 abatement in the secondary treatment unit (ΔBOD_5)	$kgBOD_5/d$	**663**	**224**
Efficiency of the secondary treatment for BOD_5	%	**96**	**94**
Nitrogen mass balance			
TKN load	kgN/d	205	92
N nitric load entering the WWTP	kgN/d	0	0
TKN abatement in the primary sedimentation unit*	**%**	**0**	**0**
TKN abatement in the primary sedimentation unit*	kgN/d	0.00	0.00
TKN entering the secondary treatment	kgN/d	205	92
$N\text{-}NH_4$ concentration in the final discharge	**gN/m^3**	**1.5**	**0.25**
$N\text{-}NH_4$ load in the final discharge	kgN/d	5.92	0.72
$N\text{-}NO_3$ concentration in the final discharge	**gN/m^3**	**14**	**17**
$N\text{-}NO_3$ load in the final discharge azoto nitrico allo scarico	kgN/d	55.23	48.76
$N\text{-}NO_2$ concentration in the final discharge	**gN/m^3**	**0.12**	**0.12**

N-NO_2 load in the final discharge	kgN/d	0.47	0.34
Organic N concentration in the final discharge	**gN/m^3**	**0**	**0**
Organic N load in the final discharge	kgN/d	0.00	0.00
N removed with BOD_5	**%**	**4**	**4**
N removed with BOD_5 (% of □BOD_5)	kgN/d	26.51	8.95
N to undergo to the nitrification process	**kgN/d**	**172.24**	**81.77**
N to undergo to the de-nitrification process	kgN/d	**117.01**	**33.01**
Efficiency of the secondary treatment on N	%	70	46

Phosphorous mass balance

Total Phosphorous load	kgP/d	39	29
P removed in the primary sedimentation unit	%	0	0
P load removed in the primary sedimentation unit	kgP/d	0	0
P total concentration in the final discharge	**gP/m^3**	**0.8**	**0.8**
P total load at the final discharge	kgP/d	3.16	2.29
P removed with BOD_5	**%**	**1**	**1**
P removed with BOD_5 (% of □BOD_5)	kgP/d	6.63	2.24
P total to be removed	kgP/d	**29.67**	**24.15**

Theoretical verification at the mean loads. Functional parameters.	**Unit of measure (U.M.)**		

Functional parameters of the primary sedimentation station* NOT EXISTING

Number of units	-		
Diameter	m		
Height at the periphery	m		
Useful height	m		
Surface	m^2		
Total volume	m^3		
Uprising velocy at Q_m	m/h		
Uprising velocity at Q_p	m/h		
Uprising velocity at Q_{max}	m/h		
Retention time at Q_m	min		
Retention time at Q_p	min		
Retention time at Q_{max}	min		
Abatement of BOD_5	%		
Abatement of TKN	%		
Abatement of P	%		
Hydraulic load discharged after primary sedimentation (overflow)	m^3/d		

Functional parameters of the pre-de-nitrification station

Hydraulic load entering the secondary treatment unit	m^3/d	3945	2868
Mean flow Q_m	m^3/h	164	120
Peak flow Q_p	m^3/h	247	179
Max flow Q_{max}	m^3/h	329	239
Organic load IN secondary treatment	kgBOD_5/d	690	238
Sludge recirculation ratio	**-**	**0.7**	**0.6**
Recirculation sludge from secondary sedimentation unit Q_r	m^3/h	115.06	71.70
N-NO_3 concentration in the final discharge	gN/m^3	14.0	17.0
NO_3 supply with sludge re-circulation	kgN/d	38.66	29.25
Re-circulated mixed liquor ratio	**-**	**0.00**	**0.00**
Re-circulated mixed liquor flow Q_{ml}	m^3/h	0.00	0.00
N-NO_3 concentration in the mixed liquor	gN/m^3	14.0	17.0

NO_3 supply with mixed liquor recirculation	kgN/d	0.00	0.00
NO_3 supply at pre-denitrification $Q_m + Q_r + Q_{ml}$	**kgN/d**	**38.66**	**29.25**
Entering flow at the pre-denitrification with $Q_m + Q_r + Q_{ml}$	m^3/h	279.44	191.20
Number of units or compartments	-	1	1
Total volume	m^3	610	610
Suspended Solids concentration (SS)	$kgSS/m^3$	5	5
VSS/SS	kgSSV/kgSS	0.75	0.75
Temperature	°C	15	15
De-nitrification specific velocity	kgN/kgSSV*d	0.036	0.036
Nitrogen to undergo de-nitrification	**kgN/d**	**38.66**	**29.25**
De-nitrification capacity of the basin	**kgN/d**	**82.35**	**82.35**
Removed N in pre-denitrification	kgN/d	**38.66**	**29.25**
BOD_5 removed in pre-denitrification	$kgBOD_5/kgN$	**2**	**2**
BOD_5 removed in pre-denitrification	$kgBOD_5/d$	**77.32**	**58.51**
Retention time	h	2.18	3.19

Theoretical verification at the mean loads. Functional parameters.	**Unit of measure (U.M.)**		

Functional parameters of the biologic oxidation and nitrification station

Number of units/compartments	-	2	2
Total volume	m^3	1470	1470
Organic load after pre-denitrification	$kgBOD_5/d$	613	180
Volumic load C_V	$kgBOD_5/m^3*d$	0.42	0.12
Suspended Solids load (SS)	$kgSS/m^3$	5	5
Sludge load c_F	**$kgBOD_5/kgSS*d$**	**0.08**	**0.02**
Removed BOD_5 (oxidation. + denitr.: ΔBOD_5)	$kgBOD_5/d$	663	224
Removed BOD_5 in oxidation	$kgBOD_5/d$	585	165
BOD_5 removal (oxidation + de-nitrification)	%	96.0	94.0
Growth index	**$kgSS/kgBOD_{5,aat}$**	**0.75**	**0.75**
Production of excess sludge F_S (oxidation + de-nitrification)	kgSS/d	497	168
Sludge age	**d**	**15**	**44**
Theorethical oxigen demand	kgO_2/d	1815	1191
Exercise temperature	C	15	15
Saturation concentration	gO_2/m^3	9.8	9.8
Oxygen residual concentration	gO_2/m^3	2.2	1.9
Effective oxygen request	kgO_2/d	2.910	1.838
Mean efficiency of the insufflation system	%	20	20
Air request/need	m^3/d	51233	32352
Oxygenation capacity of bowers and surface aerators	m^3/d	80000	80000
Nitrification velocity (safe value)	$kgN\text{-}NH_4^+/kgSS*d$	0.05	0.05
Nitrification capacity	**kgN/d**	**368**	**368**
N to be nitrified	kgN/d	**172**	**82**
N produced in nitrification	kgN/d	172	82
Retention time	h	**5.26**	**7.69**

Functional parameters of the post-de-nitrification station* NOT EXISTING

Number of units	-		
Total volume	m^3		
Concetration of Suspended Solids (SS)	$kgSS/m^3$		
VSS/SS	kgSSV/kgSS		
Temperature	C		
De-nitrification specific velocity	kgN/kgSSV*d		

N to be de-nitrified	kgN/d		
De-nitrification capacity of the basin	kgN/d		
N removed in pre-denitrification	kgN/d		
BOD_5 removed in post-denitrification	$kgBOD_5/kgN$		
BOD_5 removed in post-denitrification	$kgBOD_5/d$		
External supply of readily bio-degradable organic substances	$kgBOD_5/d$		
N associated to the external source of Carbon	kgN/d		
$N-NO_3$ supply to post-denitrification	kgN/d		
Entering flow to post-denitrification $Q_m + Q_r$	m^3/h		
Ritention time	h		
Mixing specific power	W/m^3		

Functional parameters for the secondary sedimentation station

Number of units	-	3	2
Total surface of the station	m^2	389	226
Total volume of the station	m^3	1476	572
Uprising velocity at Q_m	m/h	**0.42**	**0.53**
Uprising velocity at Q_p	m/h	0.63	0.79
Uprising velocity at Q_{max}	m/h	0.85	1.06
Retention time at Q_m	m/h	**8.98**	**4.79**
Retention time at Q_p	m/h	5.99	3.19
Retention time at Q_{max}	h	4.49	2.39
Recirculation ratio according to influent	h	0.7	0.6
Surface load of SS at Q_m	**h**	**3.59**	**4.23**
SS concentration in the re-circulated flow	-	12.1	13.3
Plant retention time	h	**13.4**	**14.1**
% reduction Ntot	**%**	**70**	**46**
% reduction Ptot	**%**	**92**	**92**
Served agglomeration		Eraclea	Eraclea
Resident population	PE	5485	5485
Fluctuating population	PE	13599	13599
Industrial load agglomeration	PE	274	274
Generated load	PE	19358	1935lomeration8
Treated load	PE	11506	3967
% treated load of agglomeration, treated by the WWTP	%	**59**	**69**

* Station not present.

Comments :

The plant has a project potentiality of 32,000 PE, but from the functionality verification at mean loads it appears that the plant treats 12,000 PE (organic load) in high season and 4,000 PE in the low season. From Veneto Region deliberation the reference agglomeratoion is Eraclea with a calculated generated load of 5,500 resident PE, about 300 industrial PE (laundries and car washings) and about 14,000 PE of touristic population. From the calculations the percentage of the treated load in the plant with reference to the generated load in the agglomeration is about the 60-70%.

Both in the high seson as well in the low season asset the plant is a "**extended aeration**" (total oxidation) plant (sludge load C_F respectively 0.08 and 0.02). The sludge age is 15 days in the high season increasing to 44 days in the low season.

From the integrated control with the functionality verification at mean loads, the plant does not present significant criticities and treats satisfactorily the received loads.

VII.3. Jesolo WWTP

Theoretical verification at the mean received loads and mass balances	**Unit of measure (U.M.)**	**Values**

Estimation of the received loads to the WWTP

Hydraulic Population Equivalents (civil + industrial)	PE	174000
Organic Population Equivalents (civil + industrial)	PE	109040
Hydraulic specific load	l/PE*d	200.00
Organic specific load	gBOD5/PE*d	60.00
Daily hydraulic mean load	**m^3/d**	**34200**
Mean flow (Q_m)	m^3/h	1425
Peak flow ($Q_p = 1.5*Q_m$)	m^3/h	2138
Max flow ($Q_{max} = 2*Q_m$)	m^3/h	2850
Mean BOD_5 IN load	**$gBOD_5/m^3$**	**130**
Organic load (BOD_5)	$kgBOD_5/d$	4446
Mean COD IN concentration	**$gCOD/m^3$**	**247**
Organic load (COD)	kgCOD/d	8447
Mean SS IN concentration	**gSS/m^3**	**147**
Suspended solids load (SS)	kgSS/d	5027
Mean TKN IN concentration	**gN/m^3**	**35**
TKN load	kgN/d	1197
Mean concentration of NO_3^- IN	**gN/m^3**	**0**
Nitric Nitrogen load	kgN/d	0
Mean P IN concentration	**gP/m^3**	**1.70**
P load	kgP/d	58

Organic matter load balance

Organic load	$kgBOD_5/d$	4446
% abatement of BOD_5 in the primary sedimentation unit	%	0
BOD_5 removed in the primary sedimentation unit	$kgBOD_5/d$	0
BOD_5 IN at secondary treatment units	$kgBOD_5/d$	4446
BOD_5 concentration at the final discharge	$gBOD_5/m^3$	**15**
BOD_5 load at the final discharge	$kgBOD_5/d$	513
BOD_5 abatement in the secondary treatment unit (□BOD_5)	$kgBOD_5/d$	3933
Efficiency of the secondary treatment for BOD_5	%	88

Nitrogen mass balance

TKN load	kgN/d	1197
N nitric load entering the WWTP	kgN/d	0
TKN abatement in the primary sedimentation unit	%	0
TKN abatement in the primary sedimentation unit	kgN/d	0.00
TKN entering the secondary treatment	kgN/d	1197
$N\text{-}NH_4$ concentration in the final discharge	gN/m^3	**2**
$N\text{-}NH_4$ load in the final discharge	kgN/d	68.40
$N\text{-}NO_3$ concentration in the final discharge	gN/m^3	**10.0**
$N\text{-}NO_3$ load in the final discharge azoto nitrico allo scarico	kgN/d	342.00
$N\text{-}NO_2$ concentration in the final discharge	gN/m^3	**0.1**
$N\text{-}NO_2$ load in the final discharge	kgN/d	3.42
Organic N concentration in the final discharge	gN/m^3	**2**
Organic N load in the final discharge	kgN/d	68.40
N removed with BOD_5	%	4
N removed with BOD_5 (% of □BOD_5)	kgN/d	157.32
N to undergo to the nitrification process	kgN/d	**899.46**
N to undergo to the denitrification process	kgN/d	**557.46**
Efficiency of the secondary treatment on N	%	60

Phosphorous mass balance

Total Phosphorous load	kgP/d	58
P removed in the primary sedimentation unit	%	0
P load removed in the primary sedimentation unit	kgP/d	0
P total concentration in the final discharge	gP/m^3	**2**
P total load at the final discharge	kgP/d	68.40
P removed with BOD_5	%	1
P removed with BOD_5 (% of □BOD_5)	kgP/d	39.33
P total to be removed	kgP/d	-49.59

Theoretical verification at the mean loads. Functional parameters.	Unit of measure (U.M.)	Values

Functional parameters of the primary sedimentation station

Number of units	-	4
Diameter	m	0
Height at the periphery	m	0
Useful height	m	0
Surface	m^2	4630.00
Total volume	m^3	0.00
Uprising velocy at Q_m	m/h	0.00
Uprising velocity at Q_p	m/h	0.00
Uprising velocity at Q_{max}	m/h	0.00
Retention time at Q_m	min	0
Retention time at Q_p	min	0
Retention time at Q_{max}	min	0
Abatement of BOD_5	%	0
Abatement of TKN	%	0
Abatement of P	%	0
Hydraulic load discharged after primary sedimentation (overflow)	m^3/d	0

Functional parameters of the pre-de-nitrification station

Hydraulic load entering the secondary treatment unit	m^3/d	34200
Mean flow Q_m	m^3/h	1425
Peak flow Q_p	m^3/h	2138
Max flow Q_{max}	m^3/h	2850
Organic load IN secondary treatment	$kgBOD_5/d$	4446
Sludge recirculation ratio	-	1
Recirculation sludge from secondary sedimentation unit Q_r	m^3/h	1425.00
$N\text{-}NO_3$ concentration in the final discharge	gN/m^3	10.0
NO_3 supply with sludge re-circulation	kgN/d	342.00
Re-circulated mixed liquor ratio	-	2.00
Re-circulated mixed liquor flow Q_{ml}	m^3/h	2850.00
$N\text{-}NO_3$ concentration in the mixed liquor	gN/m^3	10.0
NO_3 supply with mixed liquor recirculation	kgN/d	684.00
NO_3 supply at pre-denitrification $Q_m + Q_r + Q_{ml}$	kgN/d	**1026.00**
Entering flow at the pre-denitrification with $Q_m + Q_r + Q_{ml}$	m^3/h	5700.00
Number of units or compartments	-	4
Total volume	m^3	1360
Suspended Solids concentration (SS)	$kgSS/m^3$	4.5
VSS/SS	kgSSV/kgSS	0.7
Temperature	°C	15
De-nitrification specific velocity	kgN/kgSSV*d	0.036
Nitrogen to undergo de-nitrification	kgN/d	**557.46**
De-nitrification capacity of the basin	kgN/d	**154.22**
Removed N in pre-denitrification	kgN/d	154.22

BOD_5 removed in pre-denitrification	$kgBOD_5/kgN$	2
BOD_5 removed in pre-denitrification	$kgBOD_5/d$	308.45
Retention time	h	0.24
Mixing specific power	W/m^3	0.00

Theoretical verification at the mean loads. Functional parameters.	**Unit of measure (U.M.)**	**Values**

Functional parameters of the biologic oxidation and nitrification station

Number of units/compartments	-	2
Total volume	m^3	1960
Organic load after pre-denitrification	$kgBOD_5/d$	4138
Volumic load c_V	$kgBOD_5/m^3*d$	2.11
Suspended Solids load (SS)	$kgSS/m^3$	4.5
Sludge load c_F	**$kgBOD_5/kgSS*d$**	**0.47**
Removed BOD_5 (oxidation. + denitr.: ΔBOD_5)	$kgBOD_5/d$	3933
Removed BOD_5 in oxidation	$kgBOD_5/d$	3625
BOD_5 removal (oxidation + de-nitrification)	%	88.5
Growth index	$kgSS/kgBOD_{5,aat}$	0,75
Production of removal (supero) sludges F_S (oxidation + de-nitrification)	kgSS/d	2950
Sludge age	**d**	**3**
Theorethical oxigen demand	kgO_2/d	6805
Exercise temperature	°C	15
Saturation concentration	gO_2/m^3	9.8
Oxygen residual concentration	gO_2/m^3	3
Effective oxygen request	kgO_2/d	12195
Mean efficiency of the insufflation system	%	16
Air request/need	m^3/d	**268372**
Oxygenation capacity of blowers	m^3/d	0
Oxygenation capacity of surface aerators	kgO_2/d	0
Nitrification velocity (safe value)	$kgN\text{-}NH_4^+/kgSS*d$	0.05
Nitrification capacity	**kgN/d**	**441**
N to be nitrified	**kgN/d**	**899**
N produce in nitrification	kgN/d	441
Retention time	h	0.34

Functional parameters of the post-de-nitrification station

Number of units	-	0
Total volume	m^3	0
Concetration of Suspended Solids (SS)	$kgSS/m^3$	4.5
VSS/SS	kgSSV/kgSS	0
Temperature	C	0
De-nitrification specific velocity	kgN/kgSSV*d	0
N to be de-nitrified	kgN/d	0.00
De-nitrification capacity of the basin	kgN/d	0.00
N removed in pre-denitrification	kgN/d	0.00
BOD_5 removed in post-denitrification	$kgBOD_5/kgN$	0
BOD_5 removed in post-denitrification	$kgBOD_5/d$	0.00
External supply of readily bio-degradable organic substances	$kgBOD_5/d$	0.00
N associated to the external source of Carbon	kgN/d	0
$N\text{-}NO_3$ supply to post-denitrification	kgN/d	0.00
Entering flow to post-denitrification $Q_m + Q_r$	m^3/h	0.00
Ritention time	h	#DIV/0!
Mixing specific power	W/m^3	0.00

Functional parameters for the secondary sedimentation station

Number of units	-	2
Diameter	m	
Mean depth	m	
Total surface of the station	m^2	454
Total volume of the station	m^3	1258
Overflow length	m	0
Hydraulic load at the overflow at Q_m	m^3/m^*h	
Uprising velocity at Q_m	**m/h**	**3.14**
Uprising velocity at Q_p	m/h	4.71
Uprising velocity at Q_{max}	m/h	6.28
Retention time at Q_m	**h**	**0.88**
Retention time at Q_p	h	0.59
Retention time at Q_{max}	h	0.44
Recirculation ratio according to influent	-	1
Surface load of SS at Q_m	$kgSS/m^2{*}h$	28.25
SS concentration in the re-circulated flow	$kgSS/m^3$	9

Comments:

The functional verification has been performed considerino the maximum loads according to the population served using the manager data. The plant does not present structural shortcomings and is quite well dimensioned. During the control it was assumend that 100% of the effluent from primary sedimentation goes to feed the oxidation station. This assumption substantially does not influence on the balances of pre-denitrification and oxidation stations. Moreover the plant manager does not make the aerated mixed liquor flow to predenitrification considering sufficient the recirculation of secondary sedimentation sludge.

According to Masotti (1999) this plant can be classified as a "**mean load**" plant (C_F = 0.47 and low sludge age o 3 days).

VII.4. San Donà di Piave WWTP

Theoretical verification at the mean received loads and mass balances	**Unit of measure (U.M.)**	**Values**
Estimation of the received loads to the WWTP		
Hydraulic Population Equivalents (civil + industrial)	PE	66500
Organic Population Equivalents (civil + industrial)	PE	20615
Hydraulic specific load	l/PE*d	200.00
Organic specific load	$gBOD_5/PE{*}d$	60.00
Daily hydraulic mean load	**m^3/d**	**13.300**
Mean flow (Q_m)	m^3/h	554
Peak flow ($Q_p = 1.5{*}Q_m$)	m^3/h	831
Max flow ($Q_{max} = 2{*}Q_m$)	m^3/h	1108
Mean BOD_5 IN load	**$gBOD_5/m^3$**	**93**
Organic load (BOD_5)	$kgBOD_5/d$	1237
Mean COD IN concentration	**$gCOD/m^3$**	**208**
Organic load (COD)	kgCOD/d	2766
Mean SS IN concentration	**gSS/m^3**	**159**
Suspended solids load (SS)	kgSS/d	2115
Mean TKN IN concentration	gN/m^3	**30**

TKN load	kgN/d	399
Mean concentration of NO_3^- IN	gN/m^3	**0**
Nitric Nitrogen load	kgN/d	0
Mean P IN concentration	gP/m^3	**3.80**
P load	kgP/d	51

Organic matter load balance

Organic load	kgBOD$_5$/d	1237
% abatement of BOD$_5$ in the primary sedimentation unit	**%**	**20**
BOD$_5$ removed in the primary sedimentation unit	kgBOD$_5$/d	247
BOD$_5$ IN at secondary treatment units	kgBOD$_5$/d	990
BOD$_5$ concentration at the final discharge	**gBOD$_5$/m^3**	**15**
BOD$_5$ load at the final discharge	kgBOD$_5$/d	**200**
BOD$_5$ abatement in the secondary treatment unit (ΔBOD$_5$)	kgBOD$_5$/d	**790**
Efficiency of the secondary treatment for BOD$_5$	%	**80**

Nitrogen mass balance

TKN load	kgN/d	399
N nitric load entering the WWTP	kgN/d	0
TKN abatement in the primary sedimentation unit	**%**	**7.5**
TKN abatement in the primary sedimentation unit	kgN/d	29.93
TKN entering the secondary treatment	kgN/d	369
N-NH$_4$ concentration in the final discharge	**gN/m^3**	**1**
N-NH$_4$ load in the final discharge	kgN/d	13.30
N-NO$_3$ concentration in the final discharge	**gN/m^3**	**10.9**
N-NO$_3$ load in the final discharge azoto nitrico allo scarico	kgN/d	144.97
N-NO$_2$ concentration in the final discharge	**gN/m^3**	**0.1**
N-NO$_2$ load in the final discharge	kgN/d	1.33
Organic N concentration in the final discharge	**gN/m^3**	**2**
Organic N load in the final discharge	kgN/d	26.60
N removed with BOD$_5$	**%**	**4**
N removed with BOD$_5$ (% of ΔBOD$_5$)	kgN/d	31.60
N to undergo to the nitrification process	**kgN/d**	**296.24**
N to undergo to the denitrification process	**kgN/d**	**151.27**
Efficiency of the secondary treatment on N	%	53

Phosphorous mass balance

Total Phosphorous load	kgP/d	51
P removed in the primary sedimentation unit	**%**	**5**
P load removed in the primary sedimentation unit	kgP/d	3
P total concentration in the final discharge	**gP/m^3**	**1**
P total load at the final discharge	kgP/d	13.30
P removed with BOD$_5$	**%**	**1**
P removed with BOD$_5$ (% of ΔBOD$_5$)	kgP/d	7.90
P total to be removed	kgP/d	**26.81**

Theoretical verification at the mean loads. Functional parameters.	**Unit of measure (U.M.)**	**Values**

Functional parameters of the primary sedimentation station

Number of units	-	2
Diameter	m	0
Height at the periphery	m	0
Useful height	m	0
Surface	m^2	508
Total volume	m^3	1720
Uprising velocy at Q_m	**m/h**	**1.09**

Uprising velocity at Q_p	m/h	1.64
Uprising velocity at Q_{max}	m/h	2.18
Retention time at Q_m	**min**	**186**
Retention time at Q_p	min	124
Retention time at Q_{max}	min	93
Abatement of BOD_5	%	20
Abatement of TKN	%	7.5
Abatement of P	%	5
Hydraulic load discharged after primary sedimentation (overflow)	m^3/d	0

Functional parameters of the pre-de-nitrification station

Hydraulic load entering the secondary treatment unit	m^3/d	13300
Mean flow Q_m	m^3/h	554
Peak flow Q_p	m^3/h	831
Max flow Q_{max}	m^3/h	1108
Organic load IN secondary treatment	$kgBOD_5/d$	990
Sludge recirculation ratio	**-**	**1**
Recirculation sludge from secondary sedimentation unit Q_r	m^3/h	554.17
$N\text{-}NO_3$ concentration in the final discharge	gN/m^3	10.9
NO_3 supply with sludge re-circulation	kgN/d	144.97
Re-circulated mixed liquor ratio	**-**	**0.50**
Re-circulated mixed liquor flow Q_{ml}	m^3/h	277.08
$N\text{-}NO_3$ concentration in the mixed liquor	gN/m^3	10.9
NO_3 supply with mixed liquor recirculation	kgN/d	72.49
NO_3 supply at pre-denitrification $Q_m + Q_r + Q_{ml}$	**kgN/d**	**217.46**
Entering flow at the pre-denitrification with $Q_m + Q_r + Q_{ml}$	m^3/h	1385.42
Number of units or compartments	-	2
Total volume	m^3	2.000
Suspended Solids concentration (SS)	$kgSS/m^3$	4
VSS/SS	kgSSV/kgSS	0.75
Temperature	°C	15
De-nitrification specific velocity	kgN/kgSSV*d	0.036
Nitrogen to undergo de-nitrification	**kgN/d**	**151.27**
De-nitrification capacity of the basin	**kgN/d**	**216.00**
Removed N in pre-denitrification	**kgN/d**	**151.27**
BOD_5 removed in pre-denitrification	**$kgBOD_5/kgN$**	**2**
BOD_5 removed in pre-denitrification	**$kgBOD_5/d$**	**302.55**
Retention time	h	1.44
Mixing specific power	W/m^3	10.00

Theoretical verification at the mean loads. Functional parameters.	**Unit of measure (U.M.)**	**Values**

Functional parameters of the biologic oxidation and nitrification station

Number of units/compartments	-	4
Total volume	m^3	2700
Organic load after pre-denitrification	$kgBOD_5/d$	687
Volumic load c_V	$kgBOD_5/m^3{*}d$	0.25
Suspended Solids load (SS)	$kgSS/m^3$	4
Sludge load c_F	**$kgBOD_5/kgSS{*}d$**	**0.06**
Removed BOD_5 (oxidation. + denitr.: ΔBOD_5)	$kgBOD_5/d$	790
Removed BOD_5 in oxidation	$kgBOD_5/d$	487
BOD_5 removal (oxidation + de-nitrification)	%	79.8
Growth index	**$kgSS/kgBOD_{5.aat}$**	**0.75**
Production of removal (supero) sludges F_S (oxidation + de-nitrification)	kgSS/d	593

Sludge age	**d**	**18**
Theoretical oxigen demand	kgO_2/d	2.678
Exercise temperature	°C	15
Saturation concentration	gO_2/m^3	9.8
Oxygen residual concentration	gO_2/m^3	2
Effective oxygen request	kgO_2/d	4.183
Mean efficiency of the insufflation system	%	20
Air request/need	m^3/d	73.649
Oxygenation capacity of blowers	m^3/d	210.000
Oxygenation capacity of surface aerators	kgO_2/d	0
Nitrification velocity (safe value)	$kgN\text{-}NH_4^+/kgSS*d$	0.05
Nitrification capacity	**kgN/d**	**540**
N to be nitrified	**kgN/d**	**296**
N produce in nitrification	kgN/d	296
Retention time	h	1.95

Functional parameters of the post-de-nitrification station	NOT EXISTING	
Number of units	-	0
Total volume	m^3	0
Concetration of Suspended Solids (SS)	$kgSS/m^3$	4
VSS/SS	kgSSV/kgSS	0.75
Temperature	C	15
De-nitrification specific velocity	kgN/kgSSV*d	0.036
N to be de-nitrified	kgN/d	0.00
De-nitrification capacity of the basin	kgN/d	0.00
N removed in pre-denitrification	kgN/d	0.00
BOD_5 removed in post-denitrification	$kgBOD_5/kgN$	0
BOD_5 removed in post-denitrification	$kgBOD_5/d$	0.00
External supply of readily bio-degradable organic substances	$kgBOD_5/d$	0.00
N associated to the external source of Carbon	kgN/d	0
$N\text{-}NO_3$ supply to post-denitrification	kgN/d	144.97
Entering flow to post-denitrification $Q_m + Q_r$	m^3/h	1108.33
Ritention time	h	0.00
Mixing specific power	W/m^3	0.00

Functional parameters for the secondary sedimentation station		
Number of units	-	2
Diameter	m	27
Mean depth	m	3
Total surface of the station	m^2	1.145
Total volume of the station	m^3	3.435
Overflow length	m	169.64
Hydraulic load at the overflow at Q_m	$m^3/m*h$	3.27
Uprising velocity at Q_m	**m/h**	**0.48**
Uprising velocity at Q_p	m/h	0.73
Uprising velocity at Q_{max}	m/h	0.97
Retention time at Q_m	**h**	**6.20**
Retention time at Q_p	h	4.13
Retention time at Q_{max}	h	3.10
Recirculation ratio according to influent	-	1
Surface load of SS at Q_m	$kgSS/m^2*h$	**3.87**
SS concentration in the re-circulated flow	$kgSS/m^3$	8

Comments:

The plant appear well balanced. It is an "**extended aeration**" plant with a sludge load C_F of 0.06 (Masotti, 1999).

VII.5. Musile di Piave WWTP

Theoretical verification at the mean received loads and mass balances	**Unit of measure (U.M.)**	**Values**
Estimation of the received loads to the WWTP		
Hydraulic Population Equivalents (civil + industrial)	PE	14500
Organic Population Equivalents (civil + industrial)	PE	**2078**
Hydraulic specific load	l/PE*d	200.00
Organic specific load	$gBOD_5$/PE*d	60.00
Daily hydraulic mean load	**m^3/d**	**2900**
Mean flow (Q_m)	m^3/h	121
Peak flow ($Q_p = 1.5*Q_m$)	m^3/h	181
Max flow ($Q_{max} = 2*Q_m$)	m^3/h	242
Mean BOD_5 IN load	**$gBOD_5/m^3$**	**43**
Organic load (BOD_5)	$kgBOD_5/d$	125
Mean COD IN concentration	**$gCOD/m^3$**	**94**
Organic load (COD)	kgCOD/d	273
Mean SS IN concentration	**gSS/m^3**	**56**
Suspended solids load (SS)	kgSS/d	162
Mean TKN IN concentration	gN/m^3	**25**
TKN load	kgN/d	73
Mean concentration of NO_3^- IN	gN/m^3	**0**
Nitric Nitrogen load	kgN/d	0
Mean P IN concentration	gP/m^3	**1.90**
P load	kgP/d	6
Organic matter load balance		
Organic load	$kgBOD_5/d$	125
% abatement of BOD_5 in the primary sedimentation unit	**%**	**0**
BOD_5 removed in the primary sedimentation unit	$kgBOD_5/d$	0
BOD_5 IN at secondary treatment units	$kgBOD_5/d$	125
BOD_5 concentration at the final discharge	**$gBOD_5/m^3$**	**5**
BOD_5 load at the final discharge	$kgBOD_5/d$	**16**
BOD_5 abatement in the secondary treatment unit (ΔBOD_5)	$kgBOD_5/d$	**109**
Efficiency of the secondary treatment for BOD_5	%	**87**
Nitrogen mass balance		
TKN load	kgN/d	73
N nitric load entering the WWTP	kgN/d	0
TKN abatement in the primary sedimentation unit	**%**	**0**
TKN abatement in the primary sedimentation unit	kgN/d	0.00
TKN entering the secondary treatment	kgN/d	73
N-NH_4 concentration in the final discharge	**gN/m^3**	**0.14**
N-NH_4 load in the final discharge	kgN/d	0.41
N-NO_3 concentration in the final discharge	**gN/m^3**	**11**
N-NO_3 load in the final discharge azoto nitrico allo scarico	kgN/d	31.90
N-NO_2 concentration in the final discharge	**gN/m^3**	**0.006**
N-NO_2 load in the final discharge	kgN/d	0.02
Organic N concentration in the final discharge	**gN/m^3**	**0**
Organic N load in the final discharge	kgN/d	0.00
N removed with BOD_5	**%**	**4**
N removed with BOD_5 (% of ▯BOD_5)	kgN/d	4.36
N to undergo to the nitrification process	**kgN/d**	**67.72**
N to undergo to the denitrification process	**kgN/d**	**35.82**
Efficiency of the secondary treatment on N	%	55

Phosphorous mass balance

Total Phosphorous load	kgP/d	6
P removed in the primary sedimentation unit	**%**	**0**
P load removed in the primary sedimentation unit	kgP/d	0
P total concentration in the final discharge	**gP/m^3**	**1.5**
P total load at the final discharge	kgP/d	4.35
P removed with BOD$_5$	**%**	**1**
P removed with BOD$_5$ (% of □BOD$_5$)	kgP/d	1.09
P total to be removed	kgP/d	**0.07**

Theoretical verification at the mean loads. Functional parameters.	**Unit of measure (U.M.)**	**Values**

Functional parameters of the primary sedimentation station*

Number of units	-	0
Diameter	m	0
Height at the periphery	m	0
Useful height	m	0
Surface	m^2	0.00
Total volume	m^3	0.00
Uprising velocy at Q_m	**m/h**	
Uprising velocity at Q_p	m/h	
Uprising velocity at Q_{max}	m/h	
Retention time at Q_m	min	**0**
Retention time at Q_p	min	0
Retention time at Q_{max}	min	0
Abatement of BOD$_5$	%	0
Abatement of TKN	%	0
Abatement of P	%	0
Hydraulic load discharged after primary sedimentation (overflow)	m^3/d	0

Functional parameters of the pre-de-nitrification station

Hydraulic load entering the secondary treatment unit	m^3/d	2900
Mean flow Q_m	m^3/h	121
Peak flow Q_p	m^3/h	181
Max flow Q_{max}	m^3/h	242
Organic load IN secondary treatment	kgBOD$_5$/d	125
Sludge recirculation ratio	**-**	**0.97**
Recirculation sludge from secondary sedimentation unit Q_r	m^3/h	117.21
N-NO$_3$ concentration in the final discharge	gN/m^3	11.0
NO$_3$ supply with sludge re-circulation	kgN/d	30.94
Re-circulated mixed liquor ratio	**-**	**0.00**
Re-circulated mixed liquor flow Q_{ml}	m^3/h	0.00
N-NO$_3$ concentration in the mixed liquor	gN/m^3	11.0
NO$_3$ supply with mixed liquor recirculation	kgN/d	0.00
NO$_3$ supply at pre-denitrification $Q_m + Q_r + Q_{ml}$	**kgN/d**	**30.94**
Entering flow at the pre-denitrification with $Q_m + Q_r + Q_{ml}$	m^3/h	238.04
Number of units or compartments	-	2
Total volume	m^3	600
Suspended Solids concentration (SS)	kgSS/m^3	4.5
VSS/SS	kgSSV/kgSS	0.75
Temperature	°C	15
De-nitrification specific velocity	kgN/kgSSV*d	0.036
Nitrogen to undergo de-nitrification	**kgN/d**	**30.94**
De-nitrification capacity of the basin	**kgN/d**	**72.90**
Removed N in pre-denitrification	**kgN/d**	**30.94**

BOD_5 removed in pre-denitrification	**$kgBOD_5/kgN$**	**2**
BOD_5 removed in pre-denitrification	**$kgBOD_5/d$**	**61.89**
Retention time	h	2.52
Mixing specific power	W/m^3	0.00

Theoretical verification at the mean loads. Functional parameters.	**Unit of measure (U.M.)**	**Values**
Functional parameters of the biologic oxidation and nitrification station		
Number of units/compartments	-	3
Total volume	m^3	920
Organic load after pre-denitrification	$kgBOD_5/d$	63
Volumic load c_V	$kgBOD_5/m^3*d$	0.07
Suspended Solids load (SS)	$kgSS/m^3$	4.5
Sludge load c_F	**$kgBOD_5/kgSS*d$**	**0.02**
Removed BOD_5 (oxidation. + denitr.: ΔBOD_5)	$kgBOD_5/d$	109
Removed BOD_5 in oxidation	$kgBOD_5/d$	47
BOD_5 removal (oxidation + de-nitrification)	%	87.4
Growth index	**$kgSS/kgBOD_{5.aat}$**	**0.75**
Production of removal (supero) sludges F_S (oxidation + de-nitrification)	kgSS/d	82
Sludge age	**d**	**51**
Theorethical oxigen demand	kgO_2/d	747
Exercise temperature	°C	15
Saturation concentration	gO_2/m^3	9.8
Oxygen residual concentration	gO_2/m^3	2
Effective oxygen request	kgO_2/d	1167
Mean efficiency of the insufflation system	%	20
Air request/need	m^3/d	20548
Oxygenation capacity of blowers	m^3/d	31200
Oxygenation capacity of surface aerators	kgO_2/d	0
Nitrification velocity (safe value)	$kgN\text{-}NH_4^+/kgSS*d$	0.05
Nitrification capacity	**kgN/d**	**207**
N to be nitrified	**kgN/d**	**68**
N produce in nitrification	kgN/d	68
Retention time	h	3.86

Functional parameters of the post-de-nitrification station	NOT EXISTING	
Number of units	-	0
Total volume	m^3	0
Concetration of Suspended Solids (SS)	$kgSS/m^3$	4.5
VSS/SS	kgSSV/kgSS	0.75
Temperature	C	15
De-nitrification specific velocity	kgN/kgSSV*d	0.036
N to be de-nitrified	kgN/d	4.87
De-nitrification capacity of the basin	kgN/d	0.00
N removed in pre-denitrification	kgN/d	0.00
BOD_5 removed in post-denitrification	$kgBOD_5/kgN$	0
BOD_5 removed in post-denitrification	$kgBOD_5/d$	0.00
External supply of readily bio-degradable organic substances	$kgBOD_5/d$	0.00
N associated to the external source of Carbon	kgN/d	0
$N\text{-}NO_3$ supply to post-denitrification	kgN/d	36.77
Entering flow to post-denitrification $Q_m + Q_r$	m^3/h	238.04
Ritention time	h	0.00
Mixing specific power	W/m^3	0.00

Functional parameters for the secondary sedimentation station

Number of units	-	1
Diameter	m	20
Mean depth	m	
Total surface of the station	m^2	315
Total volume of the station	m^3	895
Overflow length	m	63
Hydraulic load at the overflow at Q_m	$m^3/m*h$	1.9
Uprising velocity at Q_m	**m/h**	**0.38**
Uprising velocity at Q_p	m/h	0.58
Uprising velocity at Q_{max}	m/h	0.77
Retention time at Q_m	**h**	**7.41**
Retention time at Q_p	h	4.94
Retention time at Q_{max}	h	3.70
Recirculation ratio according to influent	-	0.97
Surface load of SS at Q_m	$kgSS/m^2*h$	**3.40**
SS concentration in the re-circulated flow	$kgSS/m^3$	9.1

* Sation not present

Comments:

The plant can be classified as a “extended aeration” plant (total oxidation) with sludge load C_F = 0.02 and old sludge (51 days).

VII.6. Fusina WWTP

Theoretical verification at the mean received loads and mass balances	**Unit of measure (U.M.)**	**Values**
Estimation of the received loads to the WWTP		
Hydraulic Population Equivalents (civil + industrial)	PE	630900
Organic Population Equivalents (civil + industrial)	PE	395364
Hydraulic specific load	l/PE*d	200,00
Organic specific load	gBOD5/PE*d	60,00
Daily hydraulic mean load	**m^3/d**	126.180
Mean flow (Q_m)	m^3/h	5258
Peak flow ($Q_p = 1.5*Q_m$)	m^3/h	7886
Max flow ($Q_{max} = 2*Q_m$)	m^3/h	10515
Mean BOD_5 IN load	**$gBOD5/m^3$**	188
Organic load (BOD_5)	$kgBOD_5/d$	23722
Mean COD IN concentration	**$gCOD/m^3$**	293
Organic load (COD)	kgCOD/d	36971
Mean SS IN concentration	**gSS/m^3**	200
Suspended solids load (SS)	kgSS/d	25236
Mean TKN IN concentration	gN/m^3	22,78
TKN load	kgN/d	2874
Mean concentration of NO_3^- IN	gN/m^3	1,4
Nitric Nitrogen load	kgN/d	177
Mean P IN concentration	gP/m^3	4,89
P load	kgP/d	617
Organic matter load balance		
Organic load	$kgBOD_5/d$	23722

% abatement of BOD_5 in the primary sedimentation unit	**%**	0
BOD_5 removed in the primary sedimentation unit	$kgBOD_5/d$	0
BOD_5 IN at secondary treatment units	$kgBOD_5/d$	23722
BOD_5 concentration at the final discharge	**$gBOD_5/m^3$**	40
BOD_5 load at the final discharge	$kgBOD_5/d$	5047
BOD_5 abatement in the secondary treatment unit (ΔBOD_5)	$kgBOD_5/d$	18675
Efficiency of the secondary treatment for BOD_5	%	79

Nitrogen mass balance

TKN load	kgN/d	2874
N nitric load entering the WWTP	kgN/d	177
TKN abatement in the primary sedimentation unit	**%**	0
TKN abatement in the primary sedimentation unit	kgN/d	0,00
TKN entering the secondary treatment	kgN/d	2874
N-NH_4 concentration in the final discharge	**gN/m^3**	1
N-NH_4 load in the final discharge	kgN/d	126,18
N-NO_3 concentration in the final discharge	**gN/m^3**	10,0
N-NO_3 load in the final discharge azoto nitrico allo scarico	kgN/d	1261,80
N-NO_2 concentration in the final discharge	**gN/m^3**	1,0
N-NO_2 load in the final discharge	kgN/d	126,18
Organic N concentration in the final discharge	**gN/m^3**	2
Organic N load in the final discharge	kgN/d	252,36
N removed with BOD_5	**%**	4
N removed with BOD_5 (% of ΔBOD_5)	kgN/d	746,99
N to undergo to the nitrification process	**kgN/d**	1622,67
N to undergo to the denitrification process	**kgN/d**	537,53
Efficiency of the secondary treatment on N	%	42

Phosphorous mass balance

Total Phosphorous load	kgP/d	617
P removed in the primary sedimentation unit	**%**	0
P load removed in the primary sedimentation unit	kgP/d	0
P total concentration in the final discharge	**gP/m^3**	1
P total load at the final discharge	kgP/d	126,18
P removed with BOD_5	**%**	1
P removed with BOD_5 (% of ΔBOD_5)	kgP/d	186,75
P total to be removed	kgP/d	304,09

Theoretical verification at the mean loads. Functional parameters.	**Unit of measure (U.M.)**	**Values**
Functional parameters of the primary sedimentation station*		
Number of units	-	0
Diameter	m	14
Height at the periphery	m	2
Useful height	m	2,3
Surface	m^2	0,00
Total volume	m^3	0,00
Uprising velocy at Q_m	**m/h**	
Uprising velocity at Q_p	m/h	
Uprising velocity at Q_{max}	m/h	
Retention time at Q_m	min	0
Retention time at Q_p	min	0
Retention time at Q_{max}	min	0
Abatement of BOD_5	%	0
Abatement of TKN	%	0
Abatement of P	%	0

Hydraulic load discharged after primary sedimentation (overflow)	m^3/d	0

Functional parameters of the pre-de-nitrification station

Hydraulic load entering the secondary treatment unit	m^3/d	126180
Mean flow Q_m	m^3/h	5258
Peak flow Q_p	m^3/h	7886
Max flow Q_{max}	m^3/h	10515
Organic load IN secondary treatment	$kgBOD_5/d$	23722
Sludge recirculation ratio	**-**	1
Recirculation sludge from secondary sedimentation unit Q_r	m^3/h	5257,50
$N\text{-}NO_3$ concentration in the final discharge	gN/m^3	10,0
NO_3 supply with sludge re-circulation	kgN/d	1261,80
Re-circulated mixed liquor ratio	**-**	2,00
Re-circulated mixed liquor flow Q_{ml}	m^3/h	10515,00
$N\text{-}NO_3$ concentration in the mixed liquor	gN/m^3	10,0
NO_3 supply with mixed liquor recirculation	kgN/d	2523,60
NO_3 supply at pre-denitrification $Q_m + Q_r + Q_{ml}$	**kgN/d**	3962,05
Entering flow at the pre-denitrification with $Q_m + Q_r + Q_{ml}$	m^3/h	21030,00
Number of units or compartments	-	3
Total volume	m^3	18000
Suspended Solids concentration (SS)	$kgSS/m^3$	4,2
VSS/SS	kgSSV/kgSS	0,64
Temperature	°C	15
De-nitrification specific velocity	kgN/kgSSV*d	0,036
Nitrogen to undergo de-nitrification	kgN/d	537,53
De-nitrification capacity of the basin	kgN/d	1741,82
Removed N in pre-denitrification	kgN/d	537,53
BOD_5 removed in pre-denitrification	$kgBOD_5/kgN$	2
BOD_5 removed in pre-denitrification	$kgBOD_5/d$	1075,05
Retention time	h	0,86
Mixing specific power	W/m^3	10,00

Theoretical verification at the mean loads. Functional parameters.	**Unit of measure (U.M.)**	**Values**

Functional parameters of the biologic oxidation and nitrification station

Number of units/compartments	-	3
Total volume	m^3	33600
Organic load after pre-denitrification	$kgBOD_5/d$	22647
Volumic load c_V	$kgBOD_5/m^3*d$	0,67
Suspended Solids load (SS)	$kgSS/m^3$	4,2
Sludge load c_F	**$kgBOD_5/kgSS*d$**	0,16
Removed BOD_5 (oxidation. + denitr.: ΔBOD_5)	$kgBOD_5/d$	18675
Removed BOD_5 in oxidation	$kgBOD_5/d$	17600
BOD_5 removal (oxidation + de-nitrification)	%	78,7
Growth index	**$kgSS/kgBOD_{5,aat}$**	0,75
Production of removal (supero) sludges F_S (oxidation + de-nitrification)	kgSS/d	14006
Sludge age	**d**	10
Theorethical oxigen demand	kgO_2/d	30327
Exercise temperature	°C	15
Saturation concentration	gO_2/m^3	9,8
Oxygen residual concentration	gO_2/m^3	2
Effective oxygen request	kgO_2/d	47382
Mean efficiency of the insufflation system	%	16
Air request/need	m^3/d	1042728

Oxygenation capacity of blowers	m^3/d	
Oxygenation capacity of surface aerators	kgO_2/d	
Nitrification velocity (safe value)	$kgN\text{-}NH_4^+/kgSS*d$	0,05
Nitrification capacity	**kgN/d**	7056
N to be nitrified	**kgN/d**	1623
N produce in nitrification	kgN/d	1623
Retention time	h	1,60

Functional parameters of the post-de-nitrification station

Number of units	-	0
Total volume	m^3	0
Concetration of Suspended Solids (SS)	$kgSS/m^3$	4,2
VSS/SS	kgSSV/kgSS	0,64
Temperature	C	15
De-nitrification specific velocity	kgN/kgSSV*d	0,036
N to be de-nitrified	kgN/d	0,00
De-nitrification capacity of the basin	kgN/d	0,00
N removed in pre-denitrification	kgN/d	0,00
BOD_5 removed in post-denitrification	$kgBOD_5/kgN$	0
BOD_5 removed in post-denitrification	$kgBOD_5/d$	0,00
External supply of readily bio-degradable organic substances	$kgBOD_5/d$	0,00
N associated to the external source of Carbon	kgN/d	0
$N\text{-}NO_3$ supply to post-denitrification	kgN/d	1261,80
Entering flow to post-denitrification $Q_m + Q_r$	m^3/h	10515,00
Ritention time	h	0,00
Mixing specific power	W/m^3	0,00

Functional parameters for the secondary sedimentation station

Number of units	-	3
Diameter	m	25
Mean depth	m	3
Total surface of the station	m^2	5850
Total volume of the station	m^3	15000
Overflow length	m	236
Hydraulic load at the overflow at Q_m	$m^3/m*h$	22,31
Uprising velocity at Q_m	**m/h**	0,90
Uprising velocity at Q_p	m/h	1,35
Uprising velocity at Q_{max}	m/h	1,80
Retention time at Q_m	**h**	2,85
Retention time at Q_p	h	1,90
Retention time at Q_{max}	h	1,43
Recirculation ratio according to influent	-	1
Surface load of SS at Q_m	$kgSS/m^2*h$	7,55
SS concentration in the re-circulated flow	$kgSS/m^3$	8,4

Comments:

The effective hydraulic load is significantly higher tha the project dimensioning due to the presence of infiltration waters (630,900 PE). From the C_F value the plant appears as “**extended aeration**” with a low sludge age of 10 days.

VII.7. Paese WWTP

Theoretical verification at the mean received loads and mass balances	**Unit of measure (U.M.)**	**Values**
Estimation of the received loads to the WWTP		
Hydraulic Population Equivalents (civil + industrial)	PE	8740
Organic Population Equivalents (civil + industrial)	PE	18791
Hydraulic specific load	l/PE*d	250,00
Organic specific load	$gBOD_5$/PE*d	60,00
Daily hydraulic mean load	**m^3/d**	2185
Mean flow (Q_m)	m^3/h	91
Peak flow ($Q_p = 1.5*Q_m$)	m^3/h	137
Max flow ($Q_{max} = 2*Q_m$)	m^3/h	182
Mean BOD_5 IN load	**$gBOD_5/m^3$**	516
Organic load (BOD_5)	$kgBOD_5/d$	1127
Mean COD IN concentration	**$gCOD/m^3$**	1026
Organic load (COD)	kgCOD/d	2242
Mean SS IN concentration	**gSS/m^3**	487
Suspended solids load (SS)	kgSS/d	1064
Mean TKN IN concentration	gN/m^3	96
TKN load	kgN/d	210
Mean concentration of NO_3^- IN	gN/m^3	0
Nitric Nitrogen load	kgN/d	0
Mean P IN concentration	gP/m^3	9,90
P load	kgP/d	22
Organic matter load balance		
Organic load	$kgBOD_5/d$	1127
% abatement of BOD_5 in the primary sedimentation unit	**%**	0
BOD_5 removed in the primary sedimentation unit	$kgBOD_5/d$	0
BOD_5 IN at secondary treatment units	$kgBOD_5/d$	1127
BOD_5 concentration at the final discharge	**$gBOD_5/m^3$**	13
BOD_5 load at the final discharge	$kgBOD_5/d$	28
BOD_5 abatement in the secondary treatment unit (ΔBOD_5)	$kgBOD_5/d$	1099
Efficiency of the secondary treatment for BOD_5	%	98
Nitrogen mass balance		
TKN load	kgN/d	210
N nitric load entering the WWTP	kgN/d	0
TKN abatement in the primary sedimentation unit	**%**	0
TKN abatement in the primary sedimentation unit	kgN/d	0,00
TKN entering the secondary treatment	kgN/d	210
N-NH_4 concentration in the final discharge	**gN/m^3**	1,1
N-NH_4 load in the final discharge	kgN/d	2,29
N-NO_3 concentration in the final discharge	**gN/m^3**	2,9
N-NO_3 load in the final discharge azoto nitrico allo scarico	kgN/d	6,34
N-NO_2 concentration in the final discharge	**gN/m^3**	0,1
N-NO_2 load in the final discharge	kgN/d	0,22
Organic N concentration in the final discharge	**gN/m^3**	2
Organic N load in the final discharge	kgN/d	4,37
N removed with BOD_5	**%**	4
N removed with BOD_5 (% of □BOD_5)	kgN/d	43,98
N to undergo to the nitrification process	**kgN/d**	**158,90**
N to undergo to the denitrification process	**kgN/d**	**152,56**
Efficiency of the secondary treatment on N	%	94

Phosphorous mass balance

Total Phosphorous load	kgP/d	22
P removed in the primary sedimentation unit	**%**	0
P load removed in the primary sedimentation unit	kgP/d	0
P total concentration in the final discharge	**gP/m^3**	1,48
P total load at the final discharge	kgP/d	3,23
P removed with BOD_5	**%**	1
P removed with BOD_5 (% of ▯BOD_5)	kgP/d	10,99
P total to be removed	kgP/d	7,40

Theoretical verification at the mean loads. Functional parameters.	**Unit of measure (U.M.)**	**Values**

Functional parameters of the primary sedimentation station — NOT EXISISTING SECTION

Number of units	-	
Diameter	m	
Height at the periphery	m	
Useful height	m	
Surface	m^2	0,00
Total volume	m^3	0,00
Uprising velocy at Q_m	**m/h**	
Uprising velocity at Q_p	m/h	
Uprising velocity at Q_{max}	m/h	
Retention time at Q_m	min	0
Retention time at Q_p	min	0
Retention time at Q_{max}	min	0
Abatement of BOD_5	%	0
Abatement of TKN	%	0
Abatement of P	%	0
Hydraulic load discharged after primary sedimentation (overflow)	m^3/d	0

Functional parameters of the pre-de-nitrification station

Hydraulic load entering the secondary treatment unit	m^3/d	2185
Mean flow Q_m	m^3/h	91
Peak flow Q_p	m^3/h	137
Max flow Q_{max}	m^3/h	182
Organic load IN secondary treatment	$kgBOD_5/d$	1127
Sludge recirculation ratio	**-**	2,1
Recirculation sludge from secondary sedimentation unit Q_r	m^3/h	191,19
N-NO_3 concentration in the final discharge	gN/m^3	5,5
NO_3 supply with sludge re-circulation	kgN/d	25,24
Re-circulated mixed liquor ratio	**-**	1,30
Re-circulated mixed liquor flow Q_{ml}	m^3/h	118,35
N-NO_3 concentration in the mixed liquor	gN/m^3	2,9
NO_3 supply with mixed liquor recirculation	kgN/d	8,24
NO_3 supply at pre-denitrification $Q_m + Q_r + Q_{ml}$	**kgN/d**	**33,47**
Entering flow at the pre-denitrification with $Q_m + Q_r + Q_{ml}$	m^3/h	400,58
Number of units or compartments	-	1
Total volume	m^3	1125
Suspended Solids concentration (SS)	$kgSS/m^3$	7,3
VSS/SS	kgSSV/kgSS	0,65
Temperature	°C	18
De-nitrification specific velocity	kgN/kgSSV*d	0,04
Nitrogen to undergo de-nitrification	**kgN/d**	152,56
De-nitrification capacity of the basin	**kgN/d**	**213,53**

Removed N in pre-denitrification	**kgN/d**	**152,56**
BOD_5 removed in pre-denitrification	**$kgBOD_5/kgN$**	2
BOD_5 removed in pre-denitrification	**$kgBOD_5/d$**	305,12
Retention time	h	2,81
Mixing specific power	W/m^3	0,00

Theoretical verification at the mean loads. Functional parameters.	**Unit of measure (U.M.)**	**Values**

Functional parameters of the biologic oxidation and nitrification station

Number of units/compartments	-	1
Total volume	m^3	4700
Organic load after pre-denitrification	$kgBOD_5/d$	822
Volumic load c_V	$kgBOD_5/m^3*d$	0,17
Suspended Solids load (SS)	$kgSS/m^3$	7,3
Sludge load c_F	**$kgBOD_5/kgSS*d$**	**0,03**
Removed BOD_5 (oxidation. + denitr.: ΔBOD_5)	$kgBOD_5/d$	1099
Removed BOD_5 in oxidation	$kgBOD_5/d$	794
BOD_5 removal (oxidation + de-nitrification)	%	97,5
Growth index	**$kgSS/kgBOD_{5,aat}$**	0,75
Production of removal (supero) sludges F_S (oxidation + de-nitrification)	kgSS/d	825
Sludge age	**d**	**27**
Theorethical oxigen demand	kgO_2/d	4554
Exercise temperature	°C	15
Saturation concentration	gO_2/m^3	9,8
Oxygen residual concentration	gO_2/m^3	3
Effective oxygen request	kgO_2/d	8538
Mean efficiency of the insufflation system	%	16
Air request/need	m^3/d	187907
Oxygenation capacity of blowers	m^3/d	40296000
Oxygenation capacity of surface aerators	kgO_2/d	0
Nitrification velocity (safe value)	$kgN\text{-}NH_4^+/kgSS*d$	0,09
Nitrification capacity	**kgN/d**	**3019**
N to be nitrified	**kgN/d**	**159**
N produce in nitrification	kgN/d	159
Retention time	h	11,73

Functional parameters of the post-de-nitrification station NOT EXISTING

Number of units	-	0
Total volume	m^3	0
Concetration of Suspended Solids (SS)	$kgSS/m^3$	7,3
VSS/SS	kgSSV/kgSS	0,65
Temperature	C	18
De-nitrification specific velocity	kgN/kgSSV*d	0,04
N to be de-nitrified	kgN/d	0,00
De-nitrification capacity of the basin	kgN/d	0,00
N removed in pre-denitrification	kgN/d	0,00
BOD_5 removed in post-denitrification	$kgBOD_5/kgN$	2
BOD_5 removed in post-denitrification	$kgBOD_5/d$	0,00
External supply of readily bio-degradable organic substances	$kgBOD_5/d$	0,00
N associated to the external source of Carbon	kgN/d	0
$N\text{-}NO_3$ supply to post-denitrification	kgN/d	6,34
Entering flow to post-denitrification $Q_m + Q_r$	m^3/h	282,23
Ritention time	h	0,00
Mixing specific power	W/m^3	0,00

Functional parameters for the secondary sedimentation station

Number of units	-	2
Diameter	m	
Mean depth	m	
Total surface of the station	m^2	508
Total volume of the station	m^3	1750
Overflow length	m	0
Hydraulic load at the overflow at Q_m	$m^3/m*h$	
Uprising velocity at Q_m	**m/h**	**0,18**
Uprising velocity at Q_p	m/h	0,27
Uprising velocity at Q_{max}	m/h	0,36
Retention time at Q_m	**h**	**19,22**
Retention time at Q_p	h	12,81
Retention time at Q_{max}	h	9,61
Recirculation ratio according to influent	-	2,1
Surface load of SS at Q_m	$kgSS/m^2*h$	**4,06**
SS concentration in the re-circulated flow	$kgSS/m^3$	10,77619048

Comments:

The plant presents a high residual capacity which allows the treatment of liquid wastes. The sludge load is C_F = 0,03, so it can be considered an “**extended aeration**” plant with high sludge age age of 27 days.

Annex VIII: WWTPs' discharges data for dangerous substances investigation

Fusina WWTP

SIRAV code	WWTP	DATE	Chloroform (µg/l)	Chloroform (mg/l)	1,1,1 Trichloroethane (µg/l)	1,1,1 Trichloroethane (mg/l)	1,2 Dichloroethane (µg/l)	Trichloroethilene (C2HCl3) (µg/l)	Trichloroethilene (C2HCl3) (mg/l)	Trichlorofluoromethane (µg/l)	Trichlorofluorometane (mg/l)	Bromophorm (µg/l)	Bromophorm (Tribromomethane) (mg/l)	Dibromochloromethane (µg/l)	Dibromochloromethane (mg/l)	Dichlorobromomethane (µg/l)	Dichlorobromomethane (mg/l)	Tetrachloroethilene (C2Cl4) (µg/l)	Tetrachloroethilene (C2Cl4) (mg/l)	Tetrachloromethane CCl4 (µg/l)	Tetrachloromethane CCl4 (mg/l)	Total organohalogenated solvents (µg/l)	Total organohalogenated solvents (mg/l)	Phenols (mg/l)
4140	Fusina WWTP	08/02/2005		<0,001		<0,0005			<0,0005		<0,0005		<0,001		<0,001		<0,001		<0,0005		<0,0005		<0,001	<0,004
4140	Fusina WWTP	05/04/2005		0,024		<0,0005			<0,0005		<0,0005		0,004		0,022		0,032		<0,0005		<0,0005		0,082	<0,004
4140	Fusina WWTP	26/05/2005	<0,4		<0,1		<1	<0,1		<0,1		<0,7		<0,2		<0,1		<0,1		<0,1		<1		0,01
4140	Fusina WWTP	21/06/2005	<0,4		<0,1			<0,1		<0,1		<0,7		<0,2		<0,1		<0,1		<0,1		<1		0,006
4140	Fusina WWTP	23/08/2005		<0,001		<0,0005			<0,0005		<0,0005		<0,001		<0,001		<0,001		<0,0005		<0,0005		<0,001	0,004
4140	Fusina WWTP	14/09/2005	<0,4		<0,1		<1	<0,1		<0,1		<0,7		<0,2		<0,1		<0,1		<0,1		<1		0,006
4140	Fusina WWTP	15/09/2005	<0,4		<0,1		<1	<0,1		<0,1		<0,7		<0,2		<0,1		<0,1		<0,1		<1		0,009
4140	Fusina WWTP	11/10/2005		<0,001		<0,0005			<0,0005		<0,0005		<0,001		<0,001		<0,001		<0,0005		<0,0005		<0,001	<0,004
4140	Fusina WWTP	24/01/2006		<0,001		<0,0005			<0,0005		<0,0005		<0,001		<0,001		<0,001		<0,0005		<0,0005		<0,001	0,011
4140	Fusina WWTP	21/03/2006		<0,001		<0,0005			<0,0005		<0,0005		<0,001		<0,001		<0,001		<0,0005		<0,0005		<0,001	0,01
4140	Fusina WWTP	24/05/2006	<0,4		<0,1		<1	<0,1		<0,1		<0,7		<0,2		<0,1		<0,1		<0,1		<1		0,01
4140	Fusina WWTP	19/09/2006		<0,001		<0,0005			<0,0005		<0,0005		<0,001		<0,001		<0,001		<0,0005		<0,0005		<0,001	0,006
4140	Fusina WWTP	15/11/2006		<0,001		<0,0005			<0,0005		<0,0005		<0,001		<0,001		<0,001		<0,0005		<0,0005		<0,001	0,007
4140	Fusina WWTP	19/12/2006		<0,001		<0,0005			<0,0005		<0,0005		<0,001		<0,001		<0,001		<0,0005		<0,0005		<0,001	0,009
4140	Fusina WWTP	23/01/2007		<0,001					<0,0005		<0,0005		<0,001		<0,001		<0,001	<0,0005	<0,0005	<0,0005			<0,001	<0,004
4140	Fusina WWTP	20/03/2007		<0,001					<0,0005		<0,0005		<0,001		<0,001		<0,001	<0,0005	<0,0005	<0,0005			<0,001	<0,004
4140	Fusina WWTP	15/05/2007		<0,001					<0,0005		<0,0005		<0,001		<0,001		<0,001	<0,0005	<0,0005	<0,0005			<0,001	0,014
4140	Fusina WWTP	06/07/2007		<0,001					<0,0005		<0,0005		<0,001		<0,001		<0,001	<0,0005	<0,0005	<0,0005			<0,001	0,057
4140	Fusina WWTP	23/10/2007		<0,001					<0,0005		<0,0005		<0,001		<0,001		<0,001	<0,0005	<0,0005	<0,0005			<0,001	0,019
4140	Fusina WWTP	19/12/2007		<0,001					<0,0005		<0,0005		<0,001		<0,001		<0,001	<0,0005	<0,0005	<0,0005			<0,001	0,006
4140	Fusina WWTP	22/01/2008	<0,001			<0,0005			<0,0005		<0,0005		<0,001	<0,001	<0,001				<0,0005		<0,0005		<0,001	0,014
4140	Fusina WWTP	04/03/2008	<0,001			<0,0005			<0,0005		<0,0005		<0,001	<0,001	<0,001				<0,0005		<0,0005		<0,001	<0,004
4140	Fusina WWTP	29/04/2008	<0,001			<0,0005			<0,0005		<0,0005		<0,001	<0,001	<0,001				<0,0005		<0,0005		<0,001	0,015
4140	Fusina WWTP	04/06/2008	<0,001			<0,0005			<0,0005		<0,0005		<0,001	<0,001	<0,001				<0,0005		<0,0005		<0,001	0,032
4140	Fusina WWTP	02/09/2008	<0,001			<0,0005			<0,0005				<0,001	<0,001	<0,001				<0,0005		<0,0005		<0,001	0,16
4140	Fusina WWTP	26/11/2008	<0,001			<0,0005			<0,0005				<0,001	<0,001	<0,001				<0,0005		<0,0005		<0,001	0,011
4140	Fusina WWTP	11/02/2009		0,001		<0,0005			<0,0005			<0,001			<0,001		<0,001		0,001		0,004		0,006	0,082
4140	Fusina WWTP	08/04/2009		<0,001		<0,0005			<0,0005			<0,001			<0,001		<0,001		<0,0005		<0,0005			0,013
4140	Fusina WWTP	24/06/2009	<0,1					<0,1			<0,3			<0,1		<0,1		0,1				<1		0,014
4140	Fusina WWTP	01/09/2009		<0,001		<0,0005			<0,0005			<0,001			<0,001		<0,001		<0,0005		<0,0005			0,006
4140	Fusina WWTP	16/12/2009																						0,015
4140	Fusina WWTP	27/01/2010		<0,01		<0,0005			<0,0005				<0,01		<0,01		<0,01		<0,0005		<0,0005			0,021
4140	Fusina WWTP	13/04/2010		<0,001		<0,0005			<0,0005				<0,001		<0,001		<0,001		<0,0005		<0,0005			<0,004
4140	Fusina WWTP	16/06/2010		<0,001		<0,0005			<0,0005				<0,001		<0,001		<0,001		<0,0005		<0,0005			0,013
4140	Fusina WWTP	11/08/2010		<0,001		<0,0005			<0,0005				<0,001		<0,001		<0,001		<0,0005		<0,0005			0,008
4140	Fusina WWTP	09/09/2010		<0,001		<0,0005			<0,0005				<0,001		<0,001		<0,001		<0,0005		<0,0005			0,01
4140	Fusina WWTP	07/10/2010		<0,001		<0,0001			<0,0001				<0,001		<0,001		<0,001		<0,0001		<0,0001			0,006
4140	Fusina WWTP	20/10/2010		<0,001		<0,0001			<0,0001				<0,001		<0,001		<0,001		<0,0001		<0,0001			0,009
4140	Fusina WWTP	15/12/2010		<0,001		<0,0001			<0,0001				<0,003		<0,001		<0,001		<0,0001		<0,0001			0,006
4140	Fusina WWTP	26/01/2011		<0,001		<0,0001			<0,0001				<0,001		<0,001		<0,001		<0,0001	<0,0001				0,009
4140	Fusina WWTP	30/03/2011		<0,001		<0,0005			<0,0005				<0,01		<0,001		<0,001		<0,001	<0,0005				0,004
4140	Fusina WWTP	12/05/2011																						<0,004
4140	Fusina WWTP	09/06/2011		<0,01		<0,01			<0,01				<0,01		<0,01		<0,01		<0,01	<0,01				<0,004
4140	Fusina WWTP	03/08/2011		<0,001		<0,0001			<0,0001				<0,001		<0,001		<0,001		<0,0001	<0,0001				0,004
4140	Fusina WWTP	08/09/2011		<0,001		<0,0001			<0,0001				<0,001		<0,001		<0,001		<0,0001	<0,0001				0,008
4140	Fusina WWTP	11/10/2011		<0,001		<0,0001			<0,0001				<0,001		<0,001		<0,001		<0,0001	<0,0001				<0,004
4140	Fusina WWTP	01/12/2011		<0,001		<0,0001			<0,0001				<0,001		<0,001		<0,001		<0,0001	<0,0001				<0,004
4140	Fusina WWTP	31/01/2012		<0,001		<0,0001			<0,0001				<0,001		<0,001		<0,001		<0,0001		<0,0001			0,01
4140	Fusina WWTP	21/03/2012		<0,001		<0,0001			<0,0001				<0,001		<0,001		<0,001		<0,0001		<0,0001			<0,004
4140	Fusina WWTP	04/12/2012		<0,001		<0,0001			<0,0001				<0,001		<0,001		<0,001		<0,0001		<0,0001			<0,004

Campalto WWTP

SIRAV code	WWTP	DATE	Active Chlorine (mg/l)	Chlorophorm (µg/l)	Chlorophorm (mg/l)	1,1,1 Trichloroethane (µg/l)	1,1,1 Trichloroethane (mg/l)	1,1 Dicloroethane (µg/l)	1,2 Dichloroethane (µg/l)	Trichloroethilene (C2HCl3) (µg/l)	Trichloroethilene (C2HCl3) (mg/l)	Trichlorofluorometane (mg/l)	Bromophorm (µg/l)	Bromophorm (Tribromomethane) (mg/l)	Dibromochloromethane (µg/l)	Dibromochloromethane (mg/l)	Dichlorobromomethane (µg/l)	Dichlorobromomethane (mg/l)	Tetrachloroethilene (C2Cl4) (µg/l)	Tetrachloroethilene (C2Cl4) (mg/l)	Tetrachloromethane CCl4 (µg/l)	Tetrachloromethane CCl4 (mg/l)	Total organohalogenated solvents (µg/l)	Total organohalogenated solvents (mg/l)	1,1 Dichloroethilene (µg/l)	1,1,1 Trichloroethane (mg/l)	1,1,2 Trichloroethane (µg/l)	1,1,2,2 Tetrachloroethane (µg/l)	1,2 Dibromoethane (µg/l)	1,2 Dicloroethilene cis (µg/l)	1,2 Dicloroethilene trans (µg/l)	1,2 Dichloropropane (µg/l)	1,2,3 Trichloropropane µg/l	Esachlorobutadiene (HCBD) (µg/l)	Phenols (mg/l)	Aldehydes (mg/l)
4141	Campalto WWTP	25/01/2005			<0,001		<0,0005				<0,0005	<0,0005		<0,001		<0,001		<0,001		<0,0005		<0,0005		<0,001											0,005	
4141	Campalto WWTP	05/04/2005			0,011		<0,0005				<0,0005	<0,0005		0,01		0,025		0,023		<0,0005		<0,0005		0,069											0,005	
4141	Campalto WWTP	08/06/2005			<0,001		<0,0005				<0,0005	<0,0005		<0,001		<0,001		<0,001		<0,0005		<0,0005		<0,001											0,008	
4141	Campalto WWTP	17/08/2005			<0,001		<0,0005				<0,0005	<0,0005		<0,001		<0,001		<0,001		<0,0005		<0,0005		<0,001											<0,004	
4141	Campalto WWTP	11/10/2005			<0,001		<0,0005				<0,0005	<0,0005		<0,001		<0,001		<0,001		<0,0005		<0,0005		<0,001											0,012	
4141	Campalto WWTP	07/02/2006			<0,001		<0,0005				<0,0005	<0,0005		<0,001		<0,001		<0,001		<0,0005		<0,0005		<0,001											0,012	
4141	Campalto WWTP	21/03/2006			<0,001		<0,0005				<0,0005	<0,0005		<0,001		<0,001		<0,001		<0,0005		<0,0005		<0,001											0,004	
4141	Campalto WWTP	24/05/2006			<0,001		<0,0005				<0,0005	<0,0005		<0,001		<0,001		<0,001		<0,0005		<0,0005		<0,001											0,024	
4141	Campalto WWTP	19/09/2006			<0,001		<0,0005				<0,0005	<0,0005		<0,001		<0,001		<0,001		<0,0005		<0,0005		<0,001											0,008	
4141	Campalto WWTP	15/11/2006			<0,001		<0,0005				<0,0005	<0,0005		<0,001		<0,001		<0,001		<0,0005		<0,0005		<0,001											<0,004	
4141	Campalto WWTP	19/12/2006			<0,001		<0,0005				<0,0005	<0,0005		<0,001		<0,001		<0,001		<0,0005		<0,0005		<0,001											0,004	
4141	Campalto WWTP	23/01/2007			<0,001						<0,0005	<0,0005		<0,001		<0,001		<0,001	<0,0005	<0,0005	<0,0005			<0,001											0,013	
4141	Campalto WWTP	17/04/2007			<0,001						<0,0005	<0,0005		<0,001		<0,001		<0,001	<0,0005	<0,0005	<0,0005			<0,001											0,007	
4141	Campalto WWTP	29/05/2007			<0,001						<0,0005	<0,0005		<0,001		<0,001		<0,001	<0,0005	<0,0005	<0,0005			<0,001											0,006	
4141	Campalto WWTP	11/09/2007			<0,001						<0,0005	<0,0005		<0,001		<0,001		<0,001	<0,0005	<0,0005	<0,0005			<0,001											0,008	
4141	Campalto WWTP	23/10/2007			<0,001						<0,0005	<0,0005		<0,001		<0,001		<0,001	<0,0005	<0,0005	<0,0005			<0,001											0,004	
4141	Campalto WWTP	19/12/2007			<0,001						<0,0005	<0,0005		<0,001		<0,001		<0,001	<0,0005	<0,0005	<0,0005			<0,001											<0,004	
4141	Campalto WWTP	22/01/2008		<0,001			<0,0005				<0,0005	<0,0005		<0,001	<0,001	<0,001				<0,0005		<0,0005		<0,001											0,006	
4141	Campalto WWTP	24/01/2008																																		
4141	Campalto WWTP	02/04/2008		<0,001			<0,0005				<0,0005	<0,0005		<0,001	<0,001	<0,001				<0,0005		<0,0005		<0,001											0,012	
4141	Campalto WWTP	04/06/2008		<0,001			<0,0005				<0,0005	<0,0005		<0,001	<0,001	<0,001				<0,0005		<0,0005		<0,001											0,004	
4141	Campalto WWTP	02/09/2008		<0,001			<0,0005				<0,0005			<0,001	<0,001	<0,001				<0,0005		<0,0005		<0,001											<0,004	
4141	Campalto WWTP	15/10/2008		<0,001			<0,0005				<0,0005			<0,001	<0,001	<0,001				<0,0005		<0,0005		<0,001											<0,004	
4141	Campalto WWTP	03/12/2008		<0,001			<0,0005				<0,0005			<0,001	<0,001	<0,001				<0,0005		<0,0005		<0,001											0,004	
4141	Campalto WWTP	25/02/2009			<0,001		<0,0005				<0,0005		<0,001			<0,001		<0,001		<0,0005		<0,0005		<0,001											0,007	
4141	Campalto WWTP	30/03/2009	<0,05	<0,4					<0,5	<0,1									<0,1		<0,1		<1												<0,004	0,17
4141	Campalto WWTP	24/06/2009																																	0,008	
4141	Campalto WWTP	01/09/2009																																		
4141	Campalto WWTP	24/09/2009																																	0,008	
4141	Campalto WWTP	21/10/2009																																	<0,004	
4141	Campalto WWTP	16/12/2009																																	0,007	
4141	Campalto WWTP	27/01/2010		<0,1				<0,5	<0,5	<0,1			<0,3		<0,1		<0,1		<0,1				<1		<0,5		<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5			
4141	Campalto WWTP	13/04/2010			<0,001						<0,0005			<0,001		<0,001		<0,001		<0,0005		<0,0005				<0,0005									0,01	
4141	Campalto WWTP	08/06/2010			<0,001						<0,0005			<0,001		<0,001		<0,001		<0,0005		<0,0005				<0,0005									0,009	
4141	Campalto WWTP	11/08/2010			<0,001						<0,0005			<0,001		<0,001		<0,001		<0,0005		<0,0005				<0,0005									0,006	
4141	Campalto WWTP	09/09/2010		<0,1				<0,5	<0,5	<0,1			<0,3		<0,1		<0,1		<0,1				<1		<0,5		<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5		0,006	
4141	Campalto WWTP	07/10/2010		<0,1				<0,5	<0,5	<0,1			<0,3		<0,1		<0,1		<0,1				<1		<0,5		<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5		0,008	
4141	Campalto WWTP	20/10/2010		<0,1						<0,1			<0,3		<0,1		<0,1		<0,1				<1												0,01	
4141	Campalto WWTP	15/12/2010		<0,1				<0,5	<0,5	<0,1			<0,3		<0,1		<0,1		<0,1						<0,5		<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5		0,007	
4141	Campalto WWTP	26/01/2011		<0,1		<0,5		<0,5	<0,5	<0,1			<0,3		<0,1		<0,1		<0,1				<1		<0,5			<0,5	<0,5	<0,5	<0,5	<0,5	<0,5		0,009	
4141	Campalto WWTP	30/03/2011		<0,1		<0,1		<0,1	<0,5	<0,1			<0,3		<0,1		<0,1		<0,1				<1		<0,1			<0,1	<0,1	<0,1	<0,1	<0,1	<0,1		0,007	
4141	Campalto WWTP	11/05/2011																																	0,007	
4141	Campalto WWTP	23/05/2011																																		
4141	Campalto WWTP	09/06/2011		<0,1		<0,1		<0,05	<0,03	<0,05			<0,3		<0,1		<0,1		<0,05				<1		<0,03			<0,05	<0,03	<0,05	<0,05	<0,05	<0,03		0,004	
4141	Campalto WWTP	03/08/2011		<0,1		<0,1		<0,1	<0,1	<0,1			<0,3		<0,1		<0,1		<0,1				<1		<0,1			<0,1	<0,1	<0,1	<0,1	<0,1	<0,1		0,004	
4141	Campalto WWTP	08/09/2011		<0,1		<0,5		<0,5	<0,5	<0,1			<0,3		<0,1		<0,1		<0,1				<1		<0,5			<0,5	<0,5	<0,5	<0,5	<0,5	<0,5		0,008	
4141	Campalto WWTP	11/10/2011		<0,1		<0,5		<0,5	<0,5	<0,1			<0,3		<0,1		<0,1		<0,1				<1		<0,5			<0,5	<0,5	<0,5	<0,5	<0,5	<0,5		<0,004	
4141	Campalto WWTP	01/12/2011			<0,001		<0,0001				<0,0001			<0,001		<0,001		<0,001		<0,0001	<0,0001														<0,004	
4141	Campalto WWTP	31/01/2012		<0,1				<0,5	<0,5	<0,1			<0,3		<0,1		<0,1		<0,1				<1		<0,5		<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5		0,01	
4141	Campalto WWTP	21/03/2012		<0,1				<0,5	<0,5	<0,1			<0,3		<0,1		<0,1		<0,1				<1		<0,5		<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5		<0,004	
4141	Campalto WWTP	09/05/2012		0,17				<0,05	<0,03	<0,05			<0,3		<0,1		<0,1		<0,05				0,24		<0,03		<0,1	<0,05	<0,03	<0,05	<0,05	<0,05	<0,03	<0,05	<0,004	
4141	Campalto WWTP	12/06/2012		<0,5				<0,5	<0,5	<0,5			<0,5		<0,5		<0,5		<0,5				<0,5		<0,5		<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5		<0,004	
4141	Campalto WWTP	17/07/2012		<0,5				<0,5	<0,5	<0,5			<0,5		<0,5		<0,5		<0,5				<0,5		<0,5		<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5		<0,004	
4141	Campalto WWTP	19/09/2012		<0,5				<0,5	<0,5	<0,5			<0,5		<0,5		<0,5		<0,5				<0,5		<0,5		<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	0,004	
4141	Campalto WWTP	16/10/2012		0,1				<0,5	<0,5	<0,1			<0,3		<0,1		<0,1		<0,1				<1		<0,5		<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	0,007	
4141	Campalto WWTP	04/12/2012		<0,5				<0,5	<0,5	<0,5			<0,5		<0,5		<0,5		<0,5				<1		<0,5		<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5		<0,004	

Lido WWTP

SIRAV code	WWTP	DATE	Active Chlorine (mg/l)	Chlorophorm (µg/l)	Chlorophorm (mg/l)	1,1,1 Trichloroethane (mg/l)	Trichloroethilene (C2HCl3) (mg/l)	Trichlorofluorometane (mg/l)	Bromophorm (Tribromomethane) (mg/l)	Dibromochloromethane (µg/l)	Dibromochloromethane (mg/l)	Dichlorobromomethane (mg/l)	Tetrachloroethilene (C2Cl4) (µg/l)	Tetrachloroethilene (C2Cl4) (mg/l)	Tetrachloromethane CCl4 (µg/l)	Tetrachloromethane CCl4 (mg/l)	Total organohalogenated solvents (mg/l)	Phenols (mg/l)
4143	Lido WWTP	22/03/2005			0,003	<0,0005	<0,0005	<0,0005	0,011		0,013	0,008		0,0005		<0,0005	0,035	<0,004
4143	Lido WWTP	14/06/2005	<0,05		0,002	<0,0005	<0,0005	<0,0005	0,27		0,085	0,014		<0,0005		<0,0005	0,371	<0,004
4143	Lido WWTP	02/08/2005	<0,05		<0,001	<0,0005	<0,0005	<0,0005	0,211		0,018	0,001		<0,0005		<0,0005	0,23	<0,004
4143	Lido WWTP	29/11/2005			<0,001	<0,0005	<0,0005	<0,0005	<0,001		<0,001	<0,001		<0,0005		<0,0005	<0,001	<0,004
4143	Lido WWTP	11/04/2006	<0,05		<0,001	<0,0005	<0,0005	<0,0005	0,068		0,009	0,001		<0,0005		<0,0005	0,078	0,005
4143	Lido WWTP	25/07/2006	<0,05		0,001	<0,0005	<0,0005	<0,0005	0,06		0,005	<0,001		<0,0005		<0,0005	0,066	<0,004
4143	Lido WWTP	06/09/2006	<0,05		<0,001	<0,0005	<0,0005	<0,0005	0,14		0,03	0,003		<0,0005		<0,0005	0,173	<0,004
4143	Lido WWTP	03/04/2007	<0,05		<0,001		<0,0005	<0,0005	0,159		0,018	0,002	<0,0005	<0,0005	<0,0005		0,179	<0,004
4143	Lido WWTP	17/07/2007	<0,03		<0,001		<0,0005	<0,0005	0,12		0,02	0,002	<0,0005	<0,0005	<0,0005		0,142	<0,004
4143	Lido WWTP	29/08/2007	<0,05		<0,001		<0,0005	<0,0005	0,165		0,03	0,002	<0,0005	<0,0005	<0,0005		0,198	<0,004
4143	Lido WWTP	06/05/2008	<0,5	<0,001		<0,0005	<0,0005	<0,0005	0,24	0,019	<0,001			<0,0005		<0,0005	0,259	<0,004
4143	Lido WWTP	26/06/2008	<0,05	0,002		<0,0005	<0,0005		0,057	0,026	0,006			<0,0005		<0,0005	0,091	<0,004
4143	Lido WWTP	10/12/2009	<0,05															0,007
4143	Lido WWTP	30/06/2010	<0,05															0,008
4143	Lido WWTP	22/12/2010																<0,004
4143	Lido WWTP	29/06/2011	<0,05															0,005
4143	Lido WWTP	15/12/2011																0,007
4143	Lido WWTP	08/03/2012																0,008
4143	Lido WWTP	26/07/2012																
4143	Lido WWTP	13/12/2012																0,006

Cavallino WWTP

SIRAV code	WWTP	DATE	Active Chlorine (mg/l)	Chlorophorm (µg/l)	Chlorophorm (mg/l)	1,1,1 Trichloroethane (mg/l)	Trichloroethilene (C2HCl3) (mg/l)	Bromophorm (Tribromomethane) (mg/l)	Dibromochloromethane (µg/l)	Dibromochloromethane (mg/l)	Dichlorobromomethane (mg/l)	Tetrachloroethilene (C2Cl4) (µg/l)	Tetrachloroethilene (C2Cl4) (mg/l)	Tetrachloromethane CCl4 (µg/l)	Tetrachloromethane CCl4 (mg/l)	Total organohalogenated solvents (mg/l)	Phenols (mg/l)
4167	Cavallino WWTP	19/04/2005	<0,05		0,002	<0,0005	<0,0005	0,293		0,065	0,012		<0,0005		<0,0005	0,372	<0,004
4167	Cavallino WWTP	05/07/2005	<0,05		0,01	<0,0005	<0,0005	0,055		0,07	0,031		<0,0005		<0,0005	0,166	<0,004
4167	Cavallino WWTP	09/08/2005	<0,05		0,01	<0,0005	<0,0005	0,1		0,099	0,032		<0,0005		<0,0005	0,241	<0,004
4167	Cavallino WWTP	04/10/2005															0,023
4167	Cavallino WWTP	19/04/2006	<0,5		0,001	<0,0005	<0,0005	0,151		0,066	0,01		<0,0005		<0,0005	0,228	<0,004
4167	Cavallino WWTP	04/07/2006	<0,05		0,015	<0,0005	<0,0005	0,048		0,057	0,031		<0,0005		<0,0005	0,151	<0,004
4167	Cavallino WWTP	08/08/2006	<0,05		0,021	<0,0005	<0,0005	0,031		0,05	0,033		<0,0005		<0,0005	0,135	<0,004
4167	Cavallino WWTP	27/02/2007			<0,001		<0,0005	0,001		<0,001	<0,001	<0,0005	<0,0005	<0,0005		0,001	0,005
4167	Cavallino WWTP	03/07/2007	<0,05		0,006		<0,0005	0,018		0,026	0,014	<0,0005	<0,0005	<0,0005		0,064	0,018
4167	Cavallino WWTP	31/07/2007	<0,03		0,015		<0,0005	0,031		0,044	0,028	<0,0005	<0,0005	<0,0005		0,118	<0,004
4167	Cavallino WWTP	09/01/2008		<0,001		<0,0005	<0,0005	<0,001	<0,001	<0,001			<0,0005		<0,0005	<0,001	0,006
4167	Cavallino WWTP	08/07/2008		<0,001		<0,0005	<0,0005	<0,001	<0,001	<0,001			<0,0005		<0,0005	<0,001	0,009
4167	Cavallino WWTP	19/08/2008															
4167	Cavallino WWTP	20/08/2008	<0,05	<0,001		<0,0005	<0,0005	<0,001	<0,001	<0,001			<0,0005		<0,0005	<0,001	<0,004
4167	Cavallino WWTP	21/01/2009															0,004
4167	Cavallino WWTP	21/07/2009															0,011
4167	Cavallino WWTP	12/08/2009															0,011
4167	Cavallino WWTP	03/02/2010															0,004
4167	Cavallino WWTP	24/03/2010															0,006
4167	Cavallino WWTP	18/08/2010															0,005
4167	Cavallino WWTP	01/09/2010															0,007
4167	Cavallino WWTP	03/02/2011															<0,004
4167	Cavallino WWTP	24/08/2011															0,004
4167	Cavallino WWTP	26/10/2011															<0,004
4167	Cavallino WWTP	26/01/2012															0,004
4167	Cavallino WWTP	07/06/2012															<0,004
4167	Cavallino WWTP	30/08/2012															0,005

Chioggia WWTP

SIRAV code	WWTP	DATE	Active Chlorine (mg/l)	Chlorophorm (µg/l)	Chlorophorm (mg/l)	1,1,1 Trichloroethane (mg/l)	Trichloroethilene (C2HCl3) (mg/l)	Trichlorofluorometane (mg/l)	Bromophorm (Tribromomethane) (mg/l)	Dibromochloromethane (µg/l)	Dibromochloromethane (mg/l)	Dichlorobromomethane (mg/l)	Tetrachloroethilene (C2Cl4) (µg/l)	Tetrachloroethilene (C2Cl4) (mg/l)	Tetrachloromethane CCl4 (µg/l)	Tetrachloromethane CCl4 (mg/l)	Total organohalogenated solvents (µg/l)	Total organohalogenated solvents (mg/l)	Phenols (mg/l)
4139	Chioggia WWTP	09/03/2005	<0,05		<0,001	<0,0005	<0,0005	<0,0005	0,033		0,004	<0,001		<0,0005		<0,0005		0,037	<0,004
4139	Chioggia WWTP	12/07/2005	<0,05		<0,001	<0,0005	<0,0005	<0,0005	0,041		0,003	<0,001		<0,0005		<0,0005		0,044	0,005
4139	Chioggia WWTP	17/08/2005			<0,001	<0,0005	<0,0005	<0,0005	0,026		0,001	<0,001		<0,0005		<0,0005		0,027	0,006
4139	Chioggia WWTP	21/12/2005	<0,05		<0,001	<0,0005	<0,0005	<0,0005	0,066		0,004	<0,001		<0,0005		<0,0005		0,07	<0,004
4139	Chioggia WWTP	10/02/2006	<0,05		<0,001	<0,0005	<0,0005	<0,0005	0,044		0,004	<0,001		<0,0005		<0,0005		0,048	0,005
4139	Chioggia WWTP	11/07/2006	<0,05		<0,001	<0,0005	<0,0005	<0,0005	0,063		0,004	<0,001		<0,0005		<0,0005		0,067	0,005
4139	Chioggia WWTP	22/08/2006	<0,05		<0,001	<0,0005	<0,0005	<0,0005	0,08		0,004	<0,001		<0,0005		<0,0005		0,084	<0,004
4139	Chioggia WWTP	28/11/2006	<0,05		0,006	<0,0005	<0,0005	<0,0005	0,046		<0,001	<0,001		<0,0005		0,0026		0,0546	<0,004
4139	Chioggia WWTP	06/02/2007	<0,05		0,001		<0,0005	<0,0005	0,121		0,01	0,001	<0,0005	<0,0005	<0,0005			0,133	<0,004
4139	Chioggia WWTP	09/05/2007	<0,05		<0,001		<0,0005	<0,0005	0,042		0,003	<0,001	<0,0005	<0,0005	<0,0005			0,045	0,004
4139	Chioggia WWTP	20/06/2007	<0,05		<0,001		<0,0005	<0,0005	0,094		0,004	<0,001	<0,0005	<0,0005	<0,0005			0,099	<0,004
4139	Chioggia WWTP	11/07/2007	<0,03		<0,001		<0,0005	<0,0005	0,06		0,004	<0,001	<0,0005	<0,0005	<0,0005			0,064	0,007
4139	Chioggia WWTP	27/11/2007	<0,05		<0,001		<0,0005	<0,0005	0,046		0,003	<0,001	<0,0005	<0,0005	<0,0005			0,049	<0,004
4139	Chioggia WWTP	05/02/2008		<0,001		<0,0005	<0,0005	<0,0005	0,003	<0,001	<0,001			<0,0005		<0,0005		0,003	<0,004
4139	Chioggia WWTP	05/08/2008		<0,001		<0,0005	<0,0005		<0,001	<0,001	<0,001			<0,0005		<0,0005		<0,001	0,011
4139	Chioggia WWTP	09/09/2008		<0,001		<0,0005	<0,0005		<0,001	<0,001	<0,001			<0,0005		<0,0005		<0,001	0,018
4139	Chioggia WWTP	28/10/2008		<0,001		<0,0005	<0,0005		<0,001	<0,001	<0,001			<0,0005		<0,0005		<0,001	0,007
4139	Chioggia WWTP	25/02/2009																	<0,004
4139	Chioggia WWTP	02/07/2009																	0,006
4139	Chioggia WWTP	28/07/2009																	0,009
4139	Chioggia WWTP	27/08/2009																	0,006
4139	Chioggia WWTP	03/03/2010																	0,005
4139	Chioggia WWTP	30/06/2010																	0,007
4139	Chioggia WWTP	21/07/2010	<0,03																<0,004
4139	Chioggia WWTP	07/09/2010																	0,008
4139	Chioggia WWTP	05/05/2011	<0,05																<0,004
4139	Chioggia WWTP	07/06/2011	<0,05																<0,004
4139	Chioggia WWTP	19/07/2011	<0,1																<0,004
4139	Chioggia WWTP	15/12/2011	<0,05																0,005
4139	Chioggia WWTP	14/03/2012	<0,1																<0,004
4139	Chioggia WWTP	13/06/2012	<0,05																0,004
4139	Chioggia WWTP	25/07/2012																	<0,004
4139	Chioggia WWTP	29/08/2012																	<0,004
4139	Chioggia WWTP	13/12/2012																	<0,004

Quarto d'Altino WWTP

SIRAV code	WWTP	DATE	Active Chlorine (mg/l)	Chlorophorm (µg/l)	Chlorophorm (mg/l)	1,1,1 Trichloroethane (mg/l)	Trichloroethilene (C2HCl3) (mg/l)	Trichlorofluorometane (mg/l)	romophorm (Tribromomethane) (µg/l)	Bromophorm (Tribromomethane) (mg/l)	Dibromochloromethane (µg/l)	Dibromochloromethane (mg/l)	Dichlorobromomethane (mg/l)	Tetrachloroethilene (C2Cl4) (µg/l)	Tetrachloroethilene (C2Cl4) (mg/l)	Tetrachloromethane CCl4 (µg/l)	Tetrachloromethane CCl4 (mg/l)	Total organohalogenated solvents (mg/l)	Phenols (mg/l)
4164	Quarto d'Al	25/01/05			<0,001	<0,0005	<0,0005	<0,0005		<0,001		<0,001	<0,001		<0,0005		<0,0005	<0,001	0,109
4164	Quarto d'Al	27/04/05			0,001	<0,0005	<0,0005	<0,0005		<0,001		<0,001	<0,001		<0,0005		<0,0005	0,001	0,02
4164	Quarto d'Al	24/01/06			<0,001	<0,0005	<0,0005	<0,0005		<0,001		<0,001	<0,001		<0,0005		<0,0005	<0,001	0,006
4164	Quarto d'Al	03/05/06			<0,001	<0,0005	<0,0005	<0,0005		<0,001		<0,001	<0,001		<0,0005		<0,0005	<0,001	<0,004
4164	Quarto d'Al	18/10/06			<0,001	<0,0005	<0,0005	<0,0005		<0,001		<0,001	<0,001		<0,0005		<0,0005	<0,001	0,01
4164	Quarto d'Al	06/02/07			<0,001		<0,0005	<0,0005		<0,001		<0,001	<0,001	<0,0005	<0,0005	<0,0005		<0,001	0,006
4164	Quarto d'Al	16/10/07			<0,001		<0,0005			<0,001		<0,001	<0,001	<0,0005	<0,0005	<0,0005		<0,001	<0,004
4164	Quarto d'Al	04/12/07			<0,001		<0,0005	<0,0005		<0,001		<0,001	<0,001	<0,0005	<0,0005	<0,0005		<0,001	0,006
4164	Quarto d'Al	26/02/08		<0,001		<0,0005	<0,0005	<0,0005		<0,001	<0,001	<0,001			<0,0005		<0,0005	<0,001	0,038
4164	Quarto d'Al	18/06/08		<0,001		<0,0005	<0,0005			<0,001	<0,001	<0,001			<0,0005		<0,0005	<0,001	0,018
4164	Quarto d'Al	09/09/08		<0,001		<0,0005	<0,0005			<0,001	<0,001	<0,001			<0,0005		<0,0005	<0,001	0,01
4164	Quarto d'Al	04/03/09			<0,001	<0,0005	<0,0005		<0,001			<0,001	<0,001		<0,0005		<0,0005	<0,001	0,01
4164	Quarto d'Al	09/06/09			<0,001	<0,0005	<0,0005		<0,001			<0,001	<0,001		<0,0005		<0,0005		0,005
4164	Quarto d'Al	06/10/09																	0,014
4164	Quarto d'Al	05/11/09																	<0,004
4164	Quarto d'Al	10/03/10			<0,001		<0,0005			<0,001		<0,001	<0,001		<0,0005		<0,0005		<0,004
4164	Quarto d'Al	25/05/10			<0,001		<0,0005			<0,003		<0,001	<0,001		<0,0005		<0,0005		0,007
4164	Quarto d'Al	19/09/10			<0,001		<0,0001			<0,001		<0,001	<0,001		<0,0001		<0,0001		0,005
4164	Quarto d'Al	29/06/11																	0,008
4164	Quarto d'Al	27/10/11	<0,05																0,004
4164	Quarto d'Al	09/11/11																	<0,004
4164	Quarto d'Al	02/02/12																	0,012
4164	Quarto d'Al	22/08/12			<0,001		<0,0005			<0,001		<0,001	<0,001		<0,0005		<0,0005		<0,004
4164	Quarto d'Al	30/10/12			<0,001		<0,0005			<0,001		<0,001	<0,001		<0,0005		<0,0005		<0,004

Bibione WWTP

SIRAV Code	WWTP	DATE	Active Chlorine (mg/l)	Chlorophorm (µg/l)	Chlorophorm (mg/l)	1,1,1 Trichloroethane (mg/l)	Trichloroethilene (C2HCl3) (mg/l)	Trichlorofluorometane (mg/l)	Bromophorm (Tribromomethane) (mg/l)	Dibromochloromethane (mg/l)	Dichlorobromomethane (mg/l)	Tetrachloroethilene (C2Cl4) (µg/l)	Tetrachloroethilene (C2Cl4) (mg/l)	Tetrachloromethane CCl4 (µg/l)	Tetrachloromethane CCl4 (mg/l)	Total organohalogenated solvents (mg/l)	Phenols (mg/l)
4161	Bibione WWTP	02/03/2005			<0,001	<0,0005	<0,0005	<0,0005	<0,001	<0,001	<0,001		<0,0005		<0,0005	<0,001	<0,004
4161	Bibione WWTP	21/06/2005	<0,05		0,005	<0,0005	<0,0005	<0,0005	0,008	0,008	0,004		<0,0005		<0,0005	0,025	<0,004
4161	Bibione WWTP	19/07/2005	<0,05		0,001	<0,0005	<0,0005	<0,0005	0,001	<0,001	0,002		<0,0005		<0,0005	0,004	0,004
4161	Bibione WWTP	06/12/2005			0,002	<0,0005	<0,0005	<0,0005	<0,001	<0,001	<0,001		<0,0005		<0,0005	0,002	<0,004
4161	Bibione WWTP	13/06/2006	<0,05		0,003	<0,0005	<0,0005	<0,0005	0,02	0,023	0,009		<0,0005		<0,0005	0,055	0,024
4161	Bibione WWTP	01/08/2006	<0,05		0,018	<0,0005	<0,0005	<0,0005	<0,001	0,018	0,016		<0,0005		<0,0005	0,052	<0,004
4161	Bibione WWTP	12/12/2006			<0,001	<0,0005	<0,0005	<0,0005	<0,001	<0,001	<0,001		<0,0005		<0,0005	<0,001	<0,004
4161	Bibione WWTP	06/06/2007	<0,05		0,001		<0,0005	<0,0005	0,035	0,011	0,003	<0,0005	<0,0005	<0,0005		0,05	<0,004
4161	Bibione WWTP	17/07/2007	<0,03		0,002		<0,0005	<0,0005	0,004	0,006	0,004	<0,0005	<0,0005	<0,0005		0,02	<0,004
4161	Bibione WWTP	07/08/2007	296,4														
4161	Bibione WWTP	21/08/2007	<0,05		0,008		<0,0005	<0,0005	0,001	0,005	0,008	<0,0005	<0,0005	<0,0005		0,022	0,009
4161	Bibione WWTP	12/03/2008		<0,001		<0,0005	<0,0005	<0,0005	<0,001	<0,001			<0,0005		<0,0005	<0,001	<0,004
4161	Bibione WWTP	26/06/2008	<0,05	0,003		<0,0005	<0,0005		0,024	0,007			<0,0005		<0,0005	0,053	<0,004
4161	Bibione WWTP	27/08/2008	<0,05	0,002		<0,0005	<0,0005		<0,001	<0,001			<0,0005		<0,0005	0,002	<0,004
4161	Bibione WWTP	21/04/2009	<0,05														<0,004
4161	Bibione WWTP	16/06/2009	<0,05														0,009
4161	Bibione WWTP	28/07/2009	<0,05														0,01
4161	Bibione WWTP	17/02/2010															<0,004
4161	Bibione WWTP	23/06/2010	<0,05														0,005
4161	Bibione WWTP	25/08/2010	<0,05														<0,004
4161	Bibione WWTP	21/09/2010	<0,05														0,006
4161	Bibione WWTP	13/04/2011															0,006
4161	Bibione WWTP	13/07/2011	<0,05														0,005
4161	Bibione WWTP	31/08/2011	<0,05														<0,004
4161	Bibione WWTP	29/02/2012															<0,004
4161	Bibione WWTP	29/08/2012	<0,05														0,004
4161	Bibione WWTP	20/09/2012	<0,05														<0,004
4161	Bibione WWTP	18/12/2012															<0,004

S. Stino di Livenza WWTP

SIRAV code	WWTP	DATE	Active Chlorine (mg/l)	Chlorophorm (µg/l)	Chlorophorm (mg/l)	1,1,1 Trichloroethane (mg/l)	Trichloroethilene (C2HCl3) (mg/l)	Trichlorofluorometane (mg/l)	Bromophorm (Tribromomethane) (mg/l)	Dibromochloromethane (µg/l)	Dibromochloromethane (mg/l)	Dichlorobromomethane (mg/l)	Tetrachloroethilene (C2Cl4) (µg/l)	Tetrachloroethilene (C2Cl4) (mg/l)	Tetrachloromethane CCl4 (µg/l)	Tetrachloromethane CCl4 (mg/l)	Total organohalogenated solvents (mg/l)	1,1,1 Tri-Chloro-Ethane (mg/l)	Fenoli mg/l
4158	S. Stino di L. WWTP	09/05/2005	<0,05		<0,001	<0,0005	<0,0005	<0,0005	<0,001		<0,001	<0,001		<0,0005		<0,0005	<0,001		<0,004
4158	S. Stino di L. WWTP	09/06/2005			<0,001	<0,0005	<0,0005	<0,0005	<0,001		<0,001	<0,001		<0,0005		<0,0005	<0,001		0,018
4158	S. Stino di L. WWTP	03/05/2006			<0,001	<0,0005	<0,0005	<0,0005	<0,001		<0,001	<0,001		<0,0005		<0,0005	<0,001		0,004
4158	S. Stino di L. WWTP	26/09/2006			<0,001	<0,0005	0,005	<0,0005	<0,001		<0,001	<0,001		<0,0005		<0,0005	0,005		0,007
4158	S. Stino di L. WWTP	12/06/2007			<0,001		<0,0005	<0,0005	<0,001		<0,001	<0,001	<0,0005	<0,0005	<0,0005		<0,001		0,01
4158	S. Stino di L. WWTP	19/09/2007			<0,001		<0,0005	<0,0005	<0,001		<0,001	<0,001	<0,0005	<0,0005	<0,0005		<0,001		0,009
4158	S. Stino di L. WWTP	13/12/2007			<0,001		<0,0005	<0,0005	<0,001		<0,001	<0,001	<0,0005	<0,0005	<0,0005		<0,001		0,012
4158	S. Stino di L. WWTP	18/03/2008		<0,001		<0,0005	<0,0005	<0,0005	<0,001	<0,001	<0,001			<0,0005		<0,0005	<0,001		0,022
4158	S. Stino di L. WWTP	14/05/2008		<0,001		<0,0005	<0,0005	<0,0005	<0,001	<0,001	<0,001			<0,0005		<0,0005	<0,001		0,015
4158	S. Stino di L. WWTP	22/10/2008		<0,001		<0,0005	<0,0005		<0,001	<0,001	<0,001			<0,0005		<0,0005	<0,001		0,012
4158	S. Stino di L. WWTP	16/09/2009																	<0,004
4158	S. Stino di L. WWTP	06/10/2009																	<0,004
4158	S. Stino di L. WWTP	05/11/2009																	0,01
4158	S. Stino di L. WWTP	18/03/2010			<0,001		<0,0005		<0,001		<0,001	<0,001		<0,0005		<0,0005		<0,0005	
4158	S. Stino di L. WWTP	14/07/2010																	0,015
4158	S. Stino di L. WWTP	07/09/2010																	0,014
4158	S. Stino di L. WWTP	19/09/2010																	0,005
4158	S. Stino di L. WWTP	01/12/2010																	0,005
4158	S. Stino di L. WWTP	05/07/2011																	0,009
4158	S. Stino di L. WWTP	13/09/2011																	0,01
4158	S. Stino di L. WWTP	05/10/2011																	0,014
4158	S. Stino di L. WWTP	25/07/2012			<0,001		<0,0005		<0,001		<0,001	<0,001		<0,0005		<0,0005		<0,0005	0,008

Portogruaro WWTP

SIRAV code	WWTP	DATE	Active Chlorine (mg/l)	Chlorophorm (µg/l)	Chlorophorm (mg/l)	1,1,1 Trichloroethane (mg/l)	Trichloroethilene (C2HCl3) (mg/l)	Trichlorofluorometane (mg/l)	Bromophorm (Tribromomethane) (mg/l)	Dibromochloromethane (µg/l)	Dibromochloromethane (mg/l)	Dichlorobromomethane (mg/l)	Tetrachloroethilene (C2Cl4) (µg/l)	Tetrachloroethilene (C2Cl4) (mg/l)	Tetrachloromethane CCl4 (µg/l)	Tetrachloromethane CCl4 (mg/l)	Total organohalogenated solvents (mg/l)	1,1,1 Tri-Chloro-Ethane (mg/l)	Fenoli mg/l
4162	Portogruaro WWTP	21/09/05			<0,001	<0,0005	<0,0005	<0,0005	<0,001		<0,001	<0,001		<0,0005		<0,0005	<0,001		<0,004
4162	Portogruaro WWTP	11/04/06			<0,001	<0,0005	<0,0005	<0,0005	<0,001		<0,001	<0,001		<0,0005		<0,0005	<0,001		0,053
4162	Portogruaro WWTP	10/10/06			<0,001	<0,0005	<0,0005	<0,0005	<0,001		<0,001	<0,001		<0,0005		<0,0005	<0,001		0,005
4162	Portogruaro WWTP	03/05/07			<0,001		<0,0005	<0,0005	<0,001		<0,001	<0,001	<0,0005	<0,0005	<0,0005		<0,001		0,025
4162	Portogruaro WWTP	09/04/08		<0,001		<0,0005	<0,0005	<0,0005	<0,001	<0,001	<0,001			<0,0005		<0,0005	<0,001		0,012
4162	Portogruaro WWTP	24/03/09																	0,022
4162	Portogruaro WWTP	09/09/09																	<0,004
4162	Portogruaro WWTP	14/10/09																	0,007
4162	Portogruaro WWTP	10/03/10			<0,001		<0,0005		<0,001		<0,001	<0,001		<0,0005		<0,0005		<0,0005	0,007
4162	Portogruaro WWTP	25/08/10			<0,001		<0,0005		<0,001		<0,001	<0,001		<0,0005		<0,0005		<0,001	0,011
4162	Portogruaro WWTP	01/12/10			<0,001		<0,0005		<0,001		<0,001	<0,001		<0,0005		<0,0005		<0,0005	0,007
4162	Portogruaro WWTP	10/03/11	<0,05		<0,001	<0,0005	<0,005		<0,01		<0,001	<0,001		<0,0005	<0,0005				0,011
4162	Portogruaro WWTP	25/05/11																	0,006
4162	Portogruaro WWTP	28/03/12			<0,001		<0,0001		<0,001		<0,001	<0,001		<0,0001		<0,0001		<0,0001	0,013
4162	Portogruaro WWTP	27/09/12																	0,006

Jesolo WWTP

SIRAV code	WWTP	DATE	Active Chlorine (mg/l)	Chlorophorm (µg/l)	Chlorophorm (mg/l)	1,1,1 Trichloroethane (mg/l)	1,1 Dicloroethane (µg/l)	1,2 Dichloroethane (µg/l)	Trichloroethilene (C2HCl3) (µg/l)	Trichloroethilene (C2HCl3) (mg/l)	Trichlorofluorometane (mg/l)	Bromophorm (µg/l)	Bromophorm (Tribromomethane) (mg/l)	Dibromochloromethane (µg/l)	Dibromochloromethane (mg/l)	Dichlorobromomethane (µg/l)	Dichlorobromomethane (mg/l)	Tetrachloroethilene (C2Cl4) (µg/l)	Tetrachloroethilene (C2Cl4) (mg/l)	Tetrachloromethane CCl4 (µg/l)	Tetrachloromethane CCl4 (mg/l)	Total organohalogenated solvents (µg/l)	Total organohalogenated solvents (mg/l)	1,1 Dichloroethilene (µg/l)	1,1,2 Trichloroethane (µg/l)	1,1,2,2 Tetrachloroethane (µg/l)	1,2 Dibromoethane (µg/l)	1,2 Dicloroethilene cis (µg/l)	1,2 Dicloroethilene trans (µg/l)	1,2 Dichloropropane (µg/l)	1,2,3 Trichloropropane µg/l	Esachlorobutadiene (HCBD) (µg/l)	Phenols (µg/l)	Phenols (mg/l)	Phenols and Chlorophenols (sum; µg/l)	Pentaclorofenolo µg/l	2,4 Diclorofenolo µg/l	2,4,5-Triclorofenolo µg/l	2,4,6-Triclorofenolo µg/l	2-Clorofenolo µg/l	3-Clorofenolo µg/l	4-Clorofenolo µg/l
4155	Jesolo WWTP	19/04/2005			0,001	<0,0005				<0,0005	<0,0005		0,003		0,003		0,002		<0,0005		<0,0005		0,009											0,005								
4155	Jesolo WWTP	05/07/2005	<0,05		<0,001	<0,0005				<0,0005	<0,0005		<0,001		<0,001		<0,001		<0,0005		<0,0005		<0,001											<0,004								
4155	Jesolo WWTP	09/08/2005			<0,001	<0,0005				<0,0005	<0,0005		<0,001		<0,001		<0,001		<0,0005		<0,0005		<0,001											<0,004								
4155	Jesolo WWTP	04/10/2005			<0,001	<0,0005				<0,0005	<0,0005		<0,001		<0,001		<0,001		<0,0005		<0,0005		<0,001											0,004								
4155	Jesolo WWTP	04/07/2006			<0,001	<0,0005				<0,0005	<0,0005		<0,001		<0,001		<0,001		<0,0005		<0,0005		<0,001											0,006								
4155	Jesolo WWTP	08/08/2006			<0,001	<0,0005				<0,0005	<0,0005		<0,001		<0,001		<0,001		<0,0005		<0,0005		<0,001											0,006								
4155	Jesolo WWTP	04/10/2006			<0,001	<0,0005				<0,0005	<0,0005		<0,001		<0,001		<0,001		<0,0005		<0,0005		<0,001											<0,004								
4155	Jesolo WWTP	03/07/2007			<0,001					<0,0005	<0,0005		<0,001		<0,001		<0,001	<0,0005	<0,0005	<0,0005			<0,001											0,007								
4155	Jesolo WWTP	31/07/2007			<0,001					<0,0005	<0,0005		<0,001		<0,001		<0,001	<0,0005	<0,0005	<0,0005			<0,001											0,005								
4155	Jesolo WWTP	11/09/2007			<0,001					<0,0005	<0,0005		<0,001		<0,001		<0,001	<0,0005	<0,0005	<0,0005			<0,001											0,007								
4155	Jesolo WWTP	08/01/2008																																								
4155	Jesolo WWTP	09/01/2008		<0,001		<0,0005				<0,0005	<0,0005		<0,001	<0,001	<0,001				<0,0005		<0,0005		<0,001											<0,004								
4155	Jesolo WWTP	07/07/2008																																								
4155	Jesolo WWTP	08/07/2008	<0,05	0,007		<0,0005				<0,0005			0,002	0,005	0,007				<0,0005		<0,0005		0,021											0,004								
4155	Jesolo WWTP	19/08/2008																																								
4155	Jesolo WWTP	20/08/2008	<0,05	0,001		<0,0005				<0,0005			<0,001	<0,001	<0,001				<0,0005		<0,0005		0,001											<0,004								
4155	Jesolo WWTP	20/01/2009																																								
4155	Jesolo WWTP	21/01/2009																																<0,004								
4155	Jesolo WWTP	17/03/2009																																								
4155	Jesolo WWTP	18/03/2009																																								
4155	Jesolo WWTP	20/07/2009																																								
4155	Jesolo WWTP	21/07/2009	<0,05																															0,007								
4155	Jesolo WWTP	11/08/2009																																								
4155	Jesolo WWTP	12/08/2009	<0,05																															0,01								
4155	Jesolo WWTP	07/10/2009																																								
4155	Jesolo WWTP	08/10/2009																																								
4155	Jesolo WWTP	02/02/2010																																								
4155	Jesolo WWTP	03/02/2010																																0,005								
4155	Jesolo WWTP	23/03/2010																																								
4155	Jesolo WWTP	24/03/2010	<0,05																															0,005								
4155	Jesolo WWTP	16/06/2010																																								
4155	Jesolo WWTP	17/06/2010	<0,05																															<0,004								
4155	Jesolo WWTP	26/07/2010																																								
4155	Jesolo WWTP	27/07/2010	<0,05																															0,009								
4155	Jesolo WWTP	11/10/2010																																								
4155	Jesolo WWTP	12/10/2010																																								
4155	Jesolo WWTP	27/10/2010																																								
4155	Jesolo WWTP	28/10/2010																																								
4155	Jesolo WWTP	03/02/2011																																<0,004								
4155	Jesolo WWTP	14/04/2011																																								
4155	Jesolo WWTP	18/05/2011																																								
4155	Jesolo WWTP	19/05/2011																																								
4155	Jesolo WWTP	06/07/2011																																								
4155	Jesolo WWTP	07/07/2011																																								
4155	Jesolo WWTP	23/08/2011																																								
4155	Jesolo WWTP	24/08/2011	<0,1																															0,005								
4155	Jesolo WWTP	26/10/2011	<0,05																															<0,004								
4155	Jesolo WWTP	26/01/2012																																0,005								
4155	Jesolo WWTP	15/03/2012																																								
4155	Jesolo WWTP	06/06/2012																																								
4155	Jesolo WWTP	07/06/2012	<0,05																															<0,004								
4155	Jesolo WWTP	18/07/2012		<0,1			<0,05	<0,03	<0,05			<0,3		<0,1		<0,1		<0,05				<1		<0,03	<0,1	<0,05	<0,03	<0,05	<0,05	<0,05	<0,03	<0,05	0,05		<0,2	<1	<1	<1	<1	<0,4	<0,4	<0,4
4155	Jesolo WWTP	13/08/2012		<0,1			<0,05	<0,03	<0,05			<0,3		<0,1		<0,1		<0,05				<1		<0,03	<0,1	<0,05	<0,03	<0,05	<0,05	<0,05	<0,03	<0,05	0,52		0,52	<1	<1	<1	<1	<0,4	<0,4	<0,4
4155	Jesolo WWTP	29/08/2012																																								
4155	Jesolo WWTP	30/08/2012																																0,008								
4155	Jesolo WWTP	17/09/2012		<0,1			<0,05	<0,03	<0,05			<0,3		<0,1		<0,1		<0,05				<1		<0,03	<0,1	<0,05	<0,03	<0,05	<0,05	<0,05	<0,03	<0,05	0,04		<0,2	<0,05	<0,05	<0,05	<0,05	<0,02	<0,02	<0,02
4155	Jesolo WWTP	03/10/2012																																								
4155	Jesolo WWTP	15/11/2012																																								

Eraclea mare WWTP

SIRAV code	WWTP	DATE	Active Chlorine (mg/l)	Chlorophorm (µg/l)	Chlorophorm (mg/l)	1,1,1 Trichloroethane (mg/l)	Trichloroethilene (C2HCl3) (mg/l)	Trichlorofluorometane (mg/l)	Bromophorm (Tribromomethane) (mg/l)	Dibromochloromethane (µg/l)	Dibromochloromethane (mg/l)	Dichlorobromomethane (mg/l)	Tetrachloroethilene (C2Cl4) (µg/l)	Tetrachloroethilene (C2Cl4) (mg/l)	Tetrachloromethane CCl4 (µg/l)	Tetrachloromethane CCl4 (mg/l)	Total organohalogenated solvents (mg/l)	Phenols (mg/l)
4869	Eraclea mare WWTP	02/03/2005			<0,001	<0,0005	<0,0005	<0,0005	<0,001		<0,001	<0,001		<0,0005		<0,0005	<0,001	0,006
4869	Eraclea mare WWTP	14/06/2005	<0,05		0,004	<0,0005	<0,0005	<0,0005	<0,001		0,002	0,003		<0,0005		<0,0005	0,009	0,006
4869	Eraclea mare WWTP	30/08/2005	<0,05		<0,001	<0,0005	<0,0005	<0,0005	<0,001		0,002	0,006		<0,0005		<0,0005	0,008	0,014
4869	Eraclea mare WWTP	16/11/2005			<0,001	<0,0005	<0,0005	<0,0005	<0,001		<0,001	<0,001		<0,0005		<0,0005	<0,001	<0,004
4869	Eraclea mare WWTP	18/07/2006	<0,05		0,003	<0,0005	<0,0005	<0,0005	<0,001		0,001	0,002		<0,0005		<0,0005	0,006	0,009
4869	Eraclea mare WWTP	17/08/2006	<0,05		0,002	<0,0005	<0,0005	<0,0005	<0,001		<0,001	<0,001		<0,0005		<0,0005	0,002	0,015
4869	Eraclea mare WWTP	24/10/2006			<0,001	<0,0005	<0,0005	<0,0005	<0,001		<0,001	<0,001		<0,0005		<0,0005	<0,001	<0,004
4869	Eraclea mare WWTP	03/04/2007	<0,05		0,003		<0,0005	<0,0005	0,003		0,005	0,005	<0,0005	<0,0005	<0,0005		0,016	0,006
4869	Eraclea mare WWTP	10/07/2007	<0,05		0,006		<0,0005	<0,0005	<0,001		<0,001	<0,001	<0,0005	<0,0005	<0,0005		0,006	<0,004
4869	Eraclea mare WWTP	29/08/2007	<0,05		0,001		<0,0005	<0,0005	<0,001		<0,001	<0,001	<0,0005	<0,0005	<0,0005		0,001	<0,004
4869	Eraclea mare WWTP	19/02/2008	<0,05	<0,001		<0,0005	<0,0005	<0,0005	<0,001	<0,001	<0,001			<0,0005		<0,0005	<0,001	0,009
4869	Eraclea mare WWTP	22/07/2008	<0,05	0,002		<0,0005	<0,0005		<0,001	<0,001	<0,001			<0,0005		<0,0005	0,002	0,009
4869	Eraclea mare WWTP	27/08/2008	<0,05	0,006		<0,0005	<0,0005		<0,001	0,002	0,004			<0,0005		<0,0005	0,012	<0,004
4869	Eraclea mare WWTP	03/06/2009	<0,05															0,006
4869	Eraclea mare WWTP	16/07/2009	<0,05															<0,012
4869	Eraclea mare WWTP	27/08/2009	<0,05															0,007
4869	Eraclea mare WWTP	07/07/2010	<0,05															0,005
4869	Eraclea mare WWTP	04/08/2010	<0,05															0,005
4869	Eraclea mare WWTP	21/07/2011																0,008
4869	Eraclea mare WWTP	11/08/2011																0,006
4869	Eraclea mare WWTP	29/11/2011																<0,004
4869	Eraclea mare WWTP	27/06/2012	<0,05															<0,004
4869	Eraclea mare WWTP	09/08/2012	<0,05															0,006

Caorle WWTP

SIRAV code	WWTP	DATE	Active Chlorine (mg/l)	Chlorophorm (mg/l)	1,1,1 Trichloroethane (mg/l)	Bromophorm (Tribromomethane) (mg/l)	Total organohalogenated solvents (mg/l)	Trichloroethilene (C2HCl3) (mg/l)	Trichlorofluorometane (mg/l)	Tetrachloroethilene (C2Cl4) (mg/l)	Tetrachloromethane CCl4 (mg/l)	Dibromochloromethane (mg/l)	Dichlorobromomethane (mg/l)	Phenols (mg/l)
4148	Caorle WWTP	12/04/2005	<0,05	<0,001	<0,0005	0,103	0,136	<0,0005		0,011	<0,0005	0,02	0,002	<0,004
4148	Caorle WWTP	03/08/2005	<0,05	0,001	<0,0005	0,03	0,065	<0,0005		<0,0005	<0,0005	0,028	0,006	<0,004
4148	Caorle WWTP	30/08/2005	<0,05	0,005	<0,0005	0,01	0,043	<0,0005		<0,0005	<0,0005	0,018	0,01	0,005
4148	Caorle WWTP	28/03/2006		<0,001	<0,0005	<0,001	<0,001	<0,0005	<0,0005	<0,0005	<0,0005	<0,001	<0,001	<0,004
4148	Caorle WWTP	01/08/2006		<0,001	<0,0005	<0,001	<0,001	<0,0005	<0,0005	<0,0005	<0,0005	<0,001	<0,001	0,008
4148	Caorle WWTP	22/08/2006	<0,05	<0,001	<0,0005	<0,001	<0,001	<0,0005	<0,0005	<0,0005	<0,0005	<0,001	<0,001	0,013
4148	Caorle WWTP	20/06/2007	<0,05	0,003	<0,0005	0,018	0,055	<0,0005	<0,0005	<0,0005	<0,0005	0,023	0,01	<0,004
4148	Caorle WWTP	08/08/2007	<0,05	0,001	<0,0005	<0,001	0,003	<0,0005	<0,0005	<0,0005	<0,0005	0,001	0,001	0,006
4148	Caorle WWTP	02/10/2007		<0,001	<0,0005	0,002	0,002	<0,0005		<0,0005	<0,0005	<0,001	<0,001	<0,004
4148	Caorle WWTP	16/04/2008	<0,05	<0,001	<0,0005	0,051	0,059	<0,0005	<0,0005	<0,0005	<0,0005	0,008	<0,001	<0,004
4148	Caorle WWTP	03/07/2008	<0,1	0,002	<0,0005	<0,001	0,006	<0,0005		<0,0005	<0,0005	0,002	0,002	<0,004
4148	Caorle WWTP	22/07/2008	<0,05	<0,001	<0,0005	<0,001	<0,001	<0,0005		<0,0005	<0,0005	<0,001	<0,001	0,011
4148	Caorle WWTP	21/04/2009	<0,05											<0,004
4148	Caorle WWTP	16/06/2009	<0,05											0,01
4148	Caorle WWTP	08/07/2009	<0,05											0,006
4148	Caorle WWTP	03/03/2010												0,009
4148	Caorle WWTP	23/06/2010	<0,05											0,008
4148	Caorle WWTP	14/07/2010	<0,05											0,005
4148	Caorle WWTP	16/02/2011												0,004
4148	Caorle WWTP	21/07/2011	<0,1											0,005
4148	Caorle WWTP	11/08/2011	<0,05											<0,004
4148	Caorle WWTP	05/06/2012	<0,05											0,008
4148	Caorle WWTP	20/06/2012	<0,05											<0,004
4148	Caorle WWTP	09/08/2012	<0,05											0,004

San Donà di Piave WWTP

SIRAV code	WWTP	DATA	Active Chlorine (mg/l)	Chlorophorm (µg/l)	Chlorophorm (mg/l)	1,1,1 Trichloroethane (mg/l)	Trichloroethilene (C2HCl3) (mg/l)	Trichlorofluorometane (mg/l)	Bromophorm (Tribromomethane) (µg/l)	Bromophorm (Tribromomethane) (mg/l)	Dibromochloromethane (µg/l)	Dibromochloromethane (mg/l)	Dichlorobromomethane (mg/l)	Tetrachloroethilene (C2Cl4) (µg/l)	Tetrachloroethilene (C2Cl4) (mg/l)	Tetrachloromethane CCl4 (µg/l)	Tetrachloromethane CCl4 (mg/l)	Total organohalogenated solvents (mg/l)	1,1,1 Trichloroethane (mg/l)	Phenols (mg/l)
4165	San Donà di	02/02/2005			<0,001	<0,0005	<0,0005	<0,0005		<0,001		<0,001	<0,001		<0,0005		<0,0005	<0,001		<0,004
4165	San Donà di	27/04/2005			0,005	<0,0005	<0,0005	<0,0005		<0,001		0,001	0,003		<0,0005		<0,0005	0,009		<0,004
4165	San Donà di	07/06/2005																		
4165	San Donà di	08/06/2005			<0,001	<0,0005	<0,0005	<0,0005		<0,001		<0,001	<0,001		<0,0005		<0,0005	<0,001		0,008
4165	San Donà di	01/02/2006			<0,001	<0,0005	<0,0005	<0,0005		<0,001		<0,001	<0,001		<0,0005		<0,0005	<0,001		0,007
4165	San Donà di	27/06/2006			0,005	<0,0005	<0,0005	<0,0005		<0,001		<0,001	<0,001		<0,0005		<0,0005	0,005		0,006
4165	San Donà di	24/10/2006			<0,001	<0,0005	<0,0005	<0,0005		<0,001		<0,001	<0,001		<0,0005		<0,0005	<0,001		<0,004
4165	San Donà di	31/01/2007			<0,001		<0,0005	<0,0005		<0,001		<0,001	<0,001	<0,0005	<0,0005	<0,0005		<0,001		0,007
4165	San Donà di	18/04/2007			<0,001		<0,0005	<0,0005		<0,001		<0,001	<0,001	<0,0005	<0,0005	<0,0005		<0,001		<0,004
4165	San Donà di	04/09/2007			0,004		<0,0005	<0,0005		<0,001		<0,001	<0,001	<0,0005	<0,0005	<0,0005		0,004		0,006
4165	San Donà di	15/01/2008		<0,001		<0,0005	<0,0005	<0,0005		<0,001	<0,001	<0,001			<0,0005		<0,0005	<0,001		<0,004
4165	San Donà di	06/05/2008		<0,001		<0,0005	<0,0005	<0,0005		<0,001	<0,001	<0,001			<0,0005		<0,0005	<0,001		0,008
4165	San Donà di	08/10/2008		0,028		<0,0005	<0,0005			<0,001	<0,001	<0,001			<0,0005		<0,0005	0,028		0,009
4165	San Donà di	23/04/2009																		0,005
4165	San Donà di	17/06/2009																		0,004
4165	San Donà di	05/08/2009			0,009	<0,0005	<0,0005		<0,001			<0,001	<0,001		<0,0005		<0,0005			0,008
4165	San Donà di	22/09/2009			<0,001	<0,0005	<0,0005		<0,01			<0,001	<0,001		<0,0005		<0,0005			0,005
4165	San Donà di	12/05/2010	<0,05																	0,132
4165	San Donà di	04/08/2010	<0,05																	0,04
4165	San Donà di	28/09/2010	<0,05		0,013		<0,0001			<0,001		0,001	0,006		<0,0001		<0,0001		<0,0001	0,015
4165	San Donà di	23/02/2011			<0,001	<0,0001	<0,0001			<0,001		<0,001	<0,001		<0,0001	<0,0001				0,012
4165	San Donà di	16/06/2011																		0,009
4165	San Donà di	31/08/2011	<0,05		0,005	<0,0001	<0,0001			<0,001		<0,001	<0,001		<0,0001	<0,0001				<0,004
4165	San Donà di	02/02/2012	<0,05		<0,001		<0,0001			<0,001		<0,001	<0,001		<0,0001		<0,0001		<0,0001	0,017
4165	San Donà di	04/04/2012	<0,05		<0,001		<0,0001			<0,001		<0,001	<0,001		<0,0001		<0,0001		<0,0001	0,009
4165	San Donà di	12/07/2012	<0,05		<0,001		<0,001			<0,001		<0,001	<0,001		<0,001		<0,001		<0,001	0,006
4165	San Donà di	08/11/2012			<0,001		<0,0005			<0,001		<0,001	<0,001		<0,0005		<0,0005		<0,0005	<0,004

Musile di Piave WWTP

SIRAV code	WWTP	DATA	Active Chlorine (mg/l)	Chlorophorm (µg/l)	Chlorophorm (mg/l)	1,1,1 Trichloroethane (mg/l)	1,2 Dichloroethane (µg/l)	1,2 Dicloroetano mg/l	Trichloroethilene (C2HCl3) (mg/l)	Trichlorofluorometane (mg/l)	Bromophorm (Tribromomethane) (mg/l)	Dibromochloromethane (µg/l)	Dibromochloromethane (mg/l)	Dichlorobromomethane (mg/l)	Tetrachloroethilene (C2Cl4) (µg/l)	Tetrachloroethilene (C2Cl4) (mg/l)	Tetrachloromethane CCl4 (µg/l)	Tetrachloromethane CCl4 (mg/l)	Total organohalogenated solvents (mg/l)	1,1 Dichloroethilene (mg/l)	1,1,1 Trichloroethane (mg/l)	1,1,2 Trichloroethane (mg/l)	1,1,2,2 Tetrachloroethane (mg/l)	1,2 Dibromoethane (mg/l)	1,2 Dicloroethilene cis (mg/l)	1,2 Dicloroethilene trans (mg/l)	1,2 Dichloroethilene (mg/l)	1,2 Dichloropropane (mg/l)	1,2,3 Trichloropropane (mg/l)	Phenols (mg/l)
4157	Musile di P. WWTP	22/03/2005			<0,001	<0,0005			<0,0005	<0,0005	<0,001		<0,001	<0,001		<0,0005		<0,0005	<0,001											0,005
4157	Musile di P. WWTP	19/07/2005			<0,001	<0,0005			<0,0005	<0,0005	<0,001		<0,001	<0,001		<0,0005		<0,0005	<0,001											<0,004
4157	Musile di P. WWTP	08/11/2005			<0,001	<0,0005			<0,0005	<0,0005	<0,001		<0,001	<0,001		0,0005		<0,0005	<0,001											<0,004
4157	Musile di P. WWTP	01/02/2006			<0,001	<0,0005			<0,0005	<0,0005	<0,001		<0,001	<0,001		<0,0005		<0,0005	<0,001											<0,004
4157	Musile di P. WWTP	07/06/2006			<0,001	<0,0005			<0,0005	<0,0005	<0,001		<0,001	<0,001		<0,0005		<0,0005	<0,001											0,014
4157	Musile di P. WWTP	04/10/2006			<0,001	<0,0005			<0,0005	<0,0005	<0,001		<0,001	<0,001		<0,0005		<0,0005	<0,001											<0,004
4157	Musile di P. WWTP	31/01/2007			<0,001				<0,0005	<0,0005	<0,001		<0,001	<0,001	<0,0005	<0,0005	<0,0005		<0,001											0,005
4157	Musile di P. WWTP	29/05/2007			<0,001				<0,0005	<0,0005	<0,001		<0,001	<0,001	<0,0005	<0,0005	<0,0005		<0,001											0,005
4157	Musile di P. WWTP	02/10/2007			<0,001				<0,0005		<0,001		<0,001	<0,001	<0,0005	<0,0005	<0,0005		<0,001											<0,004
4157	Musile di P. WWTP	15/01/2008		<0,001		<0,0005			<0,0005	<0,0005	<0,001	<0,001	<0,001			<0,0005		<0,0005	<0,001											<0,004
4157	Musile di P. WWTP	11/06/2008		<0,001		<0,0005			<0,0005	<0,0005	<0,001	<0,001	<0,001			<0,0005		<0,0005	<0,001											<0,004
4157	Musile di P. WWTP	24/09/2008		<0,001		<0,0005			<0,0005		<0,001	<0,001	<0,001			<0,0005		<0,0005	<0,001											<0,004
4157	Musile di P. WWTP	03/02/2009																												<0,004
4157	Musile di P. WWTP	19/08/2009																												<0,004
4157	Musile di P. WWTP	27/10/2009																												0,006
4157	Musile di P. WWTP	09/02/2010																												0,004
4157	Musile di P. WWTP	08/04/2010	<0,05																											<0,004
4157	Musile di P. WWTP	12/05/2010	<0,05																											<0,004
4157	Musile di P. WWTP	10/02/2011																												0,005
4157	Musile di P. WWTP	07/06/2011																												<0,004
4157	Musile di P. WWTP	28/07/2011																												0,011
4157	Musile di P. WWTP	27/09/2011	<0,05																											<0,004
4157	Musile di P. WWTP	04/04/2012	<0,05																											0,006
4157	Musile di P. WWTP	22/06/2012	0,1		0,002		<0,0005	<0,0005	<0,0005		<0,0005		<0,0005	<0,0005		<0,0005			<0,005	<0,0005	<0,0005	<0,0005	<0,0005	<0,0005	<0,0005	<0,0005	<0,0005	<0,0005	<0,0005	
4157	Musile di P. WWTP	22/08/2012	<0,05																											0,012
4157	Musile di P. WWTP	15/11/2012																												<0,004

Acknowledgements

Tra le molte persone desidero in particolare ringraziare:

- l'ing. Luigi Falletti per la pazienza e gli utili consigli e la lunga collaborazione nel campo della depurazione delle acque reflue unitamente al prof. Lino Conte;
- la dott.ssa Patrizia Ragazzo di ASI SpA per aver fornito i dati e per l'entusiasmo con cui ha sempre affrontato le questioni realtive alla disinfezione, ma soprattutto per la stima e l'amicizia;
- la Provincia di Venezia ed in particolre l'ing. Paolo Osti;
- il dott. Fedetrico Serena del Dipartimento ARPAV di Treviso e l'ing. Achille Fantoni di SIBA SpA per i dati e gli utili consigli;
- il dott. Giorgio Marchiori di Veritas SpA per i dati e gli utili consigli;
- tutti i colleghi del Servizio laboratori ARPAV di Venezia per le analisi svolte e gli approfondimenti, in particolare la dott.ssa Luciana Menegus, la dott.ssa Francesca Zanon e la dott.ssa Rita Frate;
- il dott. Renzo Biancotto, l'ing. Mirco Zambon del Dipartimento Provinciale ARPAV di Venezia e tutti i colleghi della U.O. di Vigilanza Ambientale con cui ho collaborato per la durata dell'incarico.