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TESI DI LAUREA

Criteria for an environmentally sound reuse of construction and demolition waste in the EU within the concept of circular economy

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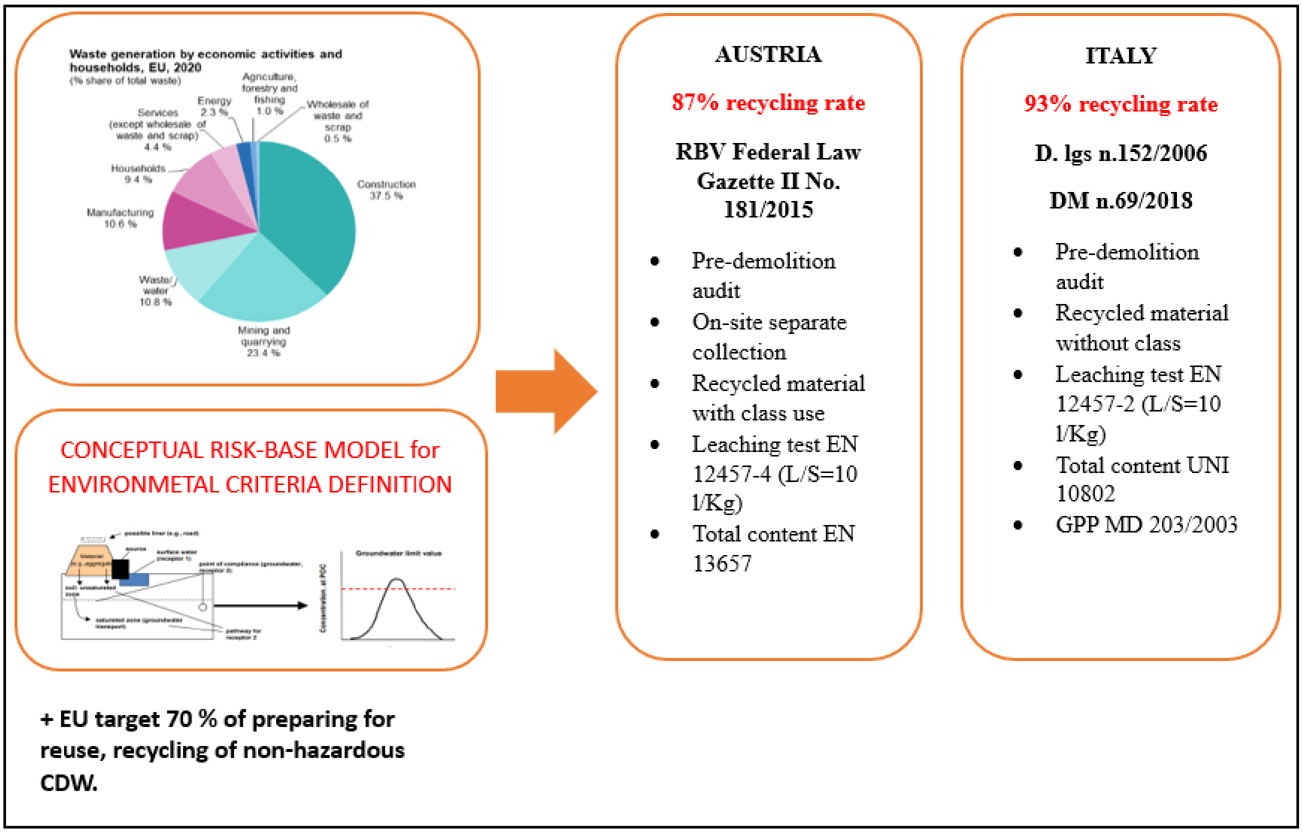
Abstract

Estate sector is energy and material intense industry. Construction and demolition waste represent the highest flux of waste at European Union. As part of the circular economy concept, the European Community has set certain limits on the re-use, recycling and recovery of other materials, including backfill for CDW, in order to make itself sustainable and more independent in terms of material sources. High recycling rate has been achieved in most EU Country as Austria and Italy, anyway to close the loop the main hurdler is the lack of confidence in the quality of the recycling aggregates. Standardised sampling methods and environmental testing increase confidence in the use of aggregates to prevent any environmental and health impacts from their use. They are also required as criteria to establish EoW status together with limit values on certain substances for an environmentally friendly use of recycled aggregates. The regulatory framework of virtuous countries with their sampling methods and analytical tests drawn up for an environmentally compatible use of CDWs was conducted by analysing common strengths and weaknesses.
Regulations implemented to date for the reuse of materials from construction and demolition activities, such as the EoW, allow member states to achieve high recovery rates, even though they feed into low-quality recycling. Composite materials and the addition of chemicals in prefabricated materials make recycling an even more difficult challenge.
The risk-based method for determining screening values or site-specific risk assessment for environmental reuse of CDWs should be implemented for emerging contaminants.

Graphical abstract



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Definition of	Description
Aggregate	granular material of natural, manufactured or recycled origin used in construction
Asphalt mixture	mixture of the binder bitumen and aggregates produced in asphalt mixing plants
Bituminous conglomerate	waste composed by mixture of inert and bituminous binders identified with the EU waste code 17 03 02 coming from: 1) the demolition of bituminous conglomerate pavements 2) cold milling operations of pavement layers made of bituminous conglomerate
Backfilling	any recovery operation where suitable non-hazardous waste is used for purposes of reclamation in excavated areas or for engineering purposes in landscaping. Waste used for backfilling must substitute non-waste materials, be suitable for the aforementioned purposes, and be limited to the amount strictly necessary to achieve those purposes
Bound use	Refers to a monolithic use of an aggregate material
Construction and demolition waste	waste generated by construction and demolition activities
Construction site waste	various building materials and elements arising from new builds, conversion and demolition, especially consisting of plastic, wood, metal, insulating materials, plasterboard and packaging
Dismantling	the demolition of a structure, generally in reverse order to the construction of a structure; separation at source of materials derived from demolition activities with the aim of ensuring that the materials resulting from the demolition can be largely reused, prepared for reuse or recycled, separating the materials produced and taking into account the pollutant contents, so as to minimise mixing and contamination of the resulting materials and to prevent the escape of pollutants
Eluate	As leachate but usually in the context of a laboratory test
Hazardous waste	waste which displays one or more of the hazardous properties listed in Annex III of the Directive 2008/98/EC
Inert waste	waste from construction and demolition activities and other inert waste of mineral origin which does not undergo any significant physical, chemical or biological transformation. Inert waste does not dissolve, burn or undergo any other physical or adversely effect other matter whit which it comes into contact in a way like to give rise to environmental pollution or harm human health. The total leachability and pollutant content of the waste and the ecotoxicity of the leachate must be insignificant, and in particular not endanger the quality of surface water and/or groundwater
Leachate	Liquid containing soluble components extracted from a solid.
Low-permeability bonded surface or base course	a binder-bonded layer (hydraulic or bituminous bond) which permanently prevents the penetration of precipitation from the underlying layers
Mineral fraction	concrete, bricks, tiles and ceramics, stones
Manufactured aggregate	Aggregate of mineral origin resulting from an industrial process involving thermal or other modification
Natural aggregate	Aggregates from mineral sources that has been subject to nothing more than mechanical processing
Preparing for re-use	checking, cleaning or repairing recovery operations, by which products or components of products that have become waste are prepared so that they can be re-used without any other pre-processing
Recycled aggregate	Aggregates resulting from the processing of inorganic or mineral material previously used in construction
Recycling	any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy

	recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations
Reclaimed asphalt	asphalt obtained by milling asphalt pavement, by crushing clods broken out of asphalt pavements, or from lumps originating from clods, or from discarded or excess asphalt
Recovery	any operation the principal result of which is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfil a particular function, or waste being prepared to fulfil that function, in the plant or in the wider economy
Re-use	any operation by which products or components that are not waste are used again for the same purpose for which they were conceived
Technical bulk material	non-hazardous excavated material of structural engineering layers such as rolling, frost case, drainage layer, which has been prepared in accordance with technical requirements, e.g. a specific grading curve
Treatment	recovery or disposal operations, including preparation prior to recovery or disposal
Unbound use	Use of an aggregate in its granular form, e.g. after crushing of bigger lumps.

1 Introduction

1.1 Background

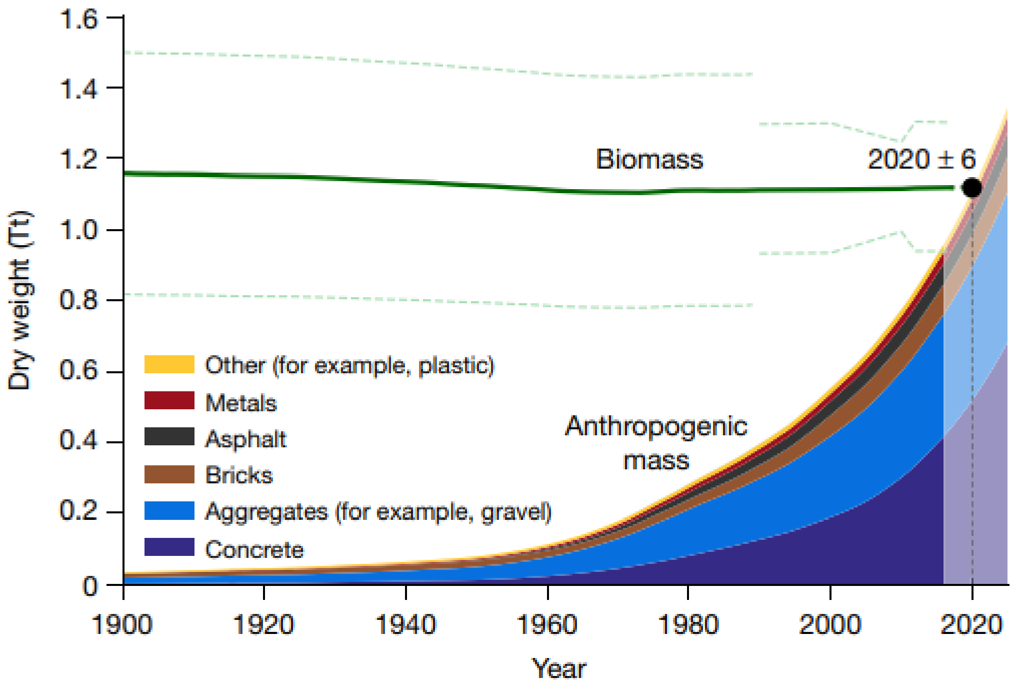


Figure 1: Biomass and anthropogenic mass estimates since the beginning of the twentieth century on a dry-mass basis. (Nature, Global human-made mass exceeding biomass, 2020).

Nature (Nature, Elhacham) has recently published an article in which compare the human-made mass, referred to as the mass embedded in inanimate solid objects made by humans to the overall living biomass on Earth; considered as a reference point to give a quantification prospective on the mass that humanity has produced. From the figure 1 we can see that over the past 100 years, anthropogenic mass has increased rapidly in contrast to total biomass, which has not changed as markedly. The two curves intersect in the years 2020 ±6, at which point anthropogenic mass will surpass biomass. Now a days, in the Anthropocene era we are at the crossover point. Concrete and aggregates are the dominant man-made materials.

In the historical context of the 21st century, the current rate of consumption of earth materials for the development of the real estate sector is not sustainable (Fernando Pacheco-Torgal, 2020). There are still abundant resources to supply the construction industry; still it is worth remembering the worrying environmental impacts caused by the extraction of non-renewable raw material, including extensive deforestation, top-soil loss, air pollution, and pollution of water reserves that will further aggravate the biodiversity loss boundary. The consumption of material resulting in an accumulation of materials within in-use stocks of buildings, buildings, infrastructure, and other manufactured goods. The useful lifetime for an infrastructure is about. On the other hand, considering the volume generated, waste derived from construction and demolition activity constitutes the largest waste stream in the European Union (EEA,Wahlström).

Waste defined by Directive 2008/98/EC Article 3 as any substance or object which the holder discards or intends or is required to discard', potentially represents an enormous loss of resources in the form of both materials and energy. EU waste management policies aim to reduce environmental and health impacts of waste and to improve EU's resource efficiency. From an obsolete linear economy system of take-make-waste, a circular economy approach adopted by EU tries to put back in cycle the materials for a sustainable development of our society. The circular economy system is in line with the 2030 Agenda for Sustainable Development, adopted by all United Nations Member States in 2015. It provides a list of development goals for a sustainable future, through them as the big concern about the building sector two goals are of our interest: n. 9 industry innovation and infrastructure; and the n. 11 sustainable city and communities. The two goals aim to more resilient infrastructure, promote inclusive and sustainable industrialisation and enhance foster innovations; on the other hand make the city and human settlement inclusive safe and resilient.

There are three phases of the building material life cycle under the linear approach, Figure 2. During the first phase, the pre-building phase, raw and manufactured materials are extracted, processed, packaged and shipped. It captures the production and delivery of the materials up to the point of installation. Second, the building phase, corresponds to the building's life, which is built and needs maintenance. The last phase is the post-building phase, the building is demolished, and materials are released as waste. In a circular economy, materials are recycled and enter the pre-building phase again. Alternatively, the materials are re-used entering the building phase. It is possible that the materials enter another system after recycling. This is, however, not preferred when aiming at a circular economy. Another option, the less preferred, is that the materials are discarded as waste.

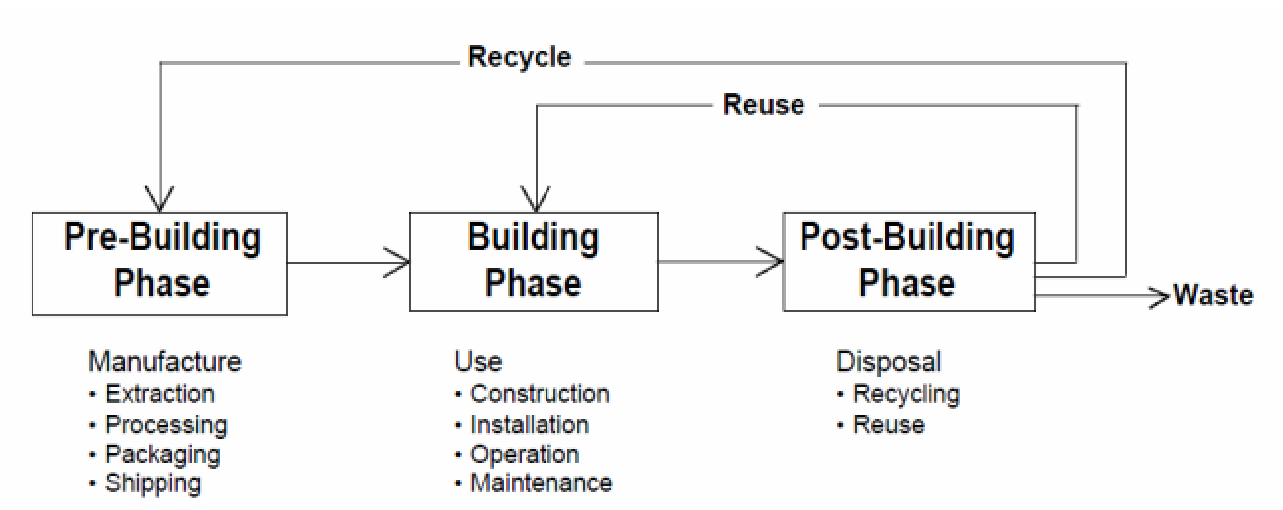


Figure 2: Material life cycle.

The pre-building phase, as energy and material intensive, which implies a large environmental impact (Utrecht University, 2016), should be replaced with the re-use of materials and trough the manufacturing of secondary raw materials in the principle of the circular economy. At the end, small material cycle ensures efficient material usage. This will reduce the environmental impact of products, by reducing raw material use, energy use and CO2 emissions. In addition, it brings economic advantages, as the supply chain is working together in order to re-use and recycle the materials.

To this condition competent authorities should implement incentives for re-use and recovery of materials coming from construction and demolition activity. Recycling is possible as it is not an expensive practice, and the technology is available (FIR). Turning the construction sector into a more sustainable practice, as the real estate sector is more interested in a high rate of return than in project sustainability is of paramount importance.

Circular Economy

Circular economy does not have a clear origin or definition in literature. According to Yuan (Utrecht University, 2016), it was coined by scholars in China in 1998. However, the idea to decouple economic growth from growing waste streams and unsustainable management of earth's resources has been put forward before, for example in The limits to growth by Meadows et al. (1972). The idea is to move away from the linear economy "make, use and waste" that has been the main driver of society since the start of the industrial revolution. However, the circular economy is aiming at optimal resource use. Biological materials are designed to return to the environment. Synthetic materials are aimed to be of high quality with a long life. When products reach the end of their life-cycle, in the circular economy concept they are disassembled and the materials are re-used or used as input for another product process. The target aims of circular economy are short cycles in which material resources circle, keeping the quality of the material as high as possible over the longest possible period of time. Expected is that by pursuing a circular economy, an efficient economy will be achieved with lower or, in the ideal case, no environmental impact. Now a day products in circular economy systems, retain their added value as long as possible and resources remain within the economic system, so that they can be used several productive purposes and create new value.

1.2 Issue definition

In this context the European Union has long ago assumed a leading role into a sustainable future and the circular economy principle concern the building sector. The European Waste Framework Directive WFD shows the importance of resource efficiency promoting the circularity of waste deriving from construction and demolition activity, which is clearly expressed by the target by 2020 for the preparing for re-use, recycling and other material recovery, including backfilling operations using waste to substitute other materials, of non-hazardous construction and demolition waste shall be increased to a minimum of 70 % by weight. Proper management of CDW and recycled materials can have major benefits in terms of sustainability and provide benefits for the EU construction and recycling sector, as it boosts demand for CD recycled materials. Although most construction and demolition waste are recyclable, one of the most common obstacles to the recycling and reuse of such waste in the EU is a lack of confidence in the quality of material resulting from their recycling (European Union, 2018). A clear definition of the possible impact derived from their uses must be evaluated to fix some boundaries on the reuse concept. The utilisation of building materials at the end of their service life, used for another purpose must be controlled and the application must be ecologically sound so as not to cause damage to the environment and human health. To this end standardized Environmental testing analysis and adequate quality control measures are of necessary importance in all material recovery process.

The objective of this study is comprehension of environmental criteria for the material recirculation. A comparison on the state of the art of CDW management strategies , especially in the mineral fraction of the virtuous EU countries, to identify the milestones and gaps in the integrated legislation of these countries, so as to be a source of inspiration for those Member States that have not reached the EU target, such as Greece, and to identify the most environmentally friendly of the two strategies, to be suggested to companies guiding the European Community through a circular economy.

As construction and demolition waste constitutes a defined waste stream for the future; this evaluation (FWMP, 2017) demonstrates the corresponding basis for the further development of the waste management industry in order to create the framework conditions for waste management, the construction of new treatment facilities and new discoveries in waste treatment, in line with the sustainability and environmental and human health protection. Also, a pre-demolition audit play an important role in the future waste management strategy of the CDW; helping in the achievement of high purity materials necessary to reach high recycling rates. The fewer impurities in the waste fraction, the higher the value it can have.

This thesis work was done in collaboration with Enydron-Environmental Protection Services, an environmental consultant's company that provide services to their client to comply with environmental legislation, mitigate their environmental impact and improve their environmental footprint. On the other hand, Enydron support company in the estate sector as companies operating airport facilities, industries in the hotel sector, brownfields on their CDW management in having in mind the sustainability of the solution proposed.

The studies aiming to define environmental compatibility limit values does not focus on other aspects of possible pollution from using waste-derived aggregates such as emission of volatile substances from aggregates or radiation from aggregates. Furthermore, the current study does not deal in detail with the use of recycled excavated soils and stones, for which other environmental considerations may apply apart from possible leaching phenomena.

To fulfil the purpose of our thesis the work is organized in three main parts. The first part regarding the environmental testing needed to provide environmentally sound re-use of construction and demolition material and reuse of recycled aggregates; therefore, at the beginning the need for environmental test is explain, the risk-base assessment procedure to derive limit values to comply with and an overview of testing methods. In the second part a quantitative and qualitative waste characterisation based on the building materials used in the last century, governing the material composition of C&DW, under the definition and guideline of the EU Waste Framework Directive. Some concepts define in the WFD are explain as a boosting tool for the achievement of the circular economy approach. From this background derive that the larger fraction and the most concern fluxes for the Member states legislation are inert material in particular concrete and asphalt don't consider excavated soil. Those fluxes are deeply analysed in the third part where legislation on recovery strategy for each country was analysed. In particular reuse, recycling, backfilling and disposal in landfill. For each treatment method analysed the legislation of each country is compared separately and contrasted with each other.

In particular, in the second chapter environmental criteria and standardised tests to define the environmentally sound use of recycled aggregates is explaining. In chapter 3 the CDW flux is described qualitative and quantitatively. A review of the guideline set at EU level to define some concepts and definitions. In the Chapter 4 at the beginning the CDW management system; and a detailed analysis on recovery legislations method (reuse, recycling, EOW, Backfilling), sampling method and environmental testing analyses, as a last resort, was provided for Austria, Italy and Greece. In the last chapter a general conclusion and discussion is provided at the end.

2 Analysis of environmental tests and definition of limit values for an environmental sound reuse of inert CDW.

In this chapter a–study is done on evaluation of the possible environmental impact posed by the recirculation of construction material in building industry for the determination of environmental protection criteria on its use. To prevent any detrimental impact a comprehensive analysis on material was done in a manner to define environmental quality measure for the conservation of the environment.

At the end standardised environmental tests a practical evaluation system, prove acceptability of secondary raw materials in construction industry.

Under the EU guidelines, each Member States develops in cooperation with experts its environmental criteria for reuse of the inert materials deriving from construction and demolition activity, with respective restriction/condition for compatible environmental and health protection.

The study of the material reused for construction purposes is a function of four factors firstly its composition whether it is a composite material or a single type of material with high purity; its grain size which gives it a different use; its degradability and the method by which the material is laid. Depending on those variables, reused aggregates may release pollutant in different environmental compartments as soil, groundwater or air. This will be discussed in more detail later.

Is significant to note that inert material can be used in engineering works that imply direct exposure to the environment, and not used as feedstock in industrial manufacturing process, therefore condition of use must be regulated to avoid free dispersion of possible source of pollution.

Materials recirculation works if technically feasible. In the perspective of the circular economy, at the end of their life span, materials are put back in cycle to close the loop, this must be regulated so that they have no impact on the environment and human health, as well as ensuring that they retain the appropriate technical properties required in their new applications. The first requirement is also specified in the WFD as condition for waste to reach the EoW status, the latter are harmonised under the product regulation and out of our interest. The first requirement is also specified in the WFD as condition for waste to reach the EoW status, but any information on the evaluation for the possible environmental risk is recommended.

The considerations about environmental criteria in this chapter apply to the reuse of materials in construction projects whether they are considered waste, have reached EoW or have yet to be considered waste. Consequently, member countries develop a legislative system that handles each type of material as appropriately as possible.

Therefore, a scientific base analysis on how limit values for prevention of any possible pollution phenomena, as criteria per environmental sound use of aggregates is derived. As leaching properties of aggregate are directly related to the environmental pollution, determine leachate limit values for material reuse is fundamental. A risk-based approach is the main method used in the European states, that identify and analyse the correlation of the pollution risk from the use of inert material, in order to regulate the source of the possible impact before use.

2.1 Environmental pollution risk of using aggregates derived from waste or natural or mineral aggregates.

It is good to clarify a few concepts before the text continues. It must be clear that the focus of this thesis is about inert fraction of the waste derived from the activity of construction and demolition of fabricated. As inert materials are mainly reused in construction industry as aggregates for new construction projects, we refer to the environmental criteria required for the utilisation of recycled aggregates. Indeed, aggregates are granular material of natural, manufactured, or recycled origin used in construction. Natural aggregates are produced from mineral sources like gravel pits and include e.g. sand and gravel resulting from rock erosion, and crushed rock extracted from quarries. If natural aggregate undergo industrial processes like thermal treatment or other modification are considered manufactured aggregates. Recycled aggregates, on the other hand, are derived from the processing of mineral materials - the inert fraction of CD waste - mostly through mechanical processes previously used in construction. For example, recycled aggregates derived from bricks, tails, asphalt, concrete…Regardless of origin, different aggregate types exhibit unequal operating outcomes in various settings. Aggregates can vary in composition, granulometry and stability consequently in chemical, physical, biological, mechanical and geotechnical characteristics. This might result in different environmental behaviour in terms of the concentration and release of possibly relevant compounds on the environment. We care about this method of interaction source -environments as leaching properties of aggregate are directly related to the environmental pollution.

Acid neutralization capacity (ANC), degradable organic matter content, pH and redox potential are chemical parameters that are necessary to characterize the leaching behaviour of chemicals from aggregates.

The redox potential of aggregates, that tell us if compound is in their reduced or oxidated form, influence leachability of different contaminants. For example the chromate (Cr(VI)) present in Portland cements after blending is reduced to Cr(III), a less soluble form. Reducing conditions can e.g. be identified from the increased leachability of Fe and Mn at neutral pH. In case of oxidation of the reduced material upon exposure with atmospheric oxygen in presence of water, species from their less soluble reduced form, may change to their more oxidised ones becoming more soluble. This might occur, for instance, after the end of the service life of the material, if the material is crushed or allowed to crumble and recycled or discarded under oxidizing circumstances in contact with ambient air. Therefore, the EoL of new construction product resulting from the use of recycled aggregate could be a potentially risk condition for environmental pollution since release of some concern substances can be improved.

Oxidation reactions may lead to acidification environment condition for aggregates containing sulphides with insufficient acid neutralisation capacity (ANC). Therefore, the utilisation of aggregates with reducing properties may also lead to environmental problems such as oxygen depletion in certain condition of applications. Regarding organic substances, aggregates will only contain traces of organic substances, and many of these, e.g. polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs), are relatively immobile in soil and groundwater. The transport may, however, be facilitated by the presence of dissolved organic carbon DOC in the leachate from the aggregates. Since DOC can also enhance the mobility of inorganic substances (e.g. Cu), there is good reason to set limits on the release of DOC from aggregates. (ONORM 3151).

Therefore, the development of environmental criteria for aggregates use must include an assessment of the potential risk that any possible use of recycled aggregate may pose to environment and human health. Condition on the use/type of application of aggregates imply control measure to guarantee that the material will be used properly. To a certain extent the technical requirements of the aggregates for specific uses are likely to control the just the use of a given aggregates for a given type of application, but in principle without environmental criteria it could be placed anywhere. it is therefore evident that there is a need for national environmental criteria for the use of recovered aggregates in construction works.

In any case, the technical requirements for recycled aggregates to be used in a construction project are beyond the scope of this study. We are just concerned about the environmental and health risk of pollution of using aggregates shall be identify and assessed to allow safe recirculation of the material in the view of the circular economy concept.

2.2 Chemical parameters controlling realise of substances from aggregates and substance release mechanism

Leaching is defined as the dissolution of a soluble substance from a solid phase into a solvent, the leachant. Accumulated dissolved substances in the leachant comprise a leachate (or an eluate, as the liquid resulting from a leaching test is called). Leaching of inorganic substances from mineral materials such aggregates can be a complex process and many factors influence the realise of substances both in short and long time.

Relevant factors influencing leaching of any substance from aggregate in different end uses are analysed for a complete understanding. The pH is the major chemical variable in the leaching of different substances, small pH variations can lead to very different realise conditions. The pH influences the solubility of important minerals that may occur in aggregates, such as oxides, hydroxides and carbonates.

A typical example of realise change due to pH variation occurs in cementitious and other alkali materials. High pH values of such products corresponding to fresh crushed material conditions, this value didn't stay high due to carbonation process that take place under prolongate exposure to atmosphere. Usually aggregates will have a relatively high starting pH (typically 10 – 12.5) that may be reduced over time to more neutral values by natural carbonation (JRC). Decrease in pH upon carbonation has an effect on release of several trace substances, in particular for oxyanions like As, Sb, Se, Mo, V and sulphate; metals are not affected by this change of pH since their leachability is generally low in the pH range from 7 – 10. At the same time the same decries on pH is considered a dietarian process for reinforce concrete in structural works (SAINT-GOBAIN, 2019). Carbonation process is a precursor of corrosion of steel bars. In its young state, concrete containing calcium hydroxide fosters a strongly alkaline environment, a field of immunity for iron. Under these conditions, the compact oxide layer covers the reinforcement, passivating the iron. if the carbonate layer rises up through the pores of the concrete to the reinforcement, the iron depassivates and corrodes. the oxidation of the iron causes it to expand, causing the protective concrete layer to fall off.

When a material contains sulphide, the potential for acidification may occur, if the neutralising capacity of the material is insufficient to compensate the acid produced from oxidation of sulphide to sulphate. Increased leaching of metals is associated with this form of pH change. In addition, pH variability influences the realise of cationic and anionic constituents bound to the solid matrix by adsorption/desorption process.

Other factors that affect the leachability of substances are the redox potential and complexation by inorganic and organic substances. High concentrations of easily soluble salts such as chlorides may influence the leaching results for substances that can form chloride complexes, e.g. Cd leachability may be increased due to complexation with chloride. On the other hand, the main physical properties affecting substances realises is the granulometry of the aggregates. As the other chemical parameters are fixed, reduction of particle size will decrease resistance to substance diffusion out of the particle and enhance the rate of release of substances that are not otherwise changed. Therefore, leachability increase, when particle size decries. Leaching test are performed on granular or size reduced material in order to account for the more critical parts of the lifecycle of the waste-derived aggregates.

Another important factor influencing substances leachability is Solid to Liquid ratio S/L.

Solid to liquid factor is defined as the ratio between the amount of a leaching solution (in a leaching test normally demineralised water) over the amount of waste material tested which are brought in contact in a leaching test (e.g. l/Kg).

For constant or average long term flow of percolation conditions, L/S is proportional to time. This is thru since S the amount of the material in question will remain constant and L, the amount of water that has been in contact with the material, will, at any time, correspond to the accumulated amount of water that has percolated through the material; therefore L/S scale can be proportional to time scale.

In field, knowing condition of the physical layout hydraulic/water balance situation for a full scale approach, the L/S scale may be converted to a time scale for a more practical application. The relationship shows the direct correlation between L/S and time. It is assumed that percolation of the infiltrated precipitation is the sole source of leachate in the application.

$t = (L/S) * d * H/I$

where

t is the time since the production leachate from the application started (years)

L is the total volume of leachate produced at time t (m3)

S is the total mass of aggregate used in the application (tonnes, dry mass)

d is the average dry bulk density of the aggregate in the application (tonnes/m3)

H is the average height of the application (m)

I is the annual net rate of infiltration of precipitation (m3 /m2).

In practical laboratory conditions L/S of 10 l/Kg are considered as the long term releases, therefore, considered the critical condition and used as comparative value. Compliance with the limit values at the higher L/S ratios of 2 and 10 l/kg ensures that the quality criteria will also be met at the End-of Life/crumbled/carbonated state of the aggregates as; this will be discussed forward in the next chapter.

The common asset to describe leaching of inorganic substance is pH at equilibrium condition and variability of L/S. The maximum release per unit time of several substances from an aggregate will occur during the initial part of the leaching period, at lower liquid to solid ratios. Hence the highest concentrations of many substances in the leachate will be seen during this period. For other substances, however, in particular substances whose releases are solubility controlled in this phase, may show constant or increasing concentration levels over a broader L/S or time range. This is due to removal of other substances or due to changes (decreases) in pH as a result of carbonation.

Results from leachate test usually are express both as concentration, meaning the quantity of substance realised for unit volume of eluate, as realise in terms of quantity of realised substance for unit of weight of aggregate. To compare resulting leachate data the same unit of measure must be adopt. Different leachate results at different liquid to solid ratio L/S can be converted throughout this formula in constituent realise:

Substance release [mg/kg] = substance concentration in eluate [mg/l] x L/S ratio [l/kg]

On the other hand, presentation of data on both unit measures as eluate concentrations and as substance realise are necessary for determination of the leaching mechanism. We can distinguish two cases of substance realise mechanism, see in figure 3.

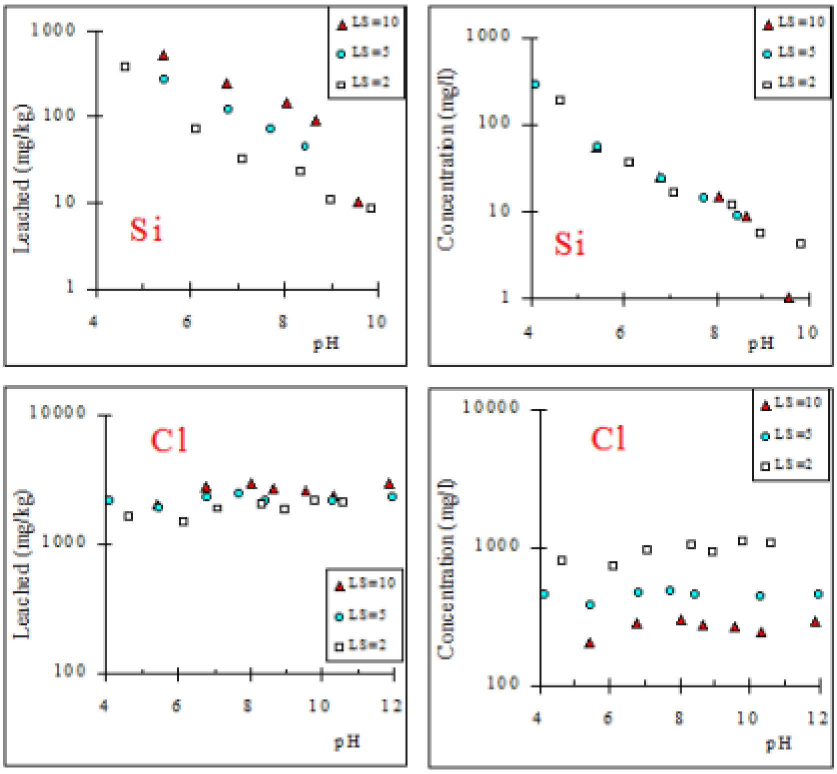


Figure 3: Distinction between solubility control (Si) and availability control (Cl) in the presentation of leaching test results. (JRC).

The two kinds of realise mechanism are presented:

- Chlorine (Cl) represents an availability controlled element. Data from tests at different L/S ratios expressed in [mg/l] lead to apparent differences, while data presented in [mg/kg] show that in all cases the whole fraction available for leaching is released.
- Silicon (Si) represents a solubility controlled element. Here, presentation of leaching data in [mg/kg] leads to differences, whereas data presented in [mg/l] show the solubility control in the pH region of 3 to 8 (constant concentration irrespective of L/S).

Once the factors controlling release are understood, the leaching process of a substance can be mathematically described. Infect for the impact assessment approach based on mathematical modelling, when using leachate data as input to transport model, is convenient to be able to qualify leaching process in terms of mathematical equation. Starting from a substance mass balance and assuming equilibrium conditions is possible to derive the amount of leachate for a specific substance per unit mass of aggregate as a function of time.

The leaching of several inorganic contaminants in equilibrium condition, can be described as resulting in an initial or early peak concentration of the substance in the leachate followed by an exponential decrease of the concentration with time (or L/S). If it is assumed that a continuously stirred tank reactor (CSTR) model can be used to interpret the results of a column leaching test on the granular waste material, the leaching of several components may be expressed by a simple decay function:

$C = C0 * e^{-(L/S)\,\kappa}$

where

C is the concentration of the contaminant in the leachate as a function of L/S (mg/l),

C0 is the initial peak concentration of the contaminant in the leachate (mg/l),

L/S is the liquid to solid ratio corresponding to the concentration C (l/kg)

K is a kinetic constant describing the rate of decrease of the concentration as a function of L/S for a given material and a given substance (kg/l).

The larger the K, the faster will the concentration in the eluate decreases as a function of L/S.

By integrating the above expression, the amount of the substance, E (in mg/kg), released over the period of time it takes for L/S to increase from 0 l/kg to the value corresponding to C, can be calculated:

$E = (C0/\kappa)(1 - e^{-(L/S)\kappa})$

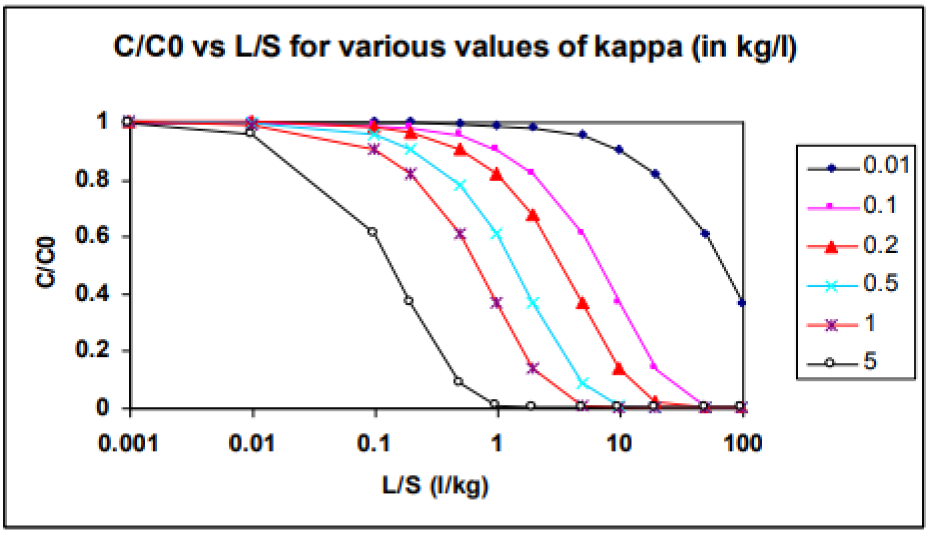


Figure 4: C/Co as a function of L/S and k (JRC).

Under the impact assessment modelling approach, in critical scenario, equilibrium condition exist, meaning that the rate of realise of a substance from the individual particles is fast compared to the advective velocity of the percolating water. Therefore the mathematical described before can be used in the model.

2.3 Reuse and recycling of inert CDW stream

In view of the possible impacts on the environment, member states draw up integrated legislation to safeguard it when recycled aggregates are used. As shown in figure inert material derived from construction and demolition activity at the end of its service life can enter again the material cycle as construction items under different regulations; they can be re-used before became a waste on the same site, or if define as a waste regulated by waste regulation. On the other hand, if CDW meet the EoW criteria they can become second raw materials, regulated by the construction product law. The use of recycled aggregates in a wide variety of construction projects need to be check for its possible pollution in the environment and related health problems, whenever the regulation it refers to.

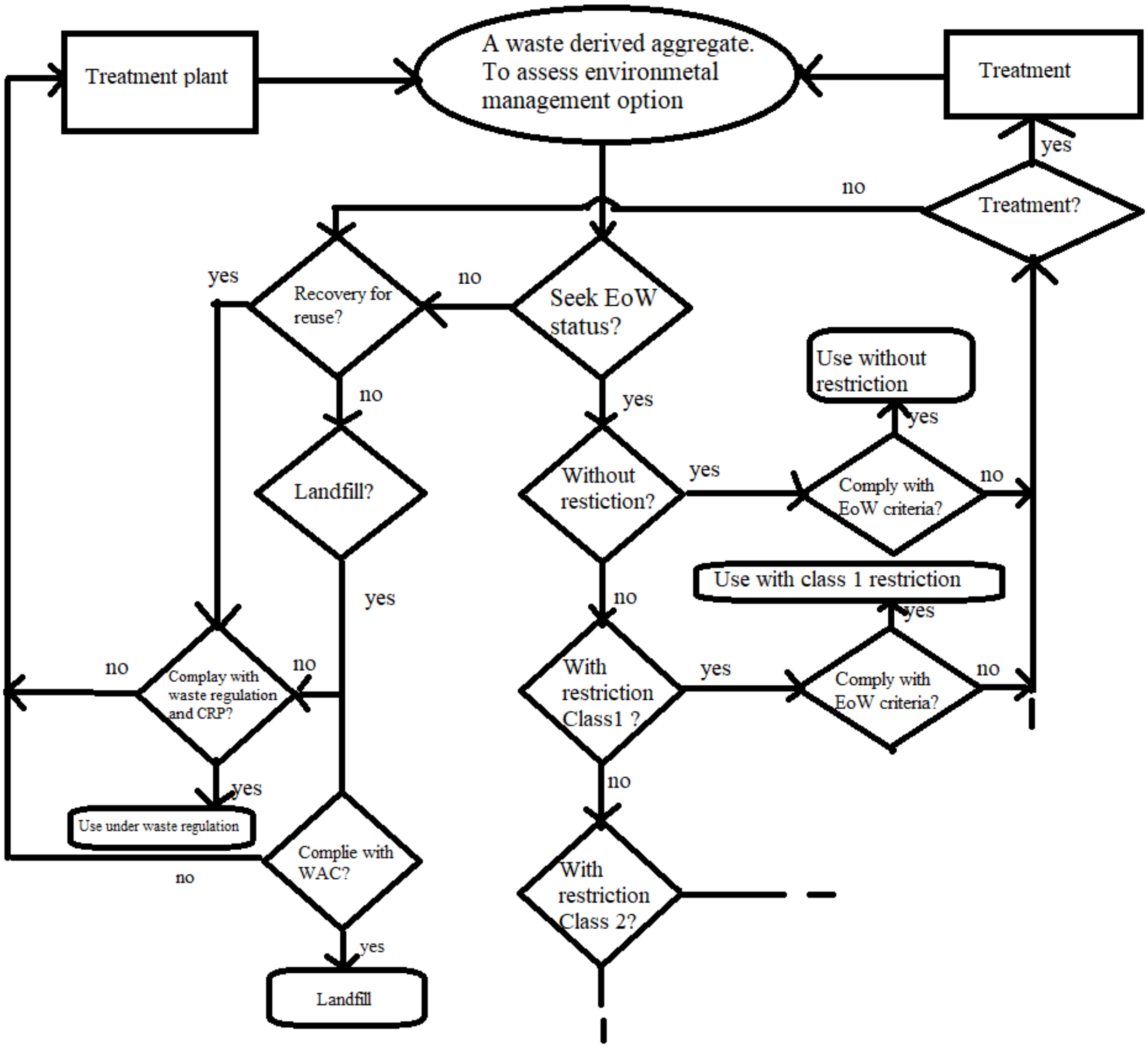


Figure 5: Example of integrated legislative scheme plan, (JRC).

Standardized environmental testing and correlated screening values on potential hazardous substances specified in those regulations, have to ensure environmental conservation. Leaching testing as composition test and their limit values are used as environmental protection criteria against pollution derived from the use of aggregates in most Member States. But before edited a regulation, it is important to understand what type of substance a limit should be set at and how to define threshold values that guarantee environmental protection. On the other hand, to be an achievable goal, these limit requirements must first demonstrate a high degree of certainty of compliance. This implies sufficient proof, e.g. in the form of a dossier, of absolute compliance with the criteria in advance and effective subsequent and consistent quality control measures.

The following sub-chapters provide answers on how to obtain appropriate limit values and search for the right substance.

2.3.1 Definitions of environmental criteria for an environmentally sound use of aggregates

To not pose any increase in the local or surround environment pollution phenomena on the use of recycled aggregates that are trade and used as construction purposes, the release mechanism of concerning substance from aggregates on the environment must be identified and studied under different conditions. A complete material characterisation respect to its environmental properties under different exposure condition, is obtain throughout environmental testing allow to understand the pollution relationship between aggregate and the surrounding environment. Based on the material characterization, environmental impact quantification techniques are implemented. Once the possible risk of pollution is quantified it should be prevented by means of environmental criteria. Those criteria must be developed or be part of directive implementing the reuse condition of recycled aggregates. Leaching test and total content test requests are made as requirements for environmental protection compliance test. If the material, tested before use, complies with the limit values defined for the substances listed in the regulation, the material may be used freely or under specific conditions as a new building material, otherwise it may not be used for this purpose.

In general, total content criteria is a poor indicator of the potential environmental damage while the leaching properties of an aggregate are directly related to this risk. The potential release of substances from aggregates concerns the following environmental compartments groundwater, surface water and soil.

It could be derived that leaching tests rather than analysis of total content should be used to assess the potential environmental impact; instead, analysis on the content of organic/inorganic substance prevent impacts on human health.

Infect the is seldom a relationship between the content of a substance in an aggregate and the leaching behaviour of that substance. Many variables govern leachability mechanism of a substance. Elements can be bond into aggregate matrix and may not became accessible upon contact with water, also solubility limitations by minerals and sorption process may prevent the element from leaching. In cases where the total content of a substance is below the critical limit for leachability, content may be used for evaluation instead of leaching. (JRC).

Assessment on content may be nevertheless necessary on those substances for which no standardised leaching tests exist or for which leaching tests cannot be performed. This could be the case for organic substances (ONORM B 3151). The main reason for this is that leaching tests for organic substances are less developed respect to the well proven leaching test for inorganic substances. At the state of the art the leaching test for organic substances is probably not sufficient developed to be apply in regulatory system, with very few exceptions as for DOC and Phenols.

Due to the lack of proper leaching techniques, organic chemicals are not well regulated in the EU in term of realise, hence such substances are regulated on a content-based basis. Instead, it is considered that limitation on the content of organic substances do in fact offer some, although non quantifiable protection against the leching, migration and impact of organic substances on the environment receptor. On the other hand, well defined standardized European leaching test apply for the determination of the leachability of inorganic substances.

Although as mentioned before, in general total content is a poor indicator of the potential risk of an impact on the environment (groundwater, surface water, soil), such results may be used in the evaluation of potential health effects caused by contact with or ingestion or inhalation (as dust) of the aggregates.

Therefore, total content of a substance in aggregates cannot be used as an indicator of the leachability or release of that substance, and since groundwater and surface water protection against released substances has high priority for those materials, leaching tests are required.

2.3.2 Explanation of leachate and content limit values, a methodological approach

A scientific-based methodological approach must be adopted to provide pollutant limit values for environmental compatibility of aggregates. Studies aimed to identify the risk of pollution from the use of aggregates result in an assessment of the need for and suitability of limit values for pollutants. Those studies are based on different standardized leaching tests and conceptual risk-assessment model. The definition of limit values is based on this principle; knowing the leachability behaviour of an aggregate and employ a risk-based model approach that describe the confining environment assessment, the correlated pollution risk derived on the application of aggregates on the environment are assessed base on require quality criteria, consequently corresponding limit values for concerning substances for the preservation of the environment defined. A scenario- and risk-based models the relationship between the primary quality criteria at the receptor and the results of a leching test performed on the aggregate in question. This relationship must ensure that when a substance complied with limit values it's sure that it doesn't pose any pollution on water quality, meaning that the water quality at the point of compliance at the receptor don't have to exceed the primary water quality criteria for any substance considered.

The search for environmental limit values concerns the possible negative effects on the environment or human health due to the leaching of substances from the use of aggregate materials, especially for waste that has obtained EoW status, which is outside the legislative framework on waste.

The same principles apply for the definition of the European inert landfill waste acceptance criteria, however more risky exposure scenario must be considered since there could be the possibility to use secondary raw materials without any kind of barriers of risk containment. Also, the list of substance against which it is considered necessary to protect the groundwater, soil and surface water should be increased respect to the screening substances set in landfill directive, since the last directive were established 20 years ago.

At European level, the same principles of the methodology for derive environmental protection criteria apply for Construction Products Regulation as well as the associated product standards.

A conceptual steps methodological approach for deriving leachate limit values for aggregates is shown as following; it also explains the fundamentals of use class classification.:

a- According to their composition or origin, aggregates are classified in different groups e.g. recovered concrete. For each group an initial detailed assessment of the leaching behaviour of a wide range of a substances is made following standardized tests, initial type testing (ITT). A wide range of tests taking into account all variability factors As comprehensive information on the average leaching behaviour of every substance from materials belonging to a group result.

b- A scientific sound risk-based approach is used to model different typical use scenarios for aggregates; those models consider a source term (the used aggregates), the transport of leaching substance following a pathway (through its surrounding environment) towards the receptor localized on soil, groundwater or surface water. As output of the model is obtain a time-dependent concentration curves of the transported leached substances, at the receptor. Therefore a mathematical equation correlate the substance concentration at receptor as a function of time.
c- Recognized quality criteria at the point of compliance are fix as a boundary; leaching limit values for aggregates at the source are determined based on the quality requirements at the final receptor.
d- At this point, a various set of leaching limit values for the different application of aggregates may be established depending on the typical pathway the leached substance will take and the quality requirements at the receptor.
e- Combining all these various sets of leaching limits, distinct material quality classes may be defined; for each of them a list of limit values. Therefore, for each material quality class a preferable use scenario is established. A number of restrictions on aggregates use may be established for every material class, in line with the foreseen application. Even though material classes exist additional restrictions on the use of certain materials or to exclude certain classes e.g. in order to protect sensitive areas, may be given. In some cases non quality classes are derived but a only limit values list is used as criteria.

Once possible material classes have been established on the basis of the possible use scenarios with their associates limit values and a group of aggregates has been comprehensively characterised, inter alia through the collection of extensive leaching data, a certain level of routine testing should be required to uphold the quality of a given aggregate. The typology and frequency on routine test are regulated under national legislations.

The subsequent routine tests for a specific material in that group will focus only on the substances most relevant to the specific group. If a substance is considered relevant for routine testing depends on its typical leaching behaviour average and spread in that group of waste aggregates, and the leaching limit imposed by the material class. For a substance as closest to the boundary conditions are the resulting leachate data more frequently this substance will be tested.

For example, we consider the material group of recovered concrete. This material was extensively initially characterized for its leaching behaviour. This characterisation has indicated that many recovered concrete materials are unlikely to meet the strict sulphate limits for material quality class 1, that suggest as use direct contact with water. This means that concrete might undergo routine sulphate leaching test if desired for the use of class 1. Nonetheless a concrete material may for example exempt from routine testing on shlphate leaching when apply for the use of quality class 3; given the less strict sulphate leaching requirement compared to the quality class 1 seen in the view of the initial type testing. On the other side if under extreme conditions (acid conditions and size reduced to a fine granular material) leachability is still limited than a constituent may often be regarded as non-critical with respect to realise.

As explain above for each material quality class a corresponding preferable use scenario is stablished as: direct contact between aggregates and surface water, covered base materials in road scenario, etc. Additionally for each material quality class, a number of restrictions on use can be recommended as: no use restriction, no used in construction project with a distance to the nears water body of less than

50 m etc. Therefore, restrictions or shielding conditions for quality class during using service life and disposal may be adopted.

At the end base on this modelling conditions the strictest leaching limits will be result for aggregate in direct contact with the receptor, more lenient limits for more shielded and remote uses of the aggregate.

In consequence for the determination of leachate limit vales risk-base assessment method are require; for limit values on total content the relationship with the "primary quality criteria" is much simple, meaning that limit values for a substance is simply the primary criteria, for example on soil quality for that substance.

Therefore, regulations on the use of aggregates for construction purposes, considering protection of the environment and human health by requiring testing and setting limit values for the leachability and content of several substances considered dangerous or undesired in the environment as a condition for various types of applications.

The proposed conceptual model methodology described below will be relevant in relation to any use of recycled aggregates regulated under waste legislation as well as for the use of aggregates in general regulated by environmental and health protection measures under construction product legislation, as on the use of waste aggregates that have obtained EoW status.

2.3.2.1 Conceptual risk-base model

The risk-base assessment approach is explained. A risk-based approach is used to model several typical use scenarios for aggregates focusing on the transport of leachate substances, meaning that the modelling of the source, pathway and receptor will be concentrated on the potential risks to the environment associated with release of substances. The risk or impacts posed by aggregates to the environment or human health can be conceptually described as a chain of events, as in figure:

Figure 6: The concept of risk/impact illustrated as a chain of events.

The chain consists of an identified potential contamination source the aggregates, the potential migration pathway on the surrounding matrix and the receptor(s) identified by one of the environmental compartments. The model to be realistic should clearly reflect the presence or absence of any restriction or conditions on the use of recycled aggregates. The impact arises only if the chain remains unbroken and there is a negative effect at the receptor.

Released substances can cross the medium transport term by leaching, direct contact with or transport through soil and aquifers or surface water bodies to points of evaluation or compliance in soil, surface water or groundwater below or downstream of the aggregate application (primary receptor). The final receptor will be the humans or the ecosystem that by use of or contact with the primary receptor are affected by the impact. Exposure routes such as inhalation, ingestion will not be addressed in this study. It will be considered that the hazards connected with these exposure routes are adequately reflected by and protected from by the current national legislation on the maximum content of (dangerous) compounds in materials (such as waste aggregates and soil) that can be used without limits.

We point out that the methodology used is independent of the aggregate in question, as except for the fact that the types of substances that may be critical may vary from one aggregate to another.

The main accent of the model will be on evaluation of relevant combinations of sources, pathways and receptors associated with the release of substances from aggregate applications. A very important aspect in order to consider any potential adverse environmental effect, is that the entire life cycle of the product, including the EoL situation, should be taken into account in the model for the derivation of leachate limit values. Based on experimental evidence it seems safe to assume that the leaching of most substances from an intact bound material will be less extensive than the leaching of the same substance from the same material in a crushed or crumbled state (17. Recycled aggregates will be used in a wide range of construction projects, so the limit values focus on aggregate substances that are subject to leaching and/or release through wear and tear. Infect the critical impact conditions occur if and when the material crumbles or otherwise disintegrates representing the long-term exposure scenario. This implies the inclusion/attention of source term scenario(s) that reflect maximum and long-term exposure conditions and includes the effects of potential chemical changes (e.g. carbonation of alkaline materials) on aggregates, on the identification of the limit values.

It is therore usually suggested to expire the possible impact conditions considering the entire life cycle of the material, but not as rule. The conditions of the take back materials at the end of its service life as adopted in the Dutch soil quality decree for example, consider only the in-use scenario in the risk assessment. However, during service life consideration of aggregate alteration as carbonation, that influence the leachability, should be address.

Therefore, appropriate source terms scenarios based on small particle size and long-term exposure (including oxidation and pH neutralisation through carbonation) should be developed for this situation. This means that aggregates used in bound applications should be tested in a granular state e.g. after size reduction, because the release of substances during the intended service life of bound aggregates is not critical impact condition.

The end-of-(service)life (EoL) situation must also be considered since a material which has been granted EoW status may no longer be subject to any environmental protection regulation after the expiration of its service life. EoL considerations are important because an aggregate with EoW status may remain in place after its primary service life has expired and hence not return to waste status, or it may deteriorate and physically disintegrate during (the later) stages of its service life. The dutch soil quality drcree regulation in this regard imposes the removal of material at the end of its end of service as a condition of new application.

For a better understanding it seems useful to consider each part of the chain separately as the basis for impact assessment scenarios and the associated models.

The source term.

Before to apply the risk-base methodology the leaching behaviour of the material under study must be clear. The origin of the possible contamination to be fully understood.

Numerous source term scenarios are possible for recovered aggregates used in construction application, potentially critical condition are the ones of major concern, this means that we are interested in the critical condition for leachability of substances from an aggregate. In order to truly represent the potentially critical source terms, one scenario should therefore represent an unbound application of aggregate of small particle size exposed to critical ambient conditions (in terms of percolation of infiltrated precipitation) over a longer period of time (a large L/S range). Another potentially critical source term scenario will be one that represents an EoL situation where a bound or unbound material has crumbled or been broken into particles of smaller size and is exposed to critical leaching conditions. Therefore, the right timeframe to be considered is the one that is extended till the EoL of the considered items, in order to take in to account any potential adverse effect.

Leaching of most substances from an intact bound material will be less extensive than the leaching of the same substances from the same material in a crushed or crumble state. Since a bound use aggregate in its entire life can end up in a crumble stage, aggregates used in bound applications should be tested in that crumbled state. Therefore, same physical condition of the source scenario is used to describe bound and unbound use conditions.

For the atmospheric point of view critical leaching conditions means high infiltration rate.

The critical scenario therefore concerns aggregates on a small particle size subjected to adverse weather conditions, high infiltration rate of rain, over an extended period of time in a manner to consider ageing reactions.

Another fundamental aspect is the mode of contact between the reused material and water, which should also be described as a function of time. The mode of contact may depend both on the nature of the material (granular (unbound), monolithic (bound)) and on the scenario conditions such as physical layout, rate of precipitation and rate of infiltration or other ingress of water. The mode of contact determines the release mechanism for the contaminants and hence the test method(s) to be applied for the basic characterisation.

The release of substances from an aggregate in contact with immobile or stagnant water is different from a granular material in contact with percolating water (and the leaching tests to be applied in each case are also different). Infect the aggregates can be used in different application in bound or unbound state. If we consider for examples a monolithic system it is important to assess the effective surface, including cracks and fissures, to determine the active surface on the realise mechanism.

Under those conditions and comprehend the mode of contact an assessment of the potentially critical leachability source term should be made with a wide range of standardized environmental tests ITT as describe in figure.

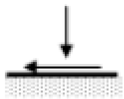
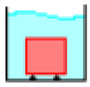
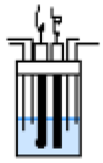
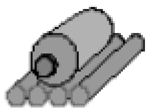
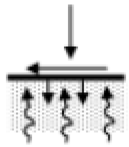
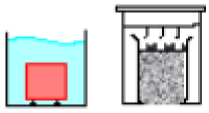
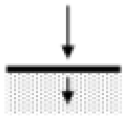
General water contact scenario		Relevant test methods Applicable to a large range of materials		
	Non-permeable material. Water is flowing over the surface of the product	Tank test (DSLT/DMLT)		pH dependency test  or 
	Low permeable material. Water is transported into the matrix by capillary forces; contribution of core to surface	Tank test (DSLT/DMLT, including the CGLT)		
	Permeable material. Water may infiltrate into the matrix driven by gravity (typically granular materials)	Percolation (column) test Batch test (for QC/FPC or compliance) CGLT for coarse granular material		
Note: The tests shown only address inorganic and a few organic substances				

Figure 7: three basic water contact scenario and relative test method for aggregates leaching behaviour. DSLT is the dynamic surface leaching test (TS-2 from CEN/TC 351) and CGLT is the compacted granular (tank) leaching test which is a special version of TS-2. QC is quality control and FPC is factory production control. See section 3.7.2 for further description of test methods (JRC).

Knowing the leaching behaviour of the material other conditions to model the source terms is the scenario-use description. When considering the latter different aspect shall be considered:

- the physical layout of the application, including mechanical and geotechnical set up;
- the hydrogeological model and climatic conditions of the application area;
- biological conditions (if relevant);
- conditions for the use of the site at different points in time.

The output from a source term is the flux defined as the amount of relevant substances released for unit of time from aggregate, as a function of time over the considered timeframe.

The pathway term.

The pathway scenarios modelling the transport of substances from the application to the primary receptor, using the output from the source term as input. In the risk assessment appropriate mathematical models describe the transport of substances.

In the calculation of the EU waste acceptance criteria (WAC) for inert waste in landfills, for example, the pathway scenario included modelling of the transport through the unsaturated zone below the landfill to the groundwater level and subsequent transport through the aquifer to the point of compliance. The modelling of the pathway across the medium taking into account both hydrodynamic dilution and dispersion and retention of the substances in the soil/aquifer. Those factors, offer referred to as attenuation will have a substantially mitigating effect on the resulting impact at the receptor, therefore the critical pathway scenario is represented by the direct contact between source and receptor. This condition would not provide any protection or modification of the receptor from the impact of the source term. If there are restrictions, even in the type of application the transport scenario must be a relatively critical condition.

As point of comparison other pathways scenario should also evaluate take in consideration attenuation factors to study the potential effect of placing certain limitations on the use of aggregates.

The output of the transport model or series of models will e.g. be the concentration of the substances in question as a function of time at one or more points of compliance at the receptor.

The receptor term.

The receptor is the point of compliance at the end of the pathway where quality criteria must be fulfilled. Since we are referring to leaching condition, it seem easier to considered quality criteria at the point of compliance based on water quality criteria. Therefore, the final receptor will be a water body, that could be groundwater or surface water. Since the purpose of the risk/impact assessment and the subsequent development of leaching criteria for aggregates is to protect groundwater and surface water, is important to determine from which substances the point of compliance POC should be protected. Boundary condition at the POC is a proved list of substances quality criteria for which concerning substance have to comply. The appropriate quality criteria that must be established and followed at the point of compliance (POC) should be based on current national or EU laws governing the quality of soil, surface water, and groundwater (primary quality standards). It appears appropriate to refer to "primary quality criteria" since they are the environmental protection criteria from which all other leaching criteria and limit values will be derived. In addition, when establishing limit values, the strictest primary water quality standards in all EU Member States should be used because the finished product may be traded internationally. The primary WQC should represent the substances against which it is considered necessary to protect the groundwater or surface water. Depending on which extent this substance is find out in and leached from the aggregates in question, those can become part of the environmental criteria. In principle, the general list of substances for which leaching limit values are to be defined should match the list of primary WQC; the substance, not included in that list but for which suspected of their hazardousness should be also included.

Therefore, the assessment of the acceptability and the quantification of “overall adverse impacts” on the environment are based on the primary water quality criteria WQC of the final receptor water.

Various attempts can be made using various POC. The POC that results in the lowest limit values should subsequently be used for the specific scenario to decide upon limit values.

In the Table 1 a resume of the procedure described before is conceptualised in the stepwise model flow, for developing leachate limit values.

Table 1: The interactive stepwise procedure for the development of leaching limit values for aggregates to be used for specific purpose under specific conditions.

Stepwise procedure	**Use conditions**
Description of the application and the imposed conditions	The specified application and the relative conditions imposed are described

Description of the receptor(s) and definition of the boundary as primary water quality criteria	The receptor (groundwater or surface water) is selected, and appropriate water quality criteria are chosen
Modelling of the source term	Modelling of the flux of leached substances as a function of time based on the chosen application, the imposed conditions, and the assumed climatic conditions. The mode of contact between aggregates and water is described as function of time. The output flux will be the input for the transport assessment.
Modelling of the migration of substances from the source to the POC	Modelling of the transport of substance from the source to the receptor, considering the mitigating effects of the imposed conditions and the attenuation/dilution effects in soil, groundwater and surface water. Transport of substances is described in a mathematical model as a function of time.
Assessment of the impact at the receptor and reverse modelling or iteration to adjust the source term to the primary WQC	The peak values of the substances at the POC are calculated, and the relationship between peak value and initial concentration at the source is established by reverse modelling or iterative modelling. As point of convergence the source term concentration corresponding to a peak value substituted by the WQC is established.
Transformation of source term criteria to specific limit values	The resulting initial source term concentration (C0) corresponding to the WQC at the POC can be converted to corresponding limit values at liquid to solid ratio L/S, NO IN CHE MODO CON LA RELAZIONE SOTTO? assuming an exponential decrease of the concentration with L/S.
Assessment of the resulting limit values; establishment of limit values or repetition of the model	If the leaching limit values calculated for a given set of conditions are considered too restrictive, the procedure can be repeated with additional or more effective conditions to find new limit values

After the risk-based model approach has been analysed, there are essentially two different modelling conditions: one approach representing free unrestricted use of aggregates based on the most critical source and pathway conditions, and a second approach representing condition in which some restriction on the use of aggregates is required allowing less severe source and pathway modelling.

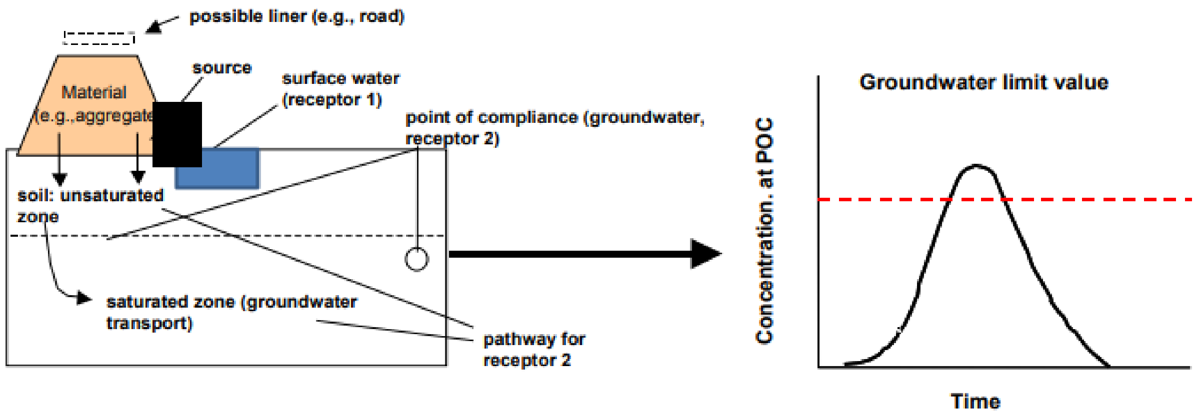


Figure 8: Illustration of the two situations for developing regulatory criteria; direct contact between source and receptor (receptor 1) and scenario considering mitigation effect on the pathway through the receptor (receptor 2) considering regulatory restriction on aggregate use. (JRC).

If it is not possible to place any restriction on uses of aggregates, the environmental and health criteria to be fulfilled must take this into account. The criteria must base on the relatively conservative if not worst application scenario. Source term must account for the "worst case" release that way potentially take place. This means that nevertheless the aggregates are used in bound or unbound application testing on reduced size material must be done both under initial conditions and long term exposure and under high infiltration rate conditions to determine the maximus release of substances. The behaviour of realise of a substance from aggregates is not easy to grasp. For most substances the highest concentrations are seen in the initial pore water, but some substances who solubility controlled one, may have high concentration in long time due to removal of other substances or due to the changes in the pH. As source terms output the pore water concentration of concerning substances is considered, as it represent the highest realise values for granular material.

The modelling of the transport of substances released from the source to the receptor on the conditions of no use restriction imply that the potentially critical pathway can be very short or in worst condition don't exist in the case aggregate are pose in direct contact with the receptor. In this case, relies of substances from source may have to directly fulfil the primary criteria at the receptor.

Base on the concentration C of the substance of concern considered in the WQC, the equivalent leachate limit values is calculated by means of the equation:

E= Cx0.2 [mg/Kg]

whit L/S= 0.2 L/Kg, the estimated value corresponding to the pore water condition, i.e., the pore volume for a material with a dry bulk density of 2 kg/l and a porosity of 40 % (JRC).

The leachability can be transformed than on the basis on the L/S values of interest.

Leachate limit values criteria derived in this way could be very stringent.

Instead of free use of aggregates a requirement or a combination of can be chosen for their use to protect the environment. The Table 2 shows some restrictions on use.

Table 2: Example of single or combined restriction on use scenario

Imposed condition	Source	Pathway	Receptor
The material can only be used for specified purposes	Can be influenced	Can be influenced	May determine which receptors are relevant
Take back the material after service life	Reduction in the time span to be considered	Not affected	Not affected
Minimum distance to groundwater level	Not affected	Attenuation in the unsaturated zone may be taken into account	Depend on POC
Minimum distance to surface water	Not affected	Attenuation in the unsaturated zone and the aquifer may be taken into account	Depend of POC
Restrictions on height of application	May reduce source term	Not affected	Not affected
Restrictions on the length and width of the application	May redue curce term	Not affected	Not affected
Restrictions on allowed rate of infiltration	Reduction of the flux	Not affected	Not affected

Some conditions on use of aggregates are shown in table, it is also indicated the part of the source-pathway-receptor chain affected.

The type of application and correlated condition must be decided in cooperation with expert. The result is a limited number of specific application scenarios and range of conditions to be used for the source modelling. If, on the other hand, some restriction was placed on the application of aggregates, less strict release behaviour may be considered without compromising the safety of the environment and human health. The imposition of some requirement on the use of aggregates lead to a less stringent leachate limit values, because a sort of barrier applies.

It is important to note that, particularly for requirements 5-7, the magnitude of the potential increase of limit values for specific substances, relative to those for unrestricted use, depends strongly on (regulatory) choices with regard to the location of the POC, the quality criteria, and the time frame considered.

Therefore, if conditions are set sets for use, the effect of these conditions should be reflected in the in-use scenario and the source term. The application scenario defined must be modelled in term of source terms as height, width, length, hydraulic conductivity, dry bulk density, porosity, and net rate of infiltration through the top cover. A water balance should be set up for the application; since the realise of substances from an aggregate is not constant over time the mass balance represents a mathematical equation that correlate release as a function of time and/or L/S. For the sake of simplicity, it is assumed that the release of each substance to be considered can be described as an exponentially decreasing function of time or L/S (although this is not entirely true for all substances). Therefore, source scenario is described by means of mathematical equation where Co is the initial peak concentration. Again, for the sake of simplicity, it is assumed that the kappa values the kinetic constant are independent of the waste material.

Then in this case the resulting source term describes the flux (e.g. in mass per unit time) as a function of time of each of the substances of interest released into matrix below the application.

In case of restriction on use, the worst-case pathway scenario is not considered, no pathway, instead the second step of the chain must be considered. On the modelling of transport term dilution and retardation phenomena along the pathway should be considered, which could result in a less stringent criteria.

Modelling of the transport step must be done differently for unsaturated and saturated zone using two different hydrological model. The first apply through the unsaturated zone to the surface of the groundwater below the application, the second (if required) through the aquifer to a point of compliance at some distance downstream of the application. The modelling of those two zones is based on hydrologically and geologically models including information on the thickness and hydraulic conductivity of the unsaturated zone, the retention properties of the unsaturated zone (i.e. a measure of the interaction between the substances in the leachate and the soil) and the general rate of (rainwater) infiltration for the area. Also The background concentration of the substances considered in the groundwater should also be determined.

Thus, the scenario conditions should be selected in such a way that they represent the chosen scenario as realistically as possible. The boundary conditions represent the element landscape of the matrix of interest should be incorporated into appropriately chosen (numeric) transport models. Generally, most state-of-the-art models work on a 3D space and are based on groundwater transport equations. The model(s) chosen should as a minimum be able to incorporate the effect of sorption/ion exchange e.g. either by use of a simple linear partitioning coefficient (Kd), The result of the pathway modelling is a description of the concentration of each of the substances as a function of time at the POC(s). Due to the dispersion and attenuation effects and the decreasing nature of the source those concentrations will increase with time, show a peak, and then decrease. The peak represents the maximum impact at the receptor that will occur over time. The resulting concentration at POC in groundwater can be considered as the average concentration over the entire depth of the aquifer.

Therefore mathematical transport equation can be resume as: If a linear Kd relationship has been used to describe the retention of substances in the model, then the relationship between the initial peak concentration at the bottom of the application, C0, and the peak concentration at the POC in the aquifer, CP, is also linear for a given substance and application. The ratio between the two, CP/C0 = fa, is called the attenuation factor for that particular scenario and substance.

If a water quality requirement, WQC, is then imposed on the groundwater at the POC (CP), this means the corresponding requirement on the source term, C0, can be calculated as follows:

$$C0 = (1/fa) \times (CP - CBG) + CBG$$

where CBG is the background concentration of the substance in the groundwater upstream of the application.

Once the value of C0 corresponding to the WQC for a given application scenario and substance has been established – and still assuming that the release of the substance can be described as an exponentially decreasing concentration as a function of time - the result can be expressed in terms of a limit value, release ELV (mg/kg), for a percolation or batch leaching test performed at a specified (accumulated) L/S value:

$$ELV = (C0/\kappa) \times (1 - e^{-(L/S)\kappa})$$

This allows the limit value to be adjusted to the preferred test method or test conditions in terms of L/S

If it is felt that the limit values are too restrictive (too low), the step-wise procedure can be repeated, starting by applying more stringent conditions in step 1.

As a rule of thumb, a thicker unsaturated zone, a longer distance to surface water bodies/POC, a more shallow and smaller application, and a lower rate of infiltration will all influence the calculations in the direction of less stringent (higher) limit values, the magnitude of which being dependent also on other criteria such as the quality criteria for water/soil at the POC and the time frame.

Then the limit values for the entire suite of substances have been established, the compliance of various relevant aggregates with these values can be assessed based on existing information or based on the performance of new tests. If an aggregate is to be recycled as part of another material (e.g. in hydraulically bound materials or bituminous mixtures) then the tests and risk assessments ideally should be carried out on the material containing the mixed-in aggregates and not on the “pure” aggregates. This is obviously not possible in the context of EoW criteria since the free mobility and free use allows too many options for different uses.

Therefore this is the procedure to derive inorganic substances leaching limit values. Organic substance due to the lack of recognized tests environmental, cannot be directly related to the leaching properties of the aggregates through the risk or impact assessment procedure. As a substitute, the total content of organic substances of concern should be determined as the basis for an assessment.

At the end the condition use for specific purposes could lead to more than one set of limit values corresponding to different application purposes, or, if that is considered impractical, to the adoption of the most restrictive of these for all the relevant purposes. If in the final assessment, the leaching criteria are to loo, then imposed condition considered could be reconsidered and changed, and stepwise procedure repeated.

Leachate limit values derived from free use of new construction materials could be very stringent. Infect if we compare leaching criteria derived in this way with the well-established landfill acceptance criteria for inert waste it is evident the calculated leaching limit values for aggregate use without condition are very stringent and they will most likely be extremely difficult to comply with for most waste derived aggregates.

To overcome this problem, conditions of use are usually adopted in the regulations of member states. For example, the condition use of a minimum distance from the application to the water table will provide protection on the groundwater allowing consideration of attenuation process in the pathway in unsaturated zone. Compared to a situation without such a minimum distance, this will result in higher limit values for most substances.

2.4 Environmental testing description

Leaching limit values is closely related with the test method to which it refers: therefore, a leachate limit values is meaningless without reference to a specific leaching test. Each test is well labelled for its purpose and its geographical validity range established. To avoiding redundant test and to reduce the amount of testing necessary a testing hierarchy was established. By requiring the same type of tests to be performed, double testing of a material possibly falling under different regulation or specification will be avoided. The principle of the hierarchy is to perform one thorough characterisation by means of series of initial type testing (ITT) of the environmental properties of a given material which then haven't been repeated if the material didn't change. Simpler test methods to compliance with criteria are then applied routinely at certain intervals. A selection of basic characterisation programme tests may be chosen for compliance testing. Tiered approach testing methods satisfies the need from a regulatory perspective to ensure compliance with health and environmental quality targets.

From characterisation data set relevant substances for compliance and frequency of testing are derived in combination with compliance testing methods required. Compliance with environmental health and quality objectives for accredited recycling companies and for beneficial reuse are based on simplified tests.

In particular for the development of the EoW environmental criteria is widely accepted that the testing tools for waste materials and products within the different legislative regimes for different evaluation should be the same to avoid double testing of the same material or product falling under different regulatory framework.

In the basic characterisation release behaviour of any material type are conducted with pH dependence and percolation test to checks the full spectrum of possible exposure scenario. pH dependence test evaluates the sensitivity of small pH changes on release behaviour; percolation test provides time-dependent release behaviour of the material. Both methods in combination allow judgment of exposure conditions outside the range of actual conditions tested. The bandwidth of cumulative release and leaching concentrations under the variety of pertinent exposure situations has to be sufficiently understood tanks to those tests.

The analytes considered in the ITT include all the major substances mainly salts, and all substances for which water quality criteria exist; any substance that may be of concern and know to be present in the aggregates, but not included in that above should also be part of that. DOC for example should be analysed in the eluates because of its ability to enhance the leachability of metals and POPs.

ITT should also include determination of the total content of a number of substances, assessing at least the 5% of the mass of the material under study. Total content is searched for TOC, PCB, BTEX, PAH and hydrocarbons and any inorganic substances of concern (ONORM B 3151). The analytical programmes for testing of leaching and content during factory production control (FPC) or compliance tests should be based upon the findings in the ITT and may be substantially reduced as compared to the ITT programme.

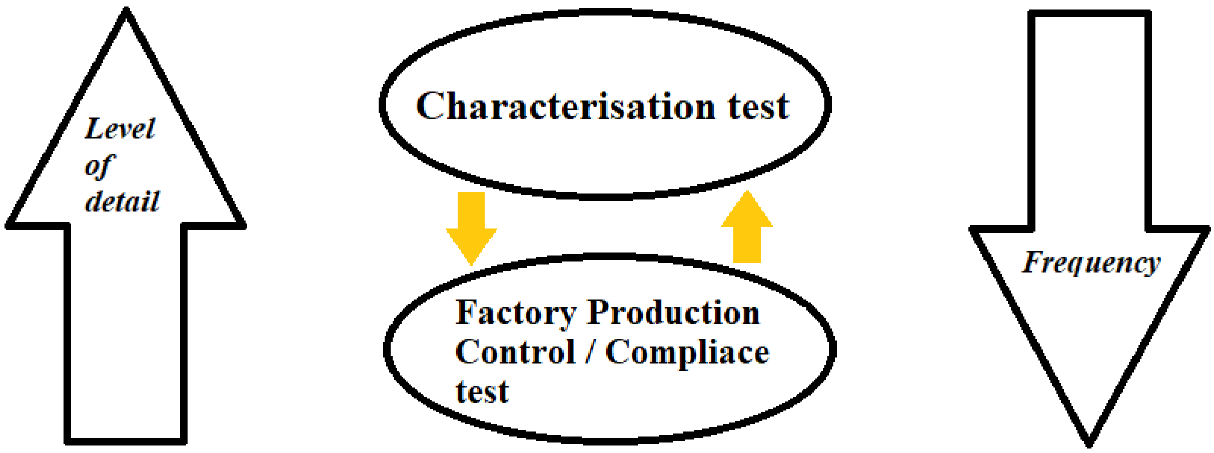


Figure 9: Tiered approach in testing.

In the following figure a comparison between percolation test and batch test are provided, being the first used in basic characterisation test and the second for compliance test.

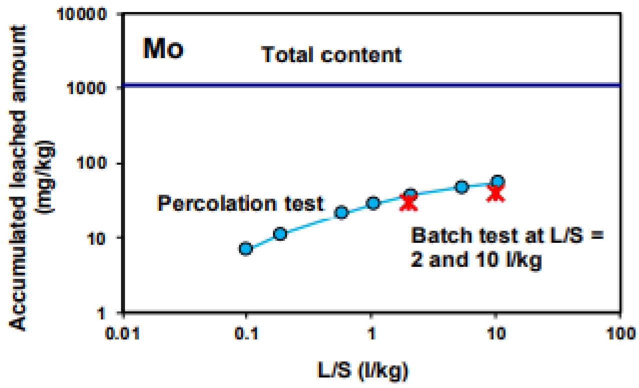


Figure 10: Results of percolation and batch leaching tests on an aggregate shown as a function of L/S (JRC).

It is evident that the batch test results reflect two points on the leaching curve that was defined by the percolation test findings. Infect the batch tests provide information similar to that obtained from the percolation test but averaged over larger L/S ranges and thus showing much less detail. In most cases where the difference in pH and redox conditions over the column experiment is limited, the results from batch tests and cumulative results from a column test will most likely be the same. An example of a situation where a difference is likely to develop is where, for instance, the pH changes during the column test, and as a result the leachability of some substances also changes, while the batch result represent only one pH value.

This means that batch test could be used as compliance test, because it represent well the real trend of the material and it is easier.

Therefore, different leachate protocols exist to provide answers to total leachability substance from aggregates, its leachability by percolation of infiltrating rainwater, its dependency on change on pH and many others. An integrate set of tests are necessary for a complete assessment of leachability of various substances from an inert aggregate. The suitable test must be selected on the base of the question to be answered and the leachate mechanism involved. A general explanation of environmental leaching test is illustrated, also some notes about total content test.

Batch leaching test:

The batch test mimics the condition a permeable matrix in which water can infiltrate, drive under gravity force. The Batch leaching test as produced by the European Community must be carried out according to the standard EN 12457 is performed on size reduced material (95 % <4 mm). Exist different variation of the same test depending on the L/S ratio and the number of stages of the batch. Two stage batch means two reactors arranged in serie. The standard EN 12457-1 (single batch test at L/S = 2 l/kg), EN 12457-2 (single batch test at L/S = 10 l/kg) or EN 12457-3 (two stage batch test at L/S = 2 and 8 l/kg to an accumulated L/S of 10 l/kg). The number of stages correspond on the number of prove of the test as different L/s ratio. The granular material is placed in a closed bottle with demineralised water and agitated for 24 hours (6 and 18 hours for the two stage test). The eluates are filtered through 0.45 μm membrane filters and analysed. Some EU Member States apply the test EN 12457-4 which is similar to EN 12457-2, except for the fact that it does not require size reduction of particles up to 10 mm. Results are reported as concentrations or leached amounts as a function of L/S. Since the interpretation of the test results are based on the assumption that near equilibrium conditions are achieved during the test, there is a risk that the leaching in EN 12457-4 will be controlled by diffusion instead of equilibrium (and therefore different) if the amount of fines in the material is small.

Results are reported as concentrations or leached amounts as a function of L/S.

The EN 12457 tests are applicable mainly measure the release of inorganic substances (and DOC) from predominantly inorganic or mineral aggregates.

In a batch leaching test L/S is based on the total amount of water added to the solid. In this kind of test, the L/S ratios typically range from 20 to 10, while relatively low L/S ratios are used in column (or field) test. (21)

Percolation test

The percolation or column test mimics the condition a permeable matrix in which water can infiltrate, drive under gravity force. The percolation leaching test on reduced material (5% 4mm is carried out on waste materials according to CEN/TS 14405. In this column test a minimum of 7 eluate fractions are collected in the range of L/S=0.1-10l/Kg. (L/S = 0-0.1, 0.1-0.2, 0.2-0.5, 0.5-1.0, 1.0-2.0, 2.0-5.0 and 5.0-10.0 l/kg). The duration of the test is approximately 23 days considering the first 2 to 3 days for the pre-equilibrium period. The material is leached by demineralized water in a column operated in up-flow. The dimension of the column are typically 30 cm height and a diameter of 5 or 10 cm. no pH control measures are used; generally the pH is controlled by the waste itself. If necessary, the eluates can be collected under nitrogen or argon to prevent e.g. oxidation of reduced species and/or uptake of atmospheric CO2 which could lower the pH of alkaline eluates. (JRC). The eluate is filtered through 0.45 μm mesh size membrane and analysed. Results are reported as concentrations or leached amounts as a function of L/S. it is assumed that the test conditions (particle size and flow velocity) cause the test to operate under local equilibrium condition between the aggregate matrix and the leachant. This test can be used for the determination of both inorganic and non-volatile organic substances. The state of the art with leaching of organic substance is, however, very limited.

In a percolation test L/S is based on the amount of eluate collected at any time during the test.

Tank leaching test

The tank test is useful to represent condition of impermeable or low-permeable material; water flow on the surface or is partially transported by capillary forces into the matrix The tank leaching test is performed on monolithic (or bound) products of regular shape above a minimum size. The minimum size of the specimen that should be at maximum 4 cm, is subject to leaching in a close tank. Being a close system, the leaching solution is renewed after 0.08, 1, 2.25, 8, 14, 15, 28, 36 and 64 days. Demineralised water is used as the leaching solution at a liquid-to-surface area ratio, (L/A) of 8 cm3 /cm2.

The pH and electric conductivity are measured in all elute before filtration (0.45 µm) and chemical analysis. Results are reported as a flux (e.g. mg/m2 /day) as a function of time or as leached amounts per unit surface area as a function of time.

pH dependence test

the pH dependence tests (CEN/TS 14429 and CEN/TS 14997) are used to characterize the pH dependent leaching behaviour of granular materials and bound materials. In both cases size of material is reduced (to 1 mm prior to testing to minimise diffusion resistance to release and formation of equilibrium. Typically, the material is leachate at eight pH values ranging from 4 to 12, each at the L/S ratio =10 l/Kg. Nitric acid and sodium hydroxide are used to adjust the pH to the desired value. In CEN/TS 14429 the different pH values are obtained through initial addition of acid or base and subsequent check of pH and adjustment after 6 hours of equilibration. In CEN/TS 14997 the different pH values are pre-set and maintained by feedback control and continuous addition of acid or base. The test duration is 48 hours, the eluate is filtered and chemically analysed. The amount of acid or base added equivalents added at the different pH values provides a measure of the acid/base neutralisation potential of the material. Results are referenced as concentrations or leached amounts as a function of pH. The test fit to assess the release of inorganic substances and DOC from inorganic or mineral aggregates and products. Attention must be posed for organic substance and the container used must prevent sorption losses. Attention must be posed also on the change of pH for very reactive materials (e.g. material containing significant amount of $Ca(OH)_2$ as concrete; the acid addition must proceed slowly to prevent too strong reactions to the base/acid additions.

Total content test

Methods for the content of both organic and inorganic substances will also be required; results are compared to existing limit values related to health risks. The total content of a substance is derived by a digestion/extraction method and subsequent analytical methods. For inorganic substances identification the proposed method is aqua regia digestion following a determination analysis by spectrometry ICP-OES ("*Inductively Coupled Plasma – Optical Emission Spectroscopy*" or ICP-MS ("inductively coupled plasma-mass spectrometry". For anions determination the recommended methods are dissolution by alkali fusion followed by quantification using Ion chromatography (IC). Regarding organic substance determination the proposed approach different extraction methods apply for different substance groups; basically, it consists of extraction, clean-up and quantification by gas chromatography-mass spectrometry. (GM-MS).

It is necessary to point out that some misunderstanding appears on the limit values on waste of polychlorinated biphenyls (PCBs. This is particularly interesting for the context of the EoW acquisitions. No EU legislation provide detailed definition of the limit values for content of PCB in waste. Regulation (EC) No. 1272/2008 of the European Parliament and of the Council of 16 December 2008 on classification, labelling and packaging of substances and mixtures refers to the substance as PCB setting a limit value on content of 0.005% (50 mg/Kg for content that will render a waste hazardous. However, is important to note the fact that PCB is a group name for hundreds congener. The commission "Commission Regulation (EC) No. 756/2010 of 24 August 2010 amending Regulation (EC) No. 850/2004 of the European Parliament and of the Council on persistent organic pollutants as regards Annexes IV and V" – "the POP Regulation" – there is a reference to the measurement of the content of PCBs. Two method of calculation prescribes: determine all congeners analytically and sum them or determine the sum of 6 congeners PCB 28, 52, 101, 153, 138 and 180 and multiply the result by 5 to get an estimate of the total continent. On the waste landfill acceptance directive 2003/33/EC the research for POC ask for 7 congeners with out specify the name and the facto for which multiply than; also is not clear the limit for who is accounted for. Therefore, is important when develop limit values for the content of PCBs specified both the congeners to be measured and the factor to estimate the total content.

2.4.1 From laboratory analysis to field conditions

Laboratory tests are an important tool to answer the main interesting question, namely, how does a material behave in full application, since field verifications results more expensive. Laboratory standardized test, in conjunction with modelling interpret the variability of the field condition and make results comparable. The key on the relationship between laboratory test and field condition are the knowledge of the realise-controlling factors. From leaching studies basically exist two the methods of release behaviour.

Fully soluble substance-availability controlled release: the substance is readily wash-out (at low L/S ratio). Under field conditions, these materials are potentially dangerous as they generate preferential paths. Preferential flow becomes a significant factor as stagnant zones in the application may contribute only limited to the mass flux, as such zones release substances by diffusion. Therefore, this can result in the accumulation of those substance in that areas.

Solubility/sorption constrains substances: same concentrations in lab or in field can be the same in spite of differences in liquid to solid ratio; concentration may change, when pH condition may change between laboratory and field. Laboratory analyses and in particular the pH dependency test can give useful information about release.

3 CDW characterisation and European guidelines

Waste from construction and demolition activities is a priority waste stream due to its volume and related resource conservation potential 31. In this chapter a qualitative and quantitative construction and demolition waste (CDW) composition analysis and, a review of how construction and demolition waste is regulated today at the EU level with respect to avoiding environmental pollution and health problems is discussed. Infect, the generation of waste entails the obligation to comply with specific regulations. When classified as a waste, environmental and health protection aspect of the use of CDW for construction purposes are regulated by national and EU waste legislation. A waste can leave its state only if it meets the EoW criteria governed by EoW regulations, became a product and in this case regulated by the construction product regulation (CPR); this is an important tool in the implementation of the circular economy concept. Due to the many stakeholders involves, CDW management is fraught with different terms and concepts. As CDW is primarily a local activity, strong difference in terminology exists between member state as well. For this reason, a unique list of terms definitions is provided at the beginning of this work. This chapter also fix some concepts that are recurrent in the elaboration. Attention will also be paid to the use of the mineral fraction of CDW as the fraction of main interest for this study. We focus on the group of materials responsible for the major part of the waste generated in construction and demolition activity. Improvements in the recycling and re-use rate of these materials will consequently have a large influence of the total CDW treatment.

Particularly in this study, the management systems of facilities such as airports, brownfields, hotels, and resorts—buildings that are of interest to Enydron consultancy services—rather than modest residential private homes are analysed.

3.1 CDW characterisation

European community define construction and demolition waste as waste derived from construction and demolition activities (WFD). Equally CDW is the left-over material from activities such as the construction of buildings and civil infrastructure, total or partial demolition of buildings and engineering work, road construction and maintenance. In building infrastructure 90% of waste arises during the demolition, conversation and restoration of buildings; the remaining accumulate during the construction of new buildings, and it primarily includes concrete, bricks, gypsum, wood, glass, metals, plastic, solvents, hazardous substances (asbestos, PCBs, etc.) and excavated soil. In civil engineering in addition to excavated materials, waste consisting of formwork timber and iron reinforcing, as well as concrete debris, accumulates. In road construction asphalt and concrete debris, as well as excavated materials, are usually produced. When building and restoring track installations, ballast is produced in addition to waste specified above. Many of which can be recycled. CDW are listed in the chapter 17 of the European List of Waste. Classification based on material typologies is show below.

Table 3: CDW typologies classes and relative description.

Waste designation	Composition

Building debris	bricks, concrete, rocks, tiles, mortar, ceramics, rendering
Road rubble	asphalt rubble, concrete, base material, bitumen
Track ballast	special aggregates
Other mineral construction and demolition waste non hazardous	gypsum, glass fibre mat
Site waste (no building waste)	plastic, wood, metal, insulating material, plasterboard, packaging

Based on volume CDW comprises the largest source of waste stream in the EU (25), accounts for more than a third of all waste generated in EU. Infect, construction and demolition activities contribute 37.5% of the total waste generation of European economic activities and was followed by mining and quarrying (23.4%). Construction sector result, therefore, as the major economic activity source for waste generation in Europe (Eurostat 23). Total CDW generation account for 847,765,740 T, when considering the EU-27(Damgaard, JRC).

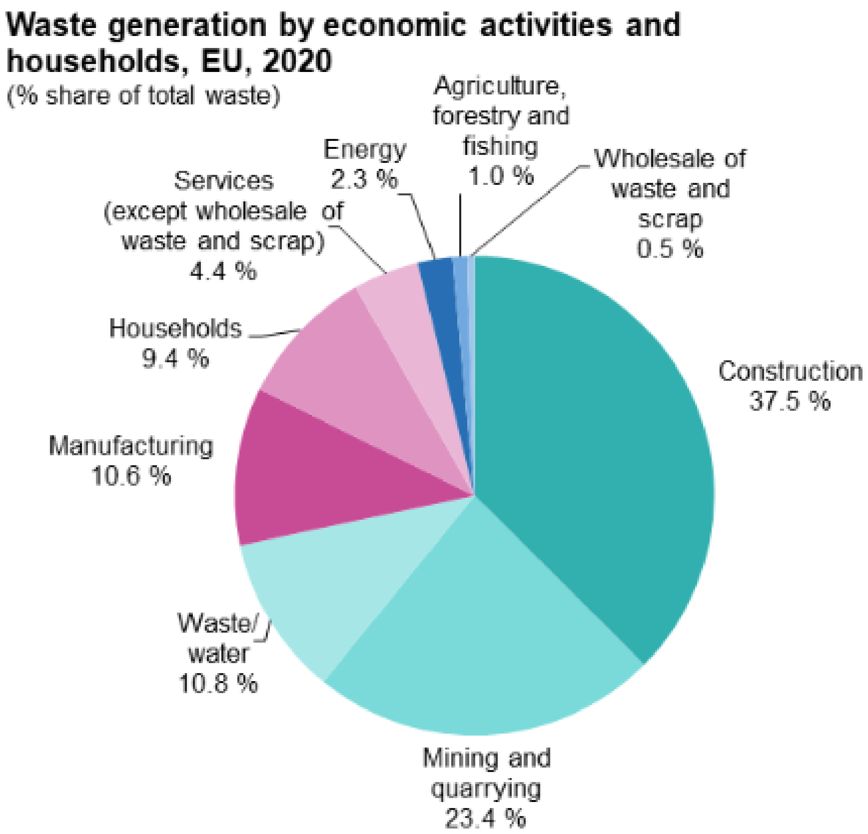


Figure 11: waste generation by economic activities at European level (Eurostat)

3.1.1 Historical background material used and construction technology.

Concrete is a modern construction material, is the most widely used in construction sector and consume huge amount of resources in particularly cement, and aggregates for its manufacturing. Natural aggregates are the main supplier of raw materials for construction sector, their extraction is the most impacting process of manufacturing of concrete; the second most consumed raw material in the word, after water, by man. Concrete is made mixing cement the blinder, gypsum, aggregates like sand, gravel ad water admixtures. It is initially a paste that by vibration harden in a process call hardening. This is also why, a particular type of sand is required for cement production. Sand reserves are running out and its extraction is causing accelerated coastal erosion. Illegal sand extraction activities are rising too. In kangaba, a town in Mali - as the fragile climatic and social balance of the area breaks down and the demand for meat increases - former fishermen have converted to work illegally as sand gatherers on the bed of the river Niger. Well paid material, from construction company middlemen, for galloping African urban development (Il grande gioco del Shael, 2021).

Portland cement is the most used binder in concrete production, is a hydraulic cement capable of setting hardening and remaining stable under water. It consists essentially of hydraulic calcium silicates and calcium aluminates, usually containing calcium sulphate. Portland cement is the primary ingredient in concrete and is responsible for the majority of concrete's carbon emission. GHGs emission originate during cement manufacturing process from the burning of fossil fuels and naturally occurring chemical reactions during the heating process. It is estimated that one ton of CO_2 is emitted during the manufacturing of each ton of ordinary Portland cement. For the production of Portland cement the first step is the extraction, by blasting, of mainly limestone and clay in natural pits. The extracted ores subsequently fracturing and grind in a mil, ingredients such as iron ores are added before to be burn in rotatory kiln at 1450 °C. The obtained cooled Clinker is grinded (often with grinding additives), gypsum and supplementary cementitious materials added.

Productivity in this sector is not evolved during last 25 years, encouraging huge primary materials extraction and producing large GHGs emission. Materials in construction adopted "take-make-dispose" linear model; are assembled for one time use and don't retain potential for reuse, making this sector not sustainable. In a change of direction technologies for new, more sustainable designed construction material are to be developed. Against a large water consumption, self-compacting concrete or super plasticizer compounds are used to make hydraulic concrete more environmentally friendly by minimizing its water footprint. To prevent material extraction recycled aggregates usage and use of supplementary cement materials (SCM) technologies - that partially substitute Portland cement - are rising. SCM are widely used in concrete either in blended cements or added separately in the concrete mixer, representing a viable solution to partially substitute Portland cement. The use of such materials, where no additional clinkering process is involved, leads to a significant reduction in CO_2 emission per ton of cementitious materials infect those components are already ready as it is they don't need to undergo to clinkering process. And is also a means to utilize by products of industrial manufacturing process. For SCM we understand fly ash, blast furnace slag, limestone,

Another valid option is the use of recycled aggregates. Recycled aggregates are obtaining by processing of CDW to comply with the technical and environmental requirements for a given application. There are two main sources of recycled aggregates from CDW: recycled concrete aggregates coming from concrete and mixed CDW. The former construction material is primarily crushed, separated from metals and light materials and soluble substances and sieves. Aggregates in civil work are used to make concrete raking (structural or not), mortar, asphalt agglomerates or bituminous concrete, road construction as granular layer in base and subbase course materials (foundation or payments, railways (ballast), embankment and backfilling.

Therefore, material composition of CDW is influenced by the typologies of building and period of construction.

3.1.2 Actual situation

Due to the not sustainable construction industry, the EC has adopted some strategies to convert this sector to a more sustainable one. The framework directive and the one how set some limit on material efficiency is the WFD 2008/8/EC, where targets to be achieved by Member States by 2020 on the non-hazardous fraction of CDW to be recovery by means of preparing for reuse, recycling and backfilling now a days it was not achieved by all European states SOURCE . The bright side is that certain Member States have already created and put into place a framework that results in up to 90% of waste being recycled. (4). The figure below describes the situation.

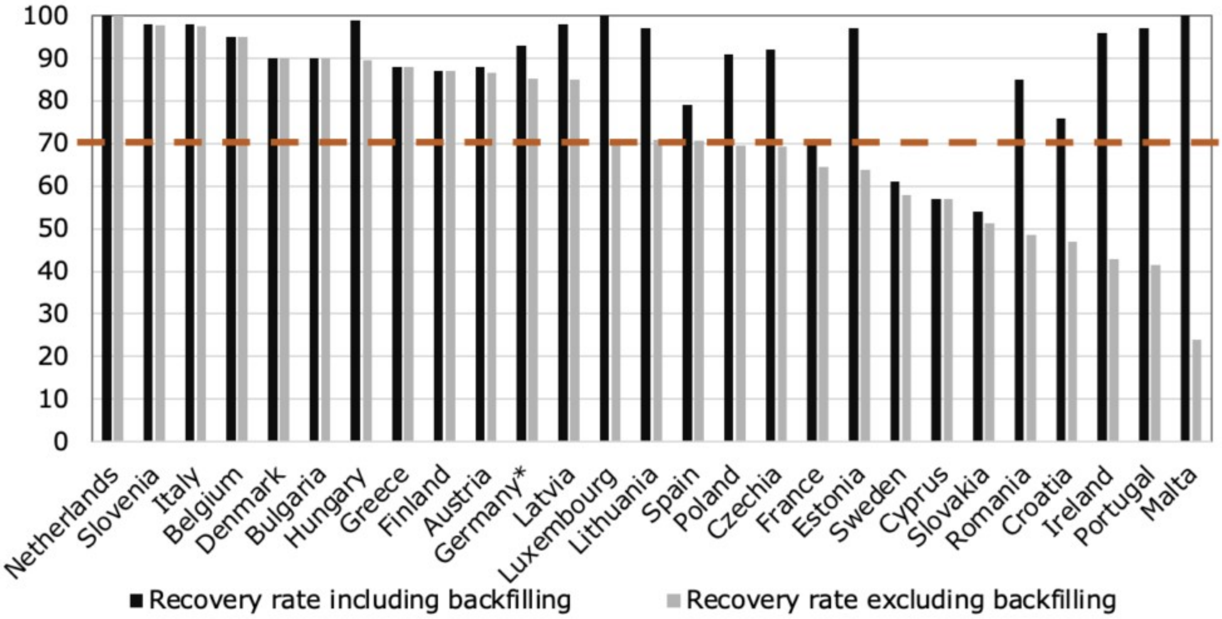


Figure 12: European Member State recovery rate as percentage of non-hazardous CDWs, in 2018(EEA, 2020).

Despite its potential, the EU has a wide range of recycling and material recovery rates for construction and demolition waste, from less than 10% to over 90%. Construction and demolition waste are defined differently across EU member states, which makes cross-country comparisons challenging. (EU rules). For the entire community achievement of its targets, the European Commission ask for more clarity on transparency in data and statistics on collection, generation and treatment that are needed to improve policies and practices, including allowing comparison between Member States. Also EC ask, for the sake of data comparability, to use common names for the different CDW fractions among different Member states.

On the other hand European Commission is considering the possibility of reducing waste production by giving space for the development of BAT, calling for a concrete sorting system to improve the safe management of hazardous waste and a selective dismantling of at least a number of material fractions from CD activities such as wood, mineral fractions, metal, glass, plastic and gypsum, thinking about new target policies to be implemented to prepare for the reuse and recycling of these material fractions. The monitoring and traceability of all generated CDW fosters knowledge of possible secondary raw materials and high-quality material recycled, the basis for the development of a demand-response link in industry for a circular economy.

3.1.3 Material flux composition and analysis

Commodity analysis consists of the extraction of a representative sample of the material to be evaluated and subsequent weighing of the different material fluxes. Performing material flux analysis testifies to the knowledge of the material being treated by investigating its composition and characteristics. Such analyses are an indispensable tool to know the physical composition of materials and thus optimise management and operational strategies. In particular, these make it possible to assess and/or plan the correct performance of separate collections and provide useful elements for the development of systems for the interception of separable fractions still present in mixed waste.

With the terms of mineral fraction of CDW we intend the materials as concrete, bricks, tiles, ceramic, stones and mortar. Is not true that all mineral fraction automatically fulfilling all criteria on inert waste, as defined by term definition itself in the Landfill Directive 1999/31/EC. For example, material containing sulphides may be subject to acidification and hence leach metals at a rate not in compliance with inert waste criteria 17. Inert fraction of CDW is commonly reused as aggregates in new construction project. Recycled aggregates are produced from processing of materials previously produced in construction. Aggregates can be used in bound or unbound form in engineering works. The type of aggregate used in construction usually involves a specific particle size gradation of the aggregate. Specific types of aggregates may be fit for one specific purpose and not for another.

The material fraction composition is presented. CDW is made up of a mix of different materials including inert, non-inert non-hazardous and hazardous waste. Material fraction composition mainly account for soil, track ballast, dredging spoils and asphalt and other materials from road demolition, representing the 67 % of the total waste. The remining 33% comprise the following material fluxes, in order of quantity as: mineral waste, mixed waste, metal, wood, hazardous waste, gypsum followed by insulation materials, paper and cardboard, glass and plastic. The excavated soil account for 382,775,342 t at EU level, instead the total amount of reclaimed asphalt is estimated to approximately 40-45 Mt/y (Damgaard, JRC). The figure below lists the material fraction composition as percentage by mass of a typical CDW material excluding soil, track ballast, dredging spoil and debris from road operations. The mineral fraction appears to be the dominant ones, which is relatively heavy and easily recyclable, but of low value. It also contains materials with positive market value (metals) or potential value if collected separately in clean fractions (such as plastics).

Table 4: CDW material fraction composition at EU expresses as % of the total per capita CDW amount. Material compositions are based on CDW data. It is excludedg excavated soil, track ballast, dredging spoils, asphalt and other materials from road demolition (Damgaard, JRC).

CDW	%
Mineral waste	77.0
Concrete	24.0
Bricks	5.0
Tiles and ceramics	1.2
Mixed/other mineral inert waste	46.8
Plastic	0.2
Metal	4.3
Mixed metals	0.5

Ferrous	3.4
Non-ferrous	0.4
Glass	0.2
Wood	2.3
Gypsum	1.4
Insulation	0.3
Paper and cardboard	0.2
Mixed waste	12.3
Hazardous waste (total, excluding haz. Soil and dredging spoil)	1.8
Total	100

Data are present in a different way as well for different country. Large spread of data for each fraction might be a indication of different practices regarding demolition and CDW management. Significant variation in the level of detail for CDW composition across the different countries also exist. Where data are available for almost all material fractions, including a breakdown into the different components of for example the mineral fraction concrete in bricks, tiles and ceramic… which might indicate a good level of source separation. This is the example of Denmark, Germany, Luxemburg, Netherland. Other countries e.g. Belgium, Finland only report mineral waste data in aggregate forms, without any further breakdown, possibly reflecting poor practices with source segregation and selective demolition. JRC1 This reveals that the available CDW data do not necessarily represent the actual material composition, but rather reflect CDW management practices (Damgard, JRC). therefore, the data presented is a result of an estimation.

We exclude the following fraction on our interest of the study.

- Dredging spoils as it is not relevant in the context of building CDW, and constitute a negligible fraction of it JRC1

- Excavated soil is not a specific relevant fraction in the context of building infrastructure. In addition, the 70% target on CDW recycling defined in the Waste Framework Directive 2008/98/EC as amended by Directive (EU) 2018/851 excludes naturally occurring material (category 17 05 04 in the list of waste 2014/955/EC, i.e. soil and stones). Furthermore, it is representing a relatively large share of CDW thus in some cases overshadowing the remaining fractions. Thus, it was decided to exclude excavated soils in order to focus on other fractions that are more relevant.

Therefore, it was decided to exclude these material fractions, in order to focus on fractions that are more relevant.

In detail insulating materials can be inorganic (e.g. glass wool or stone wool), organic (e.g. cellulose insulation) or polymer based

Mineral fraction is well suited to being crushed and recycled as a substitute for new natural aggregates. Those material are largely used in low grade application most notably engineering fill and road sub-base applications. The use of such recycled concrete aggregates in more demanding applications, such as new concrete production, is much less common and technically much more demanding. (Greece. This implies a recycling strategy but of low grade. To be recycled inert fraction has to be deprive of impurities like gypsum. To limit sulphate content, it is important: collect separate items that include high plaster content, remove the finest fraction (less than 4 mm) and, ensure the separation of light materials. Infect to recycle concrete as new construction material no tainting by chemical additives, mortar paste, and gypsum must be present. Gypsum and mortar paste want to be avoided due to its low beating resistance and evolution during time. Chemical additives should have to be removed for the reason we explain in precedence. Concrete is critical in laying foundations, delineating floors and walls, and reinforcing building elements. Two barriers hinder its recycling: the various contaminants that are found in demolition waste infect installed concrete is never just concrete but is mixed with everything from mortar and gypsum to trace plastic, metals and woods; the concrete's chemicals additives being potentially hazardous and unwanted on its recyclability process.

Steel is the most common structural material for no-residential building; after building demolished, almost much all steel will get recycled. In fact, steel is the most recycled material in the world. Reinforcing steel in concrete construction is still recycled but in a low percentage.

Architectural glass is very salient product used decoratively throughout interiors and deployed in the envelopes of supertall and transparent structure. It removed alone during demolition it could be reused infinitely recyclable to virgin quality, with a broad capacity for recycling.

As we are interest in inert fraction of CDW below a review of recycled aggregates typologies annotate:

Recycled crushed concrete.

Recycled concrete is generated from recycled concrete. Recycled concrete could be reprocessed into coarse or fine aggregates. Prior to crunching and grinding, the concrete must be separated from materials such as stell reinforcement, insulation, wood, gypsum plats board and other impurities. This could be done in situ by mobile units or at centralized processing facility. A main application for recycled concrete aggregates is road construction, also used as backfilling material, in earthwork construction, foundations and in production of new concrete. Fine aggregates can be used in place of natural sand in mortars. The majority concern in relation to environmental and health risk from concrete aggregates would be associated with the potential contamination with other materials due to insufficient sorting and with substances originally present in the concrete. Infect for example coal fly ash, during several years was used in manufacturing of Portland cement added to the rotary kiln as a substitute for clay, and additional amount of fly ash could be added as a substitute for cement in the concrete production process. The sources of RecCon will generally be very diverse and the environmental/health quality therefore difficult to predict without testing. Newly produced RecCon aggregates will normally have a very alkaline reaction with water. This is likely to move towards a neutral pH due to carbonation (uptake of CO_2) as a result of exposure to ambient conditions.

Recycled bricks, tiles and ceramics

Those materials represent a fraction of CDW and are obtained from selective demolition.

Mixture of concrete, bricks, tile and ceramics

Mixture of concrete, bricks, tile and ceramics is a flux of CDW. This fraction is well suited to be crushed and recycled as a substitute for newly quarried aggregates in low-grade applications as engineering fill and road sub-base. Other applications are fill on-site for constitution of landscape hillocks and anti-noise banks; wearing courses which can be regenerated in place, hot or cold; pavement which can be treated in place by mixture with binders; pavement which can be treated on the spot by crushing or screening before reemployment.

Recycled asphalt

Recycled asphalt granulates originates from the milling or scraping of asphalt pavements prior to maintenance, resurfacing or renewal of the top layer, and/or from the demolition and grinding of such pavements. This material mainly contains asphalt and aggregates.

When it is properly crushed consist of high quality and well graded aggregates coated by asphalt binder. (Bitumen). It is returned back into roadway structure: incorporated into asphalt paving by means of hot or cold recycling, as aggregate in base or subbase construction. Generally, in Member States to be reused no tar contamination is request.

3.1.4 Mixed CDW

The mixed fraction represents in average a consistent fraction of the total CDW amount.

Mixed fraction represents an unknown mix of the previously mentioned material fractions and is therefore a significant unknown variable in the assessment of the real material composition of CDW, and thus also in the establishment of potential material-specific recycling targets. However, it is not known whether the mixed fraction also represents an equally significant loss in recovery potential at the current state, as there might be different practices regarding the sorting of the mixed fraction. While the mixed CDW might be disposed of as it is, the possibility exists that it is sorted at a later stage, meaning that some of the mixed fraction, potentially even its entire amount, could be recovered (JRC, 2020).

3.1.5 Sorting of material no-site or off-site

Improved waste identification, separation and collection at source are at the stat of the CDW management process. Sorting of waste materials is a crucial step in recycling. Waste materials need to be clean in order to be suitable for inclusion in the production of products. By separating a larger number of different materials on-site, the amount of rubble and mixed materials will theoretically decrease, as is shown in figure (Utrecht). Separation close to the source will prevent the waste being mixed with other wastes and increase the amount of materials suitable for recycling. Some regulation requires the sorting of specific fraction of CDW on-site. Generally hazardous waste should have to be separated on site. If materials end up in the mixed waste stream, some of them will be difficult to filter out in off-site sorting. Once mixed materials are not separable anymore, the quality of the secondary material stream is lower, which complicates recycling at a high quality. The size of sorting residue of the sorting facility may increase due to improper sorting on-site. This residue is likely to be incinerated and is therefore not available anymore for recycling. Furthermore, separation of the demolition waste is easier in case a building is designed to be taken apart at the end of its life, this means that in the design phase of the building deconstruction should be considered.

Therefore, when possible, consider on-site operations as they can offer cost advantages and reduce transport needs. However, decisions on such on-site preparation for re-use and recycling need to be taken on a case by-case basis depending on the site characteristics like size of the site and proximity to green areas, residents and businesses.

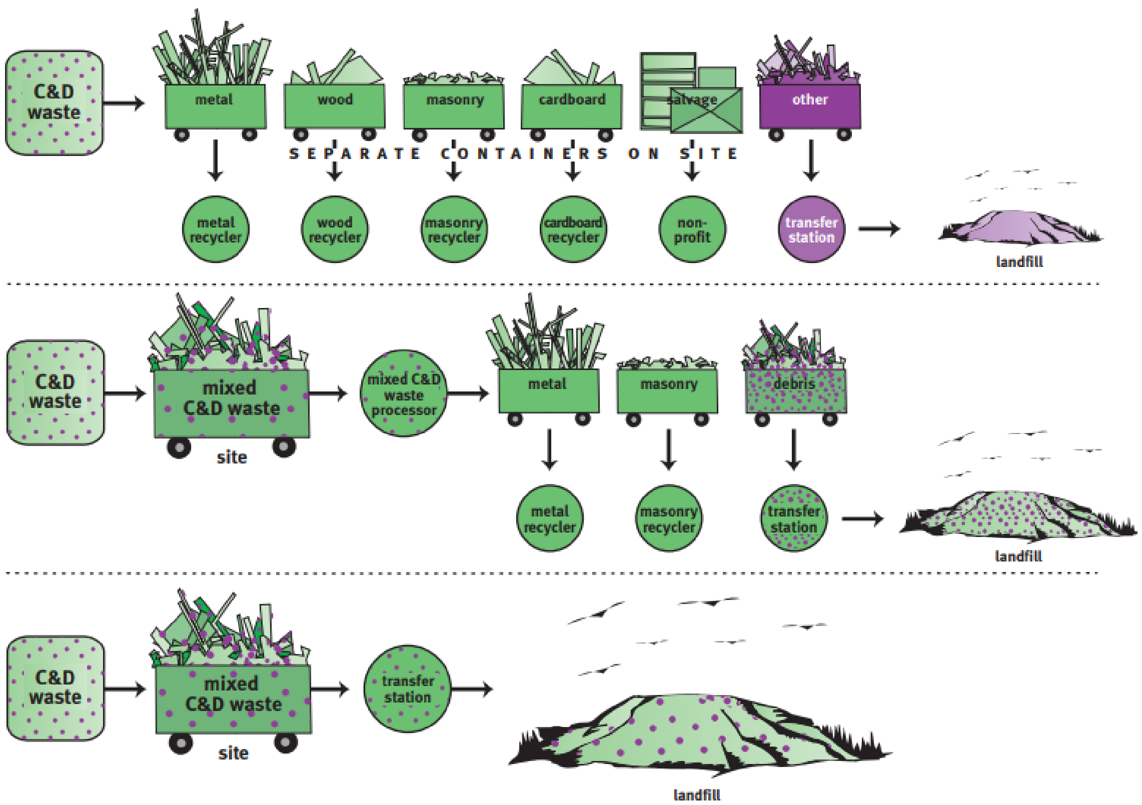


Figure 13: Sorting af materials at different stages leads to different amouns of material, (DDC, 2003).

3.2 Eu guidelines and management strategy

3.2.1 European Waste Framework directive 2008/98/EC

The Waste Framework Directive 2008/98/EC (WFD) pose guideline on waste management strategy at EU level. Waste framework directive lays down measures to protect the environment and human health by preventing or reducing the generation of waste, the adverse impacts of the generation and management of waste and by reducing overall impacts of resources use and improving the efficiency of such use, which are crucial for the transition to a circular economy and for guaranteeing the Union's long-term competitiveness. The following waste hierarchy shall apply as a priority order in waste prevention and management legislation and policy:

(a) prevention;

(b) preparing for re-use;

(c) recycling;

(d) other recovery, e.g. energy recovery; and

(e) disposal.

Looking at the EU waste hierarchy the first step for a good management is prevention. Promote waste prevention trough smart design, extending the lifetime of construction, reuse and improving planning and logistics on construction site. When this action can't be taken recycling should be applied. France for example have adopt a high taxation strategy "general tax on polluting activity" to avoid landfilling of waste to make company more preferred on recycling. Of course, higher tax was applied for those material potentially recyclable and lower tax for material less potentially recyclable. The final target is making recycling economically competitive with the traditional approach and decrease firm's footprint.

Eu 2008/98/EC makes it clear that refusal uncontaminated soil and other naturally occurring material excavated in the course of construction activities is outside the scope of regulation, where it is certain that the material will be used for the purposes of construction in its natural state on the site from which it was excavated. This statement ensures that this kind of material resulting from construction and demolition activities will not be considered as a waste. land (in situ) including unexcavated contaminated soil and buildings permanently connected with land are outside this regulation too. The objectives of this Directive in order to move to a European circular economy with a high level of resource efficiency, for the CDW is that Member States shall take the necessary measures designed to achieve the specific target: by 2020, the preparing for re-use, recycling and other material recovery, including backfilling operations using waste to substitute other materials, of non-hazardous construction and demolition waste excluding naturally occurring material defined in category 17 05 04 in the list of waste shall be increased to a minimum of 70 % by weight. The waste code 17 05 04 under the section 17 of the waste list identify soil and stones devoid of contaminants. In our case soil material is out the interest of our study. Therefore, this target set refers to the CDW in general, and the mineral fraction, which as we have seen is the main one, must be taken into account for the achievement of this target.

As a supplement European Union encourages selective demolition. Where necessary to facilitate or improve preparing for re-use, recycling and other recovery operations, waste shall be subject to separate collection and shall not be mixed with other waste or other materials with different properties. During decommissioning project, the resulting material have to be separated in situ, the selective dismounting of hazardous materials enable its removal and safely handle, and all the other material separated to make it easier to reuse resources and recycle them in a high-quality manner. The Union advised that sorting systems be established for building and demolition debris, at least for wood, metal, glass, plastic, and plaster, mineral fractions include concrete, bricks, tiles, and ceramics. Also, by 31 December 2024, the Commission shall consider the setting of preparing for re-use and recycling targets for construction and demolition waste and its material-specific fractions.

The directive also regulates the EoW for a waste. The EoW concept is explain as a key tool for the achievement of materials recirculation in the principle of the circular economy to close the loop. If a waste obtains the status of EoW if cease to be a waste and became a product. If Eow criteria are fulfilled, the material will no longer be classified as waste, but it will instead become a construction product at EU level subject to free trade and use, unless some restrictions are included in the EoW status approval procedure.

The EC declare that a waste which has undergone a recycling or other recovery operation is considered to have ceased to be waste if it complies with the following conditions:

- further use of the substance or object is certain,
- the substance or object can be used directly without any further processing other than normal industrial practice;
- the substance or object is produced as an integral part of a production process; and
- further use is lawful, i.e. the substance or object fulfils all relevant product, environmental and health protection requirements for the specific use and will not lead to overall adverse environmental or human health impacts; point of interest of this study.

Therefore, member States shall define detailed criteria for ensure high level of protection of the environment and human health and facilitate the prudent and rational utilisation of natural resources. They criteria shell include:

- permissible waste input material for the recovery operation;
- allowed treatment processes and techniques;
- quality criteria for end-of-waste materials resulting from the recovery operation in line with the applicable product standards, including limit values for pollutants where necessary;
- requirements for management systems to demonstrate compliance with the end-of-waste criteria, including for quality control and self-monitoring, and accreditation, where appropriate; and
- a requirement for a statement of conformity.

Those detailed criteria shall ensure a high level of protection of the environment and human health and facilitate the prudent and rational utilisation of natural resources.

In shorth the EoW status is reached when the product has commonly used for specific purpose, has a market value, fulfils the technical requirements for the specific purpose and meets existing standard and legislation applicable to products.

3.2.2 EoW criteria for inert recycled aggregates

In construction sector the EoW concept is well developed for mineral fraction that under specific criteria condition became a recycled aggregate. In this study the environmental requirements for a waste how had reach EoW status are taken in consideration. Therefore, the establishment of criteria on limit values for pollutants must take into account any possible negative environmental and health effects resulting from the use of recycled aggregates. The environmental protection aspects of the use of a recycled aggregate that would achieve possible EoW status at EU level and become a construction product would no longer be regulated by waste legislation; it would only be subject to compliance with the Construction Products Regulation about technical and structural requirements. Therefore, national environmental protection requirements on the use of aggregate products in construction works must be implemented in Member States as criteria for the EoW status.
Other end-of-waste conditions according to Article 6 of the Waste Framework Directive, such as the use, market conditions and technical requirements or legal standards are excluded from the scope of this study. In particular, requirements on geometry, durability and physical properties of waste aggregates are not being addressed in this document but may be important when considering possible end-of-waste criteria for waste aggregates (JRC). If aggregates don’t seek to EoW status they can be intended for beneficial reuse and gone under waste legislation

The advantages for the industry of obtaining EoW status for certain waste-derived aggregates include e.g. the lifting of requirements related to the handling of waste such as the need to have a permit for temporary storage of waste and the need to have people on staff trained to handle waste.

3.2.2.1 Construction products regulation and REACH

A close relationship exist between EoW legislation and CPR. The marketing and use of waste-derived Construction and demolition activity aggregates which obtains EoW status and becomes a construction product will, still be regulated by the CPR as far as the functional criteria and the CE marking are concerned. The CPR ensures the smooth functioning of the single market and the free movement of construction products in the EU. It does so through harmonised technical specifications, which provide for a common technical language on how to test and communicate the performance of construction products (e.g. reaction to fire, thermal conductivity or sound insulation). Construction products covered by such standards must bear the CE market.

Only technical or functional requirements for the use of CDW that reach the EoW status, for construction purposes are regulated under the Construction Product Regulation (CPR) by harmonised European Product Standards therefore the product must already comply with environmental criteria. This means that a CD material with the EoW status may no longer be subject to any environmental quality criteria or specific use conditions, except for those laid down in the requirements for obtaining the EoW status itself (ECN). CPR provide the technical regulatory and logistic framework for management of waste-derived aggregates with EoW status as well as pristine aggregates, used for construction purposes.

The Construction Products Regulation (EU/305/2011, CPR) establishes uniform guidelines for the marketing of construction products and offers instruments for evaluating their effectiveness. To foster transparency, construction products covered by Harmonized European Standards are required to have a Declaration of Performance and to bear the CE mark.

Additionally, as soon as a material ceased to be waste, REACH requirements apply in principle in the same way as to any other material, this is because requirement in Article 6 of the WFD states, that the substance or article fulfils the technical requirements for the specific purpose and meets the existing legislation and standards applicable to products, where the REACH Regulation is part of. Registration, Evaluation, Authorisation and Restriction of Chemicals, REACH is a European Union regulation adopted to improve the protection of human health and the environment from the risks that can arise from chemicals. Candidate List substances are substances of very high concern (SVHCs), because of their very serious effect on human health and the environment.

Therefore, if a substance listed on the Candidate List is contained in articles, this may trigger additional obligations for companies producing, importing and supplying these articles and require REACH authorisation to bring it on the market. In agreement the supplier has to provide the name of substance and all relevant safety information, the request for an authorisation is expensive, which could be a problem for recycling companies (ECHA). Articles are defined under the Article 3 of the REACH Regulation, as an object, during production, is given a special shape, surface or design which determines its function to a greater degree than its chemical composition.

Recovered aggregates resulting from the processing of inorganic material previously used in construction, can have different applications; when the recovered aggregates have application in civil engineering works, roads and railway ballast, the main function is to provide stability and resistance to degradation/fragmentation. For this function shape, surface or design has been deliberately determined and given during product production as the main interesting properties (e.g. in order to meet certain recognised aggregate standard such as EN 12620, 13043 or 13242). These particles are therefore considered to be articles according to the article definition under REACH. (ECHA, 2010)

Therefore the technical legislation no longer distinguishes the aggregate based on their origins, but based on their characteristics. Meaning that the products placed on the market must be evaluated for their performance characteristics and not on their nature. Only the CE marking of the aggregates can guarantee the end-user about the characteristics of the material purchased.

3.2.3 Hazardous waste

Regarding hazardous waste a clear set of rules are set by EC to be followed. At fist in the WFD 2008/98 hazardous waste definition is clearly regulated, meaning waste which displays one or more of the hazardous properties like: explosive, oxidising, flammable, irritant-skin irritation and eye damage, special target organ toxicity (STOT) aspiration toxicity, acute toxicity, carcinogenic, ecotoxic etc. Therefore, if a waste contains one or more substances classified by one of the hazard class and category code, and Hazard statement code, for each hazard property HP, its criteria for classification under the relative HP are discussed in the Annex III the aforementioned regulations.

It's important to remember that the dilution paradigm is not valid "Dilution is the solution to pollution"; the reclassification of hazardous waste as non-hazardous waste may not be achieved by diluting or mixing the waste with the aim of lowering the initial concentrations of hazardous substances to a level below the thresholds for defining waste as hazardous. This can happen as management of hazardous substances entail higher operational cost.

Specifications for hazardous waste are indicates in the Regulation. Member States shall take the necessary measures, before or during recovery, to remove hazardous substances, mixtures and components from hazardous waste with a view to their treatment. Production, collection and transportation of hazardous waste, as well as its storage and treatment, shall carried out in conditions providing protection for the environment and human health, also action to ensure traceability from production to final destination and control of hazardous waste shall be included.

Member States shall also take the necessary measures to ensure that hazardous waste is not mixed, either with other categories of hazardous waste or with other waste, substances or materials. Mixing shall include the dilution of hazardous substances as explain previously. In particular:

1. In the course of collection, transport and temporary storage, hazardous waste is packaged and labelled in accordance with the international and Community standards in force.
2. Whenever hazardous waste is transferred within a Member State, it shall be accompanied by an identification document, which may be in electronic format, containing the appropriate data specified in Annex IB to Regulation (EC) No 1013/2006.

The producers of hazardous waste, and the establishments and undertakings which collect or transport hazardous waste on a professional basis, or act as dealers and brokers of hazardous waste, shall keep a chronological record of: the quantity, nature and origin of that waste and the quantity of products and materials resulting from preparing for re-use, recycling or other recovery operations; and where relevant, the destination, frequency of collection, mode of transport and treatment method foreseen in respect of the waste. For hazardous waste, the records shall be preserved for at least three years except in the case of undertakings transporting hazardous waste which must keep such records for at least 12 months.

As suggested from some internationally renowned professors, (Arne) is no clear what to considered hazardous in a decommissioning project, meaning that is not clear when an hazardous material is harmless accessible. For example, if we consider an insulating layer containing PAH present in the interlude of an external load-bearing wall mage of brick how have we to proceed; we have to remove the entire artefact and considered as hazardous or we have to remove the layer containing the PAH individually by means of pneumatic hammer and then proceed with the demolition the remains? No clear guideline applies; is good practice to remove before the deconstruction the insulating layer consider it as hazardous waste and then proceed to the demolition. This is a situation of free interpretation that must be argued with a structured decommissioning national plan and call for a pre-demolition audit request.

3.2.4 Landfill waste acceptance criteria directive 2003/33/EC

Following the European waste hierarchy disposal holds the last position for waste management strategy and policy. For those material that can't retain any potential to be put back in cycle; general landfill entrance guidelines are disposed by the Commission to regulate the entrance flux of waste. European Community with the directive n. 33/2003 establishing criteria and procedures sampling and testing methods for the acceptance of waste at landfills pursuant to Article 16 of and Annex II to Directive 1999/31/EC. For different landfill class different acceptance criteria apply. In order to support the Union's transition to a circular economy and to fulfil the requirements of Directive 2008/98/EC of the European Parliament, the aim of this Directive is to ensure a progressive reduction in the landfilling of waste and to provide, through strict operational and technical requirements, for waste and measures, procedures and guidelines to prevent or reduce as far as possible negative effects on the environment and risks to human health.

Once a waste flux wants to be disposed of, it should undergo the admission procedure. Waste may be accepted at a landfill only if it fulfils the acceptance criteria of relevant landfill class. The procedure to determine the acceptability of a waste at landfill consist of the basic characterisation, compliance testing be checked before the waste will be transported in the landfill site, and on-site verification.

The starting point of the procedure for the acceptance of waste at landfill is the basic characterisation of the waste, a full characterisation of the waste gathering all necessary information for a safe disposal of the waste in the long term. The function of the basic characterisation is to obtain basic information on the waste (type and origin, composition, consistency, leachability and, where necessary and available, other characteristic properties, waste code number), basic information for understanding the behaviour of waste in landfill option for its treatment before to reach the landfill, assessing waste against limit values and detection of critical parameters. In accordance with Article 6(a) of the Landfill Directive, some treatment is required prior to landfilling for most wastes. The person responsible for the waste management is responsible for ensuring a correct characterisation information. If the basic characterisation of the waste shows that the waste fulfils the criteria for a landfill class, the waste is deemed to be acceptable at this landfill class. As a general rule waste must be tested to obtain the above information; standardized waste sampling and testing methods are listed in the section 3 of the Annex of this directive, as reported in table 5.

When we consider the basic characterisation a differentiation can be made from waste that are regularly generated in the same process and waste that are not regularly generated, in the content of the characterisation and the extent of laboratory testing. Individual and consistent wastes regularly generated in the same well-known process can be considered already characterised and shall subsequently be subject to compliance testing only unless significant change in the generation process occur. For the waste generally not regularly generated in the same process in the same installation and are not part of a well-characterised waste stream; each batch produced of such waste need to be characterised, as each batch is characterised, no compliance testing is needed. The basic characterisation shall include the fundamental requirements:

(a) Source and origin of the waste

(b) Information on the process producing the waste (description of raw materials and products)

(c) Description of the waste treatment before landfill or a statement of reasons why such treatment is not considered necessary

(d) Data on the composition of the waste and the leaching behaviour, where relevant

(e) Appearance of the waste (smell, colour, physical form)

(f) Code according to the European waste list

(g) For hazardous waste in case of mirror entries: the relevant hazard properties according

(h) If necessary, additional precautions to be taken at the landfill

(i) Check if the waste can be recycled or recovered.

When waste has been deemed acceptable for a landfill class on the basis of a basic characterisation it shall subsequently be subjected to compliance testing to determine if it complies with the results of the basic characterisation and the relevant acceptance criteria. In practice the function of compliance testing is periodically (at least once a year) to check regularly arising waste streams. The relevant parameters to be tested are determined in the basic characterisation and the check has to show that the wastes meet the limit values for the critical parameters. The tests used for compliance testing shall be one or more of those used in the basic characterisation; the testing shall consist at least of a batch leaching test.

As last steps of the procedure each load of waste delivered to a landfill shall be visually inspected before and after unloading, and the required documentation shall be checked.

Table 5: Sampling and testing method that shall apply by European Union. Council decision establishing criteria and procedures for the acceptance of waste at landfills 2003/33/EC

Method	**Description**
SAMPLING	
CEN/TR 15310-1	Characterisation of waste – Sampling of waste materials – Part 1: Guidance on the selection and application of criteria for sampling under various conditions.
GENERAL WASTE PROPERTIES	
EN 15936:2012	Sludge, treated biowaste, soil and waste - Determination of total organic carbon (TOC) by dry combustion
EN 15934:2012	Sludge, treated biowaste, soil and waste - Calculation of dry matter fraction after determination of dry residue or water content
LEACHING TEST	
EN 14405	Leaching behaviour test - Up-flow percolation test (Up-flow percolation test for inorganic constit
EN 12457/1-4	Leaching — Compliance test for leaching of granular waste materials and sludges: part 1: L/S = 2 l/kg, particle size < 4 mm part 2: L/S = 10 l/kg, particle size < 4 mm part 3: L/S = 2 and 8 l/kg, particle size < 4 mm part 4: L/S = 10 l/kg, particle size < 10 mm
DIGESTION OF RAW WASTE	

EN 13657:2002	Digestion for subsequent determination of aqua regia soluble portion of elements (partial digestion of the solid waste prior to elementary analysis, leaving the silicate matrix intact)
EN 13656:2020	Soil, treated biowaste, sludge and waste - Digestion with a hydrochloric (HCl), nitric (HNO3) and tetrafluoroboric (HBF4) or hydrofluoric (HF) acid mixture for subsequent determination of elements
ANALYSIS	
ENV 12506:2000	Characterization of waste - Analysis of eluates - Determination of pH, As, Cd, Cr Vl, Cu, Ni, Pb, Zn, Cl, NO, SO
CEN/TR 16192:2020	Waste - Guidance on analysis of eluates
EN 14039:2004	Characterization of waste - Determination of hydrocarbon content in the range of C10 to C40 by gas chromatography

For the sampling of waste, a sampling plan shall be developed by Member States according to part 1 of the sampling standards currently developed by CEN. Sampling and testing methods for basic characterisation and compliance testing shall by adopted by Member state in accordance with the recommend by EU.

As material of interest for this thesis, the acceptance criteria for waste in the inert waste landfill class is analysed. Some types of waste as reported in table 6 due to their classification are already considered complied with the criteria, as defined as inert waste, of acceptability of inert landfill therefore any test should be done.

Table 6: Waste code directly accepted in inert landfill site without any acceptance testing analysis.

EWC code	Description	Restriction
17 01 01	Concrete	Selected C&D waste only (*)
17 01 02	Brick	Selected C&D waste only (*)
17 01 03	Tiles and ceramics	Selected C&D waste only (*)
17 01 07	Mix of concrete	Selected C&D waste only (*)
17 05 04	Soil and stones	Excluding top soils peat, excluding soil and stones from contaminated sites

The waste must be a single stream (only one source) of a single waste type. Different wastes considered in the list may be accepted, provided they are from the same source. In case of suspicion of contamination (either from visual inspection or from knowledge of the origin of the waste) testing should be applied or the waste refused. Metals, asbestos, plastics, chemical, etc. are considered contaminants.

Waste not appearing on this list must be subject to testing to determine if it fulfils the criteria for waste acceptance at landfills for inert waste. Criteria pose limit values on leachate and total content of organic parameters. For sleek of compilation leachate limit values of liquid to solid ratio of L/S=10 l/Kg is considered. The following leaching limit values apply for waste acceptable at landfills for inert waste.

Table 7: leachate limit values for waste accepted at landfill for inert waste (Directive 2003/33/EC)

Component	**L/S =10l/Kg**
	mg/kg dry substance
As	0,5
Ba	20
Cd	0,04
Cr tot	0,5
Cu	2
Hg	0,01
Mo	0,5
Ni	0,4
Pb	0,5
Sb	0,06
Se	0,1
Zn	4
Chloride	800
Fluoride	10
Sulphate	1000
DOC	500
TDS	4000
Phenol index	1

Almost for all heavy metals limit values are set, as exception of V, Mn, Fe, Co, and Al. Chloride, Fluorife; sulphate, Phenol are analysed too. Limit values for total content of organic parameters are shown in picture.

Table 8: limit values for total content of organic substances for acceptance in inert waste landfill (Directive 2003/33/EC)

Parameter	**Value** **mg/Kg**
TOC (total organic carbon)	30 000
BTEX (benzene, toluene, ethylbenzene and xylenes)	6
PCBs (polychlorinated biphenyls, 7 congeners)	1
Mineral oil (C10 to C40)	500
PAHs (polycyclic aromatic hydrocarbons)	Member States to set limit value

For other no inert materials different landfill class exist non hazardous waste landfill, hazardous waste landfill. For example gypsum-bases materials that don't contains any hazardous substances, not considered as inert material, should be disposed of only in landfills for non-hazardous waste in cells where no biodegradable waste is accepted. Limit values are applied for waste landfilled together in the same site. The limit values for TOC and DOC given in sections 2.3.2 and 2.3.1

3.2.5 EU Construction and Demolition Waste Management Protocol

Because CDW is the largest waste stream in the EU in terms of volume, its proper management and recycled materials can have significant benefits in terms of sustainability and quality of life; it can also provide crucial benefits to the EU construction and recycling industries by increasing demand for CD recycled materials. Nevertheless, one of the most significant barriers to recycling and reusing C&D trash in the EU is a lack of confidence in the quality of C&D recycled products. This lack of trust diminishes and limits demand for C&D recycled materials, inhibiting the development of C&D waste management and recycling infrastructure in the EU.

In line with virtuous countries document on the good practice on waste management in particular the "EU Construction & Demolition Waste Management Protocol" and "A 10 steps approach to achieve 70 % recycling in C&D waste" helps the member state on the achievement of the EU target. There are also many companies like FIR – Federation International du recyclage- aimed to disseminate experts to spread information across state and illustrate the state of the art. It's also important to share information among country to define the so call Best Activity Techniques (BAT).

The protocol aims to increase consumer confidence by proposing quality protocols by improving waste legislative recommendations to boost global competitiveness, foster sustainable economic growth, and create new jobs. As a starting point the Construction and Demolition waste protocol includes good practices from across the EU that can be sources of inspiration for both policymakers and practitioners. The proposed actions will contribute to reaching the WFD target of 70% of CDW being recycled by 2020.

The scope of the Protocol includes waste from construction, renovation and demolition works. It excludes, however the design phase, as well as excavating and dredging soil. All components of the CDW management chain, apart from prevention was considered.

The increase in confidence on CD recycled materials could be obtain by: Improve waste identification, source separation and collection, waste logistics and processing. The protocol is based on the 'weakest link' principle, meaning that efforts to increase quality and confidence are only worthwhile if they are made along the complete waste management chain. Quality management and an appropriate policy and framework conditions are of horizontal nature.

In order to create demand proof of satisfying quality is required. To assure a certain minimum level of quality along the entire waste management process, auditing and certification are important tools for increasing quality and confidence in CD recycled materials. Transparency and traceability throughout all phases of the CDW management process will contribute to confidence in the recycled products. The protocol builds on existing standards, guidelines, best practices and certification scheme; therefore no need to reinvent the wheel. At the end there is no point in promoting recycling or reuse of C&D waste if it is at the expense of the environment, health or safety.

Here each step of waste management is discussed. Identification, separation, and on-site collection processes leads to a consider separate high quality fluxes of CDW to commit to holders on their management; accurate waste logistic and processing helps to acquiesce to a circular economy concept. Quality control and an integrate waste legislative plan go together.

Improve waste identification.

Sound planning of construction activities on construction sites are a prerequisite for high recycling rates and high-quality recycling products. This is way the initial steps are the fundamental one.

Waste audits aims to assess of construction and demolition waste streams prior to the demolition or renovation of buildings and infrastructures to facilitate and maximize the recovery of materials and components for beneficial reuse and recycling reducing the environmental and health impact produced by estate sector. Pre-demolition audit is to be carried out before any demolition, renovation, or demolition project for any material to be reused or recycled as well as for hazardous waste. Such preparation activity is crucial for larger buildings; public authorities can decide upon which threshold the audit must done. Depend on the possible amount of waste generated and the volume of the building to be demolished in the demolition project pre-demolition audit can be requested or not. Pre-demolition audit permit to a waste characterisation, detecting which kind of contaminant are present.

The audit of waste issues recommendations on its further handling and an assessment of the viable recovery route for material take account of local markets for CDW and reused and recycled materials, including the available capacity of recycling installations, to match question and answer. The waste audit should also consider any relevant legislation such as the requirements for environmental permits if waste is to be used on-site or any waste that may be hazardous and which needs to be managed in accordance with specialized waste legislation. Identified the waste generated, the auditor implements proper deconstruction and to specify dismantling and demolition practices. Also, the action based on the audit will ensure the safety of workers and lead to an increase in the quality and quantity of recycled products.

In detail a pre-demolition audit consists of two parts:

- Information collection: identification of all waste materials that will be generated with specification of the quantity, quality, location in the building or civil infrastructures, and a good estimation of the quantity of materials to be collected should be given.
- Information about: which material should mandatory be separated before the demolition process at source such as hazardous waste; which material can/cannot be reused or recycled; information about how the waste (non-hazardous and hazardous) will be managed and the recycling possibilities.

As a result, waste audit is a special task within project planning leads to the optimization of the works (how many containers, on-site versus off-site sorting, ect…).

Ideally, waste audits should be performed before the call for tenders and should be a part of the specifications for tenders. The auditing process aims to deliver the documents that the owner must attach to a demolition or renovation permit application to open a call for tenders. The waste audit delivers a clear idea of the "to be demolished" building infrastructure, findings support the decisions of the authorities to approve the planned work.

The outcome of the audit should also provide reliable estimates of waste materials to contrast them with the results from the waste management report. Furthermore the audit report should be revised in the light of final results of the construction, demolition or refurbishment process.

In consequence the implementation of these audits can help clients with setting performance levels for demolition contractors, support a site-specific waste management plan, demonstrate environmental credentials, increase material and labour efficiency, reduce waste and maximise profit.

Source separation and collection:

It is crucial that demolition activities are carried out according to a plan, for this reason processed-oriented waste management plan is to be prepared for any material from construction, demolition or renovation to be re-used or recycled. A good waste management plan contains information about how the different steps of the demolition will be performed, by whom they will be performed, which materials will be collected selectively at source, where and how they will be transported, what will be the recycling, re-use or final treatment and how to follow up, for both hazardous and not waste. It also covers how to address safety and security issues, as well as how to limit environmental impacts, including leaching and dust. Also if unexpected hazardous waste materials are found the waste management plan needs to foresee which actions are to be taken.

Ideally a meticulous job of separation and estrangement of the hazardous waste is a crucial part on the source separation, as well as the division of materials that hamper recycling. Improved collection of good for reuse and recycling requires selective demolition and appropriate on site operations.

According to the management plant material source separation involves the following operation: hazardous waste separation; deconstruction (dismantling including separation of side streams and fixation materials); separation of fixation materials, and; structural or mechanical demolition. The better inert C&D waste is separated, the more effective recycling will be and the higher the quality of recycled aggregates and materials. However, the degree of separation depends on the options available at the site (space, labour) and on the cost and revenues of separated materials. Over the last few decades, an increasing number of materials have been glued and the use of composite materials has extended as well making separation as more challenging.

The removal of hazardous waste is a stricter action to be taken in a renovation/decommissioning project. Some types of CDW are not hazardous in their original form, but during the demolition stage can become hazardous through their mixing, processing or disposal. They can also pollute non-hazardous materials and thus make them non-reusable/recyclable. A classic example is lead-based paint thrown onto a pile of bricks and concrete, turning the whole pile into hazardous waste. Proper decontamination needs to be done for a number of reasons other than reuse or recycling: to protect the environment; to protect the health of workers; to protect the health of people living in the surroundings of the site, and for safety reasons. Typical hazardous waste products from construction, renovation or demolition works are asbestos, tar, radioactive waste, PCBs, lead, electrical components containing mercury, insulation materials containing hazardous substances etc. some examples of material that need to be removed from the building before demolition are oil tank, smoke detector with radioactive components, industrial smokestacks, insulating materials, slags, cooling liquid, air conditioning units… Even if the presence of hazardous particles is present in a very small proportion of the total waste materials, its presence can reduce markets' confidence in the recycled waste material drastically and therefore the perceived quality of the recycled products. Hazardous waste therefore needs to be removed correctly and systematically prior to demolition.

Main waste streams, including inert should be treated separately (e.g. concrete, bricks, masonry, tiles and ceramics); for the use of recycled materials in high grade application, a more selective demolition can be required such as separate collection/dismantling of the concrete and masonry.

An increasingly wide range of materials need to be considered for manual dismantling, to enable re-use, typical example include glass, precious woods, traditional sanitary ware, central heating boilers, water heaters, radiators, window frames, lamps and lamp-frames, steel structures, and cladding materials. Other materials which are to be considered for re-use or recycling include gypsum, insulation foam, concrete, and mineral wool and glass wool. Such operations allow for subsequent re-use and recycling of the materials themselves, but also aim at the purification of the mainstream. Side-streams risk not being treated properly if there is no local/national regulation in place. Packaging materials brought onto construction sites should be minimised as much as possible through optimisation of the supply chain.

waste logistics:

Material traceability during all process is important for building confidence and to mitigate any negative environmental impacts. It is necessary to strengthen record keeping and traceability mechanisms in the Member States. Registration of CDW constitutes a vital step for tracking and traceability and in order to register waste, it is necessary to know what types of CDW are expected therefore, a pre-demolition audit is of high importance.

Waste logistics should be well organized especially in case of bulky materials such as aggregates. The core is to shortening transportation pathway. Proximity of sorting and recycling plants is very important. In some cases a slot nearby can be used as sorting place. Unless transported in large volumes by rail or waterway, longer distances are simply not economically attractive, while environmental benefits of recycling diminish over longer distances as well. Over possible use waste transfer station, serving as the link between the local a demolition site and the waste treatment plant.

In some cases re-use, recycling and recovery of C&D materials requires to be proper stocking particularly for big demolition site, under precautionary measures. For example, the waste should be segregated and disposed in separate dedicated containers. Stocking and stockpiling must be undertaken only in suitable circumstances for genuine and beneficial purposes. In any case stockpiling can only be done during limited amount of times, this is because they can cause various emissions and risks.

Waste processing and treatment

A wide variety of waste processing and treatment option exist following the waste hierarchy. The actual choice of the waste management option differs from case to case, depending on regulatory requirements, as well as economic, environmental, technical, public health and other considerations. Preparing for reuse is to be promotes as it involves application with little or no processing, however in practice this may not be easy always. Material can either be recycled on-site into new construction resources or off-site at a recycling plant. CDW recycling needs to be promoted particularly in densely populated areas, where supply and demand are geographically close, resulting in shorter transport distances than for the supply of primary materials, such as in the case of aggregates.

Backfilling is one way to reuse non-hazardous CDW, specially in public and earthmoving works. European communions suggest limiting backfilling operations to those that are in line with the definition included in the Waste Framework Directive. The use of backfilling as a last resort option as it has double drawbacks: it can undermine the incentives to re-use and recycle in higher value applications and it can produce environmental pollution by leaching of substance into the groundwater. As a final step landfilling is considered. Austria for example under a soil ordinance generally allow C&D backfilling; recycled C&D waste that are mainly concrete are milled, tested to meet construction criteria like grain size, stability and the environmental one if they meet requirements can be used. It also depends on proximity to sensitive area. Regarding the brownfield some county Austria for example adopt a different legislation on the theme.

Quality management:

The quality value of recycled construction materials is based on environmental features and on the technical performance. It is necessary to encourage quality assurance of the key processes (from the demolition site to trash logistics and waste processing), as well as the dissemination of trustworthy and accurate data regarding the functionality of recycled or repurposed goods. Environmentally sound application of recycled aggregates can be secured by introducing quality management checks, good documentation and traceability. General quality management schemes such as ISO 9000, and environmental management systems such as ISO 14001 and eco-management and audit scheme (EMAS).

Table 9: quality management steps in different stages of recycling route. Source (JRC).

Waste identification, source separation and collection	**Waste transportation**	**Waste processing and treatment**
- Pre-demolition audit; - Selective demolition; - Identification and separation of hazardous waste.	- Safe transport; - Special provision/declaration for hazardous waste; identification form; registered or approved transport/carrier.	- Waste acceptance (at recycling site; - Input control (for example asbestos protocol; - Factory production control (addressing essential characteristics of products;

		- Acceptance criteria (such as for raw materials used for waste-derived products manufacturing; - Frequency of sampling; - Identification of the recycled aggregate used in a specific product/infrastructure (delivery note.

Quality control during pre-demolition and demolition should be taken seriously. Quality management relay on pre-demolition audit, on-site reporting and final report for the recycling plant. Some Member States have voluntary quality management certification schemes for demolition projects and processes. For example in the Netherlands, most contractors are certified by the demolition process scheme BRL SVMS-007 which is controlled by third parties and the Council of Accreditation. Monitoring and feedback during the whole CD process will ensure correct management and allow for corrections along the way.

Transport should be done in a safely and legally way. Before transfer, the contractor should verify if the waste is hazardous or not and provide appropriate transport.

At the recycling facility the recycler must follow a number of measures in order to keep up quality. Inert waste destined for recycling is accepted if they pass acceptance protocols such as checking of the waste shipment and accompanying material certificates or delivery notes. The recycling company ensures the good quality of input materials and the elimination of hazardous substances and impurities during the treatment process.

After the processing, factory production control applies. Third party control by an accredited certification organisation is recommended, as impartial party. Where EoW citeria are in place, stakeholders are encouraged to work with them. To validate the quality of recycled materials harmonised European standard apply. When European product standard exist material must be assessed in accordance with.

Good policy:

Successful CDW management can only take place if appropriate policy and framework are in place. Key areas for public actions are appropriate regulatory framework, enforcement, right public procurement and incentives and awareness public participation and acceptance. The ownership of the waste must be clear, in accordance with current national legal frameworks and contractual provisions between the initial building and infrastructure owners, the (demolition) contractor, the intermediate holder (such as a sorting operator), the final recycling operator, and the end user of the recycled products for proper regulation of C&D waste management. Local authorities are encouraged to provide the demolition operator with incentives to climb higher in the waste hierarchy. Local, regional, or national governments might implement integrated waste management plans that would make it possible to promote C&D waste management in a more organized manner.

Landfill restriction are a prerequisite for developing a market for C&D recycled materials. Landfill ban and high landfill taxes adopted from some Member states can be a powerful instrument.

During waste identification, collection and sorting, regulatory measures need to cover the necessity of conducting a pollutant investigation in the form of a pre-demolition audit or a waste management plan, before the demolition takes place, and promote waste flow separation. Much else can be done at national and regional levels, too. As a first step, standards for the use of recycled aggregates should be put in place. Then, the demand for C&D recycled materials can be increased for instance through prescribing its use by law in tendering documents and subsequent enforcement of the provision.

Resuming we can say that good quality recycling rate can be achieved by:

-A ban for landfilling of C&D waste or high taxation on it

-Good tracking and tracing system

-An establishment of a national framework for environmental testing

-A quality assurance scheme for recycled aggregates environmentally and technically and third-party control

-Specifications for use of recycled aggregates

-Beneficial market for recycled aggregates should be implemented.

3.2.6 Pre-demolition audit

A briefly discussion pre-demolition audit must be done as it is a precursor on separation of waste for achieve high purity materials for recycling purpose. The European guidelines for the waste audits before demolition and renovation works of buildings is recommended, to be followed.

The figure illustrates the waste management process, showing actors involved and relations between stages and responsibilities. The actors involved are:

-The property owner is responsible for appointing an auditor to draw up a waste audit for the identification and classification of waste as well as preliminary planning of its handling. After all work carried out the building owner must have documentation or verification of whereabouts of waste.

-The authority issues demolition or renovation permits and should establish mechanisms to ascertain (directly or with the intervention of third parties) that waste audits are performed including a quality check system and their recommendations followed.

-The auditor or Auditor team is an expert responsible for the waste audit. The auditor must be a qualified expert with appropriate knowledge of current and historical building materials (including hazardous materials), current and historical building techniques and building history and familiar with demolition techniques, waste treatment and processing as well as with (local) markets.

-The contractor is responsible for demolition/deconstruction/renovation operations defined in the contract with the owner. The contractor should contribute to the traceability aspects of waste.

-The waste manager is responsible for the appropriate management and disposal of the waste received from the waste holder or producer. The waste manager should also contribute to the traceability aspects of waste.

-The products manufacturer may contribute to the waste audit providing solutions and/or requirements for the reused/recycled materials and components.

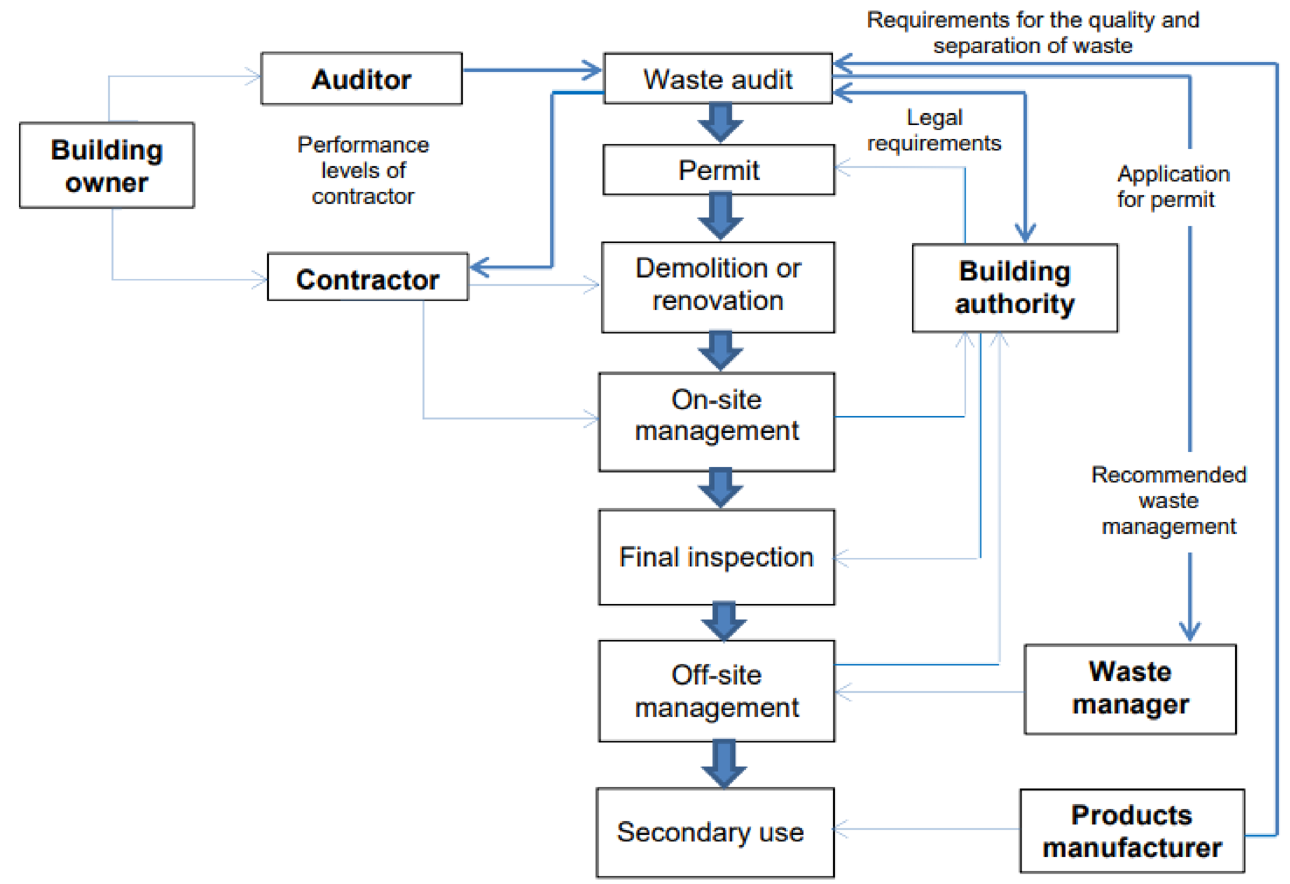


Figure 14: interconnections between participating parties.

An fruitful process for waste audit should be the steps depicted in figure.

Table 10: waste auditing efficacious process. Source waste audit

Quality assurance	Desk study	Original building documentation
	Field survey	Waste identification, measurement, sampling and analysis
	Inventory	Waste classification and quantity estimation
	Management recommendations	Legal, h6s and others
	Reporting	templates

The desk study aims to gather all the relevant information from the documentation of the building or other work. It is of great important to collect at least:

• The age of the building or infrastructure - information about the history of the building and the type of materials and construction techniques to expect. This knowledge is important if design documents are not available.

• The design documents - architectural plans and technical drawings contain information that is useful for planning the field survey and drawing up a waste inventory, whether or not they are accompanied by tender specifications or as-built documentation of the construction and/or renovation works. They serve for preliminary identification of construction date/period, dimensions, construction typology, composition, type of materials, location of machinery and installations, details of hidden or difficult to access spaces, as well as the planning of a field survey.

• The documentation of use - in particular the history of maintenance and renovations is essential as the materials may be different from the year of the first building completion. Descriptions of production activities and exploitation permits are a useful source for information on storage and use of hazardous products (that may have contaminated other materials).

• A list of dangerous substances - if the assessment of dangerous substances does not exist, the auditor will have to take relevant measures to ascertain that health and safety issues are covered when performing the site visit.

• The surroundings and accesses - The knowledge of the environments is essential to plan the best strategy to perform waste management.

• The local facilities – Knowing where to find a local salvage yard

As this stage, the auditor should collect as much information as possible to plan the site visit correctly. Based on the study of all documentation, a first draft of possible materials and uncertainties will have to be checked during the site visit.

During the field survey every room of the building to be demolished are visually inspected and inventoried on many occasions in a destructive manner. If necessary, samples are taken for analysis. Because every building is different, it is not possible to elaborate only one global method for data collection but it is important to work systematically and methodically. A good and efficient approach consists of 4 parts:

• Site visit and general analysis of the building (checking what was learned during the desk study)

• General audit and inventory. The general audit and inventory are to have an idea (for every part of the building) of which materials occur and to collect the necessary information to identify, quantify and localize them in the building.

• Detailed audit and inventory. The different rooms are inventoried in detail (floor coverings, lighting units, interior walls, false ceilings, etc.)

• Sample taking and analysis (not all materials can be visually identified. Therefore, suspect materials need to be sampled and analysed)

The **site visit** consists of visual inspections, comparisons of findings with collected documents, planning of inspections and measurements, preliminary planning of deconstruction techniques and waste handling on site as well as communication between actors engaged by the owner to the process. The auditor should aim to:

• Evaluate the consistency of the design documents and documents of the property owners with the actual situation;

• Identify locations, different structure and technical systems and their materials, with special care for materials that can seem very similar, for instance in the cases of complex systems where a material can be covered by another material.

• Take measurements or confirm those obtained during the desk-study

• Make diagrams, take notes, take pictures of the different parts and include them in the report to ease the understanding of the final report.

• Make sure to identify all the materials. In covered areas, it is important to remove a small part of the covering to make sure that the materials underneath are those expected.

• Take samples of the materials to ascertain the nature and quantity of the materials being studied. These samples should be visually inspected at the moment of collection and observations reported

The site visit must implement non-destructive or destructive techniques in order to correctly assess the whole range of materials. The destructive techniques will probably be: opening of false ceilings and walls, opening of technical shafts, making a hole in wall and floor coverings, (partial) disassembly of technical installations (ventilation ducts ...), removing coating from surfaces, drilling to observe the composition at different depths or any other operation deemed necessary for complete information of the materials. Since it is highly probable that destructive techniques should be required, the field survey is best carried out when the building is no longer in use.

If the desk-based study suggests the existence of hazardous substances at the site, or if at any stage it is suspected that hazardous substances may be present, protocols to work with hazardous substances should be established and worker protection measures applied during the site visit, mainly during destructive stages. The site visit should allow the auditor to complete the information collected during the desk-based study and take any sample required to perform the materials assessment.

The inventory of the materials and building elements is therefore the basic output of the waste audit; it is typically based on the materials assessment provided by desk study and/or the field survey and additional activities aiming to ensure the quality of the data. The demolition waste is produced by deconstruction and demolition activities, and it may also include materials due to operation and use of the property. The information about constructive and non-constructive elements (such as pillars, beams, walls, slabs, etc. and also furniture, lightning, electronics, paper, etc.) and corresponding materials should also be organized to provide not only the total amount of waste, but also the total amount of the different types of materials. As regards buildings, it is advisable to perform an assessment of the material for each floor. The material assessment should include at least:

- The type of material to be classified as inert, non-inert, non-hazardous waste or hazardous waste, detailing the Eural code and description
- Quantification

Additional information can be required by the waste holder or building authority such as:

- An inventory of elements recommended for deconstruction and reuse. Materials of these element should not be excluded from the waste inventory
- Location of the waste materials and elements in the building;
- The quality of the material to assess the impurities that could be present.
- The reusability in order to assess direct reusability of the material which depends on the nature of the material and material conditions.

Even if this set of data is considered as the minimum for a full materials assessment, to take advantage of waste audits' full potential we highly recommend to:

• Separate the source of waste by the different levels of the building

- Include photographs showing details to make the report easier to read.

This information will be of great importance in order to assess and decide the waste management procedure to be implemented.

Materials assessment should be completed considering the ease of recovery of these materials. This makes it very important to estimate if the waste will be technically and economically separable, to decide which different types of outlets should be proposed during the waste management planning stage of the waste audit. The extent to which materials may be recovered effectively in the demolition process depend on a range of f**actors**, including the following one:

-Safety, which may increase project costs;

-Time. Selective demolition needs more time than traditional demolition, so higher costs are expected. Optimal solutions regarding potential recyclability and re-use should be considered.

-Economic feasibility and market acceptance. The cost of removing an element (e.g. a roof tile) should be compensated for by its price, while, at the same time, the re-used element should be competitive and accepted by future users. For some materials, e.g. iron/metal/scrap, market prices fluctuate strongly depending also on seasonality.

-Space. When there is a space limitation on a site, separation of materials collected should take place in a sorting facility. Space limits specifically require good planning.

-Location. The number of recycling facilities in the surroundings of the project site or the local supply waste management services may limit the potential recovery of materials from a deconstruction project.

-Weather. Some techniques may be dependent on certain weather conditions that may not coincide with project timing.

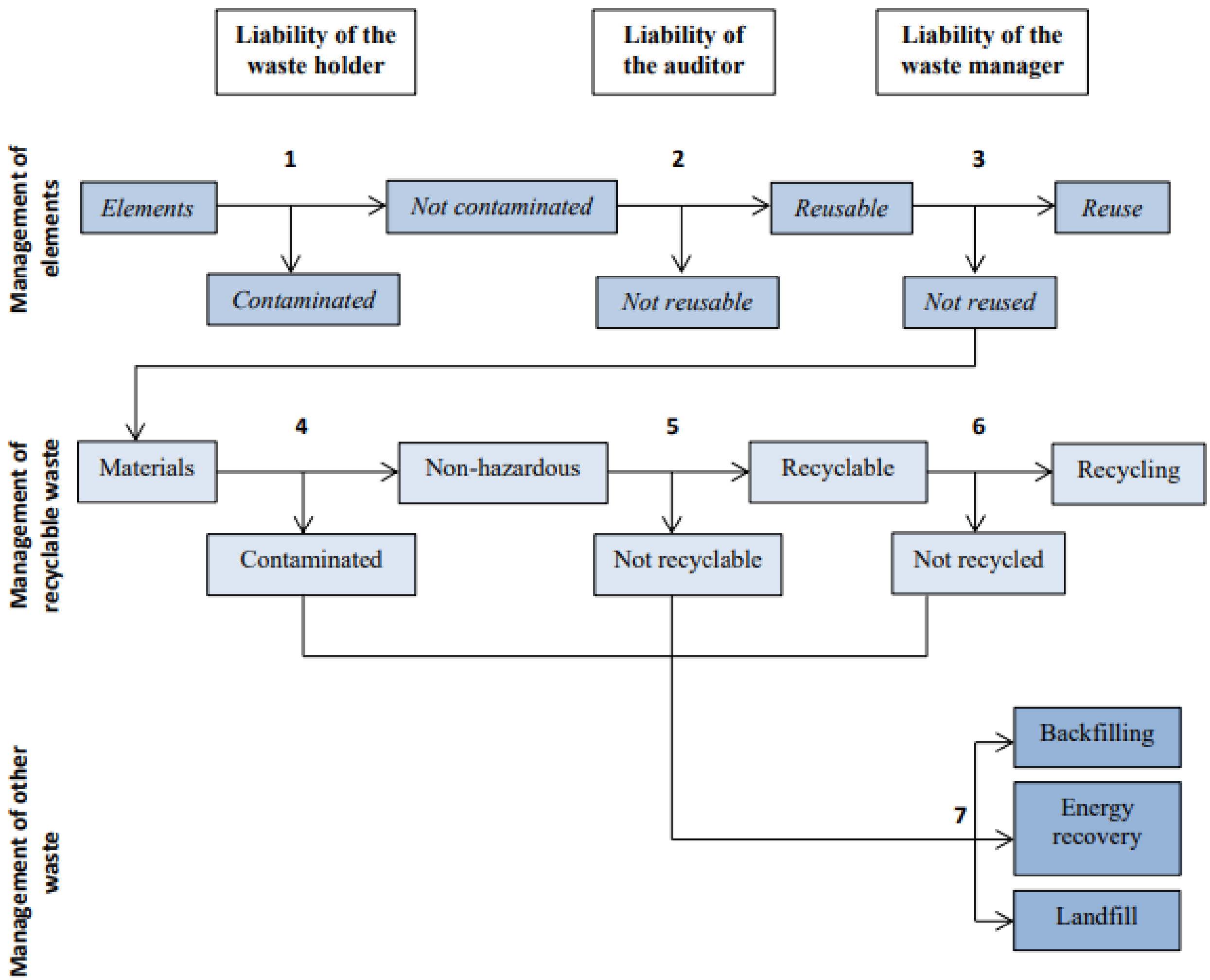


Figure 15: material selection in accordance with European waste hyerarchy.

The waste audit can be completed with recommendations on how to perform waste management on site. These recommendations can include advise and guidelines for:

- safe removal of hazardous waste materials

-Identification of potential waste diversion of certain identified waste streams Different alternatives can be provided for each materials group or waste streams; If possible, a selective dismantling should be recommended in order to maximize the waste.

-Identification of (economically or environmentally) beneficial on-site sorting activities that may include the description of the installation requirements for storage, handling, separation and for any other operation to manage the different waste streams.

It is advisable to prepare an environmental health and safety control plan describing the operations that should be performed to avoid contamination of the surrounding materials and environment including risk mitigation measures to be applied to minimize the exposition of workers and the environment. Any possible risk for workers should be specifically considered and reported to be included in a health and safety plan.

The final report of the audit should be prepared by the auditor, signed on ascertaining the accuracy of the content and revised by a third party. The report must include the information regarding the project itself, all the information collected during the desk study and field survey and any information that can be useful for the owner, the contractor or any other stakeholder involved in the value chain of the project.

The level of the required monitoring of the auditing process varies between country or regions, from occasional inspections to detailed comparison of waste audit recommendations to the real outputs. Waste audit should be considered as living documents that are revised periodically. The quality of the audit performed should be done in 3 stages:

- Stage 1: Initial assessment during the waste audit. After the waste audit is performed it has to be checked for its quality by third party certified auditor, public body or professional associations.
- Stage 2: verification after or during demolition works to checks: what happens with hazardous waste, the presence of hidden hazardous wastes, the amount that were set free should be compared with what was estimated (any discrepancies should be notified and justified), material that were collected together and materials that were separate.
- Stage 3: verification with the management process considering the amount and separation rates but also the type of waste management performed (what happened with hazardous waste, which material where separately collected but put in a mixed container how the quantity measured..)

3.2.7 EU taxonomy

In 2019 Europe adopt is new growth strategy the European green deal a set of actions that aims at a climate neutral Europe; increasing the resilience to climate changes, boosting circular economy, cutting pollution and restoring biodiversity.

To reach these objectives, it is then essential to have an environmentally sustainable economy and so, redirect capital flows towards the more sustainable activities and investments. In order to do this in 2018 the comission adopted the *action plan on financing sustainable growth*, that set out a strategies to better connect finance with sustainability. As a first step the plan call the needing of a clear, detailed and harmonized classification system for qualifying economic activities and investments that have a positive impact on the environment and the climate. The EU taxonomy regulation 2020/852 set up this common language, establishing clear definitions of what is an environmentally sustainable economy activity. To put it simple an activity is considered environmentally sustainable if contribute at least in one and do not significant harm any of the following objectives:

1. climate change mitigation
2. climate change adaptation
3. sustainable use of marine resources and water
4. transition to circular economy
5. prevention and control of pollution
6. protection and restoration of ecosystems

The taxonomy regulation generates the fields of application for which a company is defined as sustainable; the belonging of a company to a field of application must be defined by the european commission, with technical selection criteria for each environmental objective through delegated acts. So far, criteria have been set for economic activities that can make a substantial contribution to climate change mitigation and climate change adaptation

Infect all companies that fall under the new *corporate sustainability reporting directive* (CSDR) implemented in 2023, have the obligation to disclose in their annual reports to what extent their activities are covered by the EU taxonomy (taxonomy-eligibility) and comply with the criteria set in the taxonomy delegated acts (taxonomy alignment).

Taxonomy eligibility is an assessment of whether an economic activity has a corresponding set of criteria in the taxonomy to be evaluated. Alignment to the taxonomy is the positive assessment of whether an eligible activity meets the requirements of the applicable taxonomy to contribute substantially to at least one of the six objectives of the taxonomy, does not significantly harm any other objective, and meets the minimum guarantees.

In other words, an activity is eligible if it falls within one of the six fields of interest of the taxonomy; it is aligned if it positively fulfils the requirements of the taxonomy.

Large companies and all companies with securities listed on a regulated market in the EU are obliged to comply with reporting requirements. Taxonomy recognize other specific subtypes of environmentally sustainable activities, the “enabling” activities that help to improve other activities performance making a substantial contribution to one or more of the objectives; and the “transitional” activities, that have not a low carbon alternative, but that are extremely important to achieve the climate change mitigation objective.

The taxonomy defines sustainability at the individual economic activity level (e.g., cement manufacturing or hydrogen storage) rather than the company level. This means that companies themselves cannot be considered eligible, but some or all of their underlying activities may be.

The construction sector can fit into Goal 4 for a transition to a circular economy. An economic activity such as a construction company can make a contribution towards a circular transition if it uses natural resources more efficiently, such as by reducing the use of raw materials and increasing the use of secondary raw materials; prolongs the use of products through reuse as well as by repurposing. In general, an economic activity working in the construction industry to fall within the scope of the taxonomy prevents or reduces the generation of waste from the construction and demolition of buildings.

If an economic activity is susteniable as defined in this regulation it can benefit from incentives.

EU taxonomy it is expected to help companies to plan their green transition, crate security for investors, protect private investors from greenwashing. Additionally, it should be helpful in scaling up investment in environmentally sustainable activities and projects, assisting investors at recognizing them, accelerating the achieve of the green deal objectives.

4 Result: National management strategy and correlated environmental sound legislation for inert CDW recovery.

Therefore, due construction and demolition waste the most quantitative waste flow produced in Europe and because the European regulation that set for non-hazardous CDW by 2020 a threshold of about 70 % on its preparation for recycling - not reached from all Member states - and because it is possible an amendment on the threshold a robust CDW management plant should be applied in each country to meet the obsolete by now target and to guarantee to accommodate the new EC invoice . Anyway, a good management strategy to be effective should be supported by an integrated legislation.

This chapter focuses on non-hazardous mineral construction and demolition waste, since of particular importance from the point of view of the EU's. In this chapter an overview of the practice of some member States on inert CDW management and law implemented are analysed. Each European Member States have adopted its own legislation for the control of pollution from aggregates. A deep survey of the legislative environmental criteria analysis is explained for the selected EU Member States.

Legislative requirements about Identification, separation, and collection action have been highlighted as the first steps for an effective CDW management.

Screening values of substances of concern to be searched for are shown. For the interest of comparison Tables of leaching limit values are expressed at eluate concentration of substances as mg of substance for Liter of eluate, for a fix value of L/S=10 l/Kg.

This comparison will be result of particular interest for Enydron in its company consultant activities. Infect as first steps in the consultancy process a robust background of the legislative framework followed by a validation step, through which confidence in the proposed management strategy is established. Legislation at the European level and at the national level was validated through research on government sites and with the collaboration of experts from other countries in the field.

To establish the most environmental sound strategy, to be proposed, a comparative analysis of the most virtuous counties integrated legislation was taken in consideration. In this study Austria and Italy was studied. The first was chosen for its high recycling rate, Italy instead is analysed because it sets very stringent limit vales in the pollutant parameters, as environmental criteria.

As far as recycled materials are concerned, reference is made to the set of standards concerning the treatment of CDW for the acceptance of the resulting product. These standards can be divided according to the relevant requirements. Technical requirements, suitability for use of EU CPR No. 305/2011, environmental requirements and, if present, purchase constraints.

4.1 National approach and integrate legislative plan for inert CDW management strategy.

In this subchapter, a comparison of inert CDW management strategies highlights the gaps and commonalities between the two counties. Italy was evaluate as home country, Austria is considered because considered leading European country in CDWs management.

4.1.1 Austria

Austria's waste management industry is structured in such a way that the precautionary principle and sustainability are complied with so that:

1 adverse or detrimental effects on humans, flora and fauna, their livelihoods and their natural environment are prevented, or otherwise kept to a minimum,

2. resources (raw materials, water, energy, countryside, land, landfill volumes) are conserved,

3. in the case of material recovery, the waste or the substances recovered therefrom do not have a higher risk potential than comparable primary raw materials or products from the same and

4. such waste is only left behind if sending it to landfill does not represent a damage to coming generations. On the basis of the precautionary principle, final sinks are needed in waste management.

Austria has adopted a management strategy for which waste for recovery is generally subject to less stringent requirements, so as to give consideration to the efficiency of the treatment plants and the capacity and specialisation thereof (FWMP).

Austria is a federation of nine autonomous states (Burgenland, Carinthia, Lower Austria, Upper Austria, Salzburg, Styria, Tyrol, Vorarlberg, Vienna). In the scope of construction and demolition activities waste management are regulated by the federal government under Waste Management Act 2002 and its relative Ordinances. Waste label, classification and traceability as well as waste treatment are also regulated at Federal level. Legislation on hazardous waste is also the exclusive competence of the Federal Government as laid down in Article 10 of the Austrian Federal Constitutional Law (Federal Law Gazette No. 1/1930, as amended).

The following summary constitutes the national legislative plan concerning inert waste produced by the state of Austria:

- Waste management Act 2002 (Federal Law Gazette I No 102/2002, as amended) bring together key areas of regulation in this regard concerning hazardous and non-hazardous waste and, in addition, transpose EU law in Austria.
- Recycled Building Materials Ordinance RBV, Federal Law Gazette II No. 181/2015 as amended by Federal law Gazette No 290/2016. Ordinance on the obligations to be observed in the course of construction and demolition works, the separation and treatment of waste, the manufacture and EoW of recycled construction materials.
- Landfill Ordinance 2008, Federal law Gazette II No 39/2008, as amended by Federal law Gazette II 291/2016.Landfill ban to promote circular economy from 2024 (EOW, Tristan).
- Ordinance on mobile plants for the treatment of waste, Federal Law Gazette II No 472/2002

In addition, in order to achieve the objectives and principles of the Waste Management Act the Federal Minister for Agriculture and Forestry, Environment and Water Management subscribe a Federal Waste Management Plant at least every six years who chronicles the waste management measures adopted hitherto along with their efficiency. It assesses the need for additional plant infrastructure that will ensure self-sufficiency and ensure the treatment of waste in one of the nearest and most appropriate plants.

In 2019 in Austria about 1.29 Kg of mineral CDW/person was produced; of the generated waste 87% enter recycling treatment plan, 12% is landfilled and about 1 % is exported (Statusbericht, 2021). The aim of processing in treatment plant is technical conditioning e.g crushing, screening, classification and removal of still existing pollutants and impurities in order to produce high-quality recycled building materials, which can be used directly as building materials (technical fill, base courses, etc.) or as aggregates for the production of building materials (asphalt mixes or concrete).

In Austria the approval for demolition requires a multi-stage procedure: at first a desk research information about the building to be demolished, it follows an on-site audit in which sample can be taken to investigate about pollutants and impurities from that the dismantling concept has to be elaborated, the removal of reusable components as of harmful and impairing substances to finally have relies stuts for mechanical deconstruction. The pre investigation audit leads to a comprehensive analysis of the inventory, basis for the planning of the recycling-oriented deconstruction project.

During the investigation of pollutants and impurities before demolition of a structure, those components which can be prepared for re-use must be documented. RBV accordingly stipulates that those components which can be sent for preparation for re-use and which are in demand by third parties are dismantled and handed over in such a way that subsequent re-use in not made more difficult or impossible. It must also be recorded whether the components are accessible at all times or whether demolition must first be started in order to dismantle the objects. This yield in investigation on local markets to explore possibilities for reuse of components. Example of potentially reusable components are radiators, furnishing, window frames, sanitary ceramics and floor coverings. Those materials can be stored for a 3-year period in a paved officially approved area. In this time materials are prepared for its reuse as testing, cleaning or repair. Those materials may be reused only for the same purpose for which they were originally intended for. According to AWG 2002 the EoW occurs only after completion of the recycling operation (examination, cleaning, and repair).

Once the demolition has taken place waste is collected on the construction site via skip containers and trucks by disposal and demolition companies. On-site separate collection is mandatory. Hazardous and non-hazardous waste as construction site from wood, metal, plastic and mineral waste must be separated in order to achieve optimal separation individual containers must be labelled.

Other demolition materials of mineral origin, such as polystyrene concrete, gypsum, fibre cement, etc. are generally not suitable for the production of recycled building materials and must therefore be rejected at the very first collection of the demolition mass. The removed waste, which contains harmful substances and contaminants, must be separated from each other on site. If the separation at the point of origin is not technically possible or involves disproportionate costs, it must be carried out in a treatment plant approved for this purpose. The separation obligation does not apply to those waste the joint treatment of which is permissible for the production of a particular recycled building material and is also to be carried out. The are responsible for separating the waste. The client is also responsible for providing the necessary space and facilities.

In particular to guarantee a separate collection system and high-quality recycling in Austria is mandatory to implement a recycling-oriented demolition process for the demolition of buildings in which more than 750 tonnes of waste will arise. If in the demolition project will arise more than 750 tonnes of CDW (excluding excavated material, rail structure and traffic area), an exploratory investigation of pollutants and contaminants in accordance with ÖNORM B 3151 "Dismantling of structures as a standard demolition method"; the same standard apply for dismantling works and must be carried out by an external specialist or specialist institute. The standard "Dismantling of buildings as a standard method for demolition" basically show the staps to be followed during a dismantling process, noxious substance prospecting, dismantling concept, preliminary dismantling, clearance and mechanical dismantling.

In the case of objects with a gross volume (width x length x height) of more than 3,500 m³ and more than 750 t of construction and demolition waste, a comprehensive investigation in accordance with ÖNORM EN ISO 16000-32 "Indoor air pollution, Part 32: Examination of buildings for pollutants", of pollutants and contaminants must be carried out by an external specialist or specialist institute. In the course of this comprehensive investigation, the presence of impurities according to ÖNORM B 3151 is to be examined and evaluated.

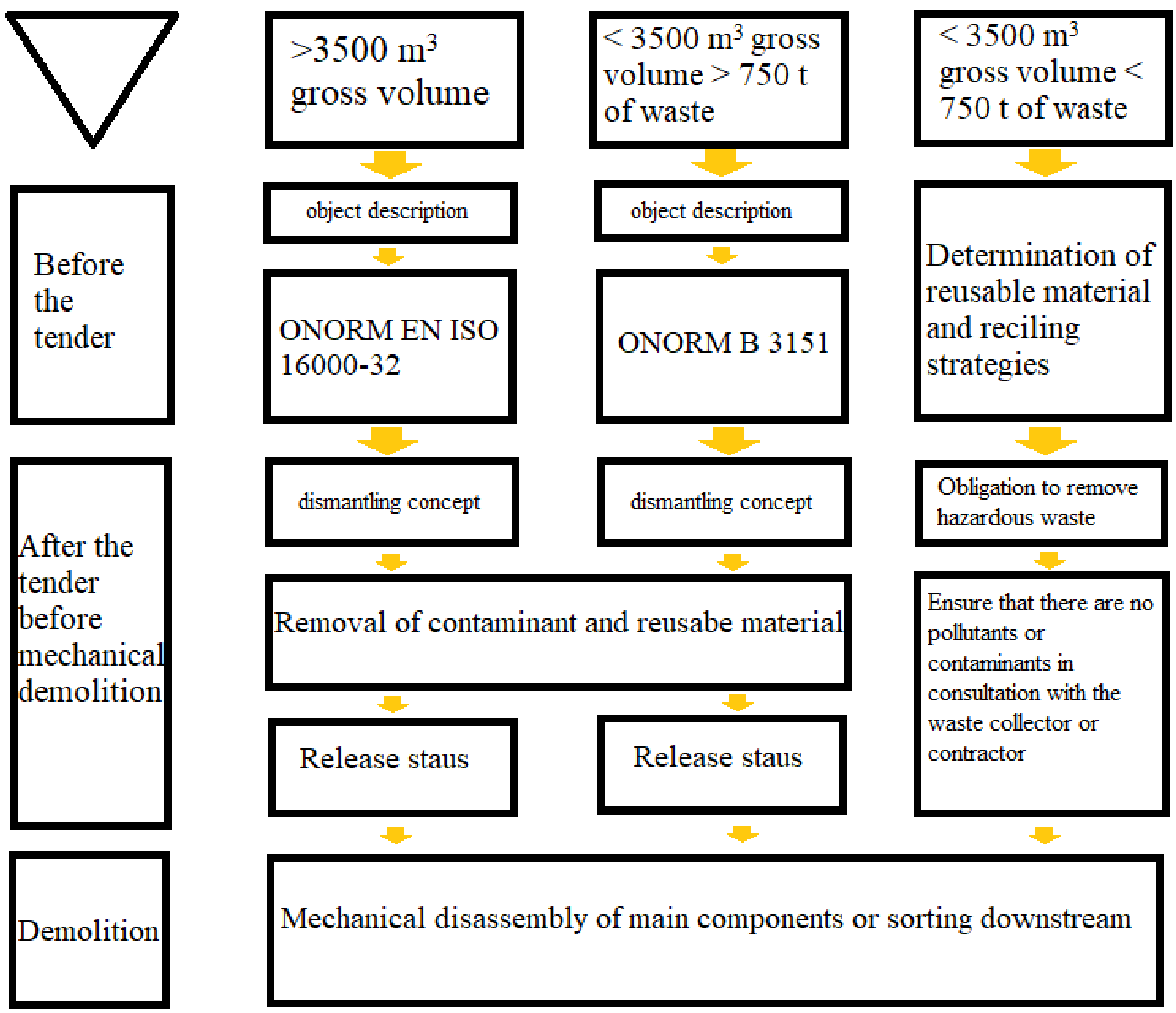


Figure 16: Stepwise procedure before the mechanical demolition.

In the dismantling works, pollutant and in particular hazardous waste (e.g. asbestos cement, asbestos-containing waste, tar-containing waste, PCB-containing waste, phenol-containing waste and (H)CFC-containing insulation materials or components), and contaminants (e.g. gypsum-containing waste (12) that make recycling more difficult, must be removed. In addition, during the preparatory dismantling process, following items, materials and substances have to be cleared away, If necessary, by means of disassembling:

- Components containing mineral oil (e.g. tank
- floor constructions and double bottoms
- non-mineral flooring materials
- non-mineral wall coverings (eg plastic, cork, wood)
- installations of plastic
- facade structures, insulation
- glass, glass walls, glass block walls
- building elements made of gypsum
- partition walls made of cork, wood, plastic
- doors and windows

For those building with less than of 3500 m^3 of gross room volume and 750 t of waste no exploratory investigation of pollutants and contaminants is required. In this case rubble can be recycled without analytical investigation on the same construction site (on-site recycling), provided that it is largely free of pollutants. It is well recommended to carry out a pollutant and contaminant investigation (ÖNORM B 3151). The list of pollutants and impurities to search for are explicit call in the standard. For those type of detritus re-use construction engineering requirements as usual apply. Simplified on-site recycling is allowed for small quantities for construction purposes. The conditions for on-site recycling are:

- The total mass of demolition waste must not exceed 750 tons where all waste generated directly during the demolition account.
- No use in groundwater, in groundwater fluctuation zone and in surface waters
- Construction recycling only in the area of the same construction site where the waste was accumulated
- Construction recycling of exclusively mineral construction waste
- Separation of wood, metal and plastic
- Comprehensible technical purpose
- Structural stability for the intended purpose
- Removal of pollutants before the demolition is carried out
- Proper, verifiable disposal of the sorted waste
- Documentation of quality assurance

Mechanical processing (crashing and screening) allows the intended use of the material. Therefore, no compliance with the required limit value, designation, and registration in accordance with the provision of the waste balance ordinance. However, this special regulation does not apply to line structures and traffic areas.

Waste collectors and processors subject to recording keeping requirements are annually obligated to submit annual an electronic waste balance sheets to the head of the Provincial Government, as requested by Ordinance on Waste Balance Sheets. Data collection is done with the aim to fulfil EU reporting requirements, improving data resources for waste management planning and traceability of waste streams.

Stationary or mobile treatment plants are used for waste conditioning. Stationary plants are stationary facilities or those that are operated over a longer period of time at one location. Mobile treatment facilities are operated a different location for no longer than six months at a time, as established in Waste Management Act 2002, Federal Law Gazette I. No. 102/2002 as amended. Processing plants for mineral construction and demolition waste usually consist of crusher and a downstream screening plant. In stationary plants in particular scrubber or air classifier can also be used. In 2019, a total of 154 stationary treatment plants were available for the treatment of mineral construction and demolition waste. In addition, 774 mobile plants were active.

A quality assured processed building debris apply. A distinction is made between processing with mobile systems directly on the construction site or in approved interim storage facilities or processing in stationary systems. A receiving inspection meaning visual inspection, cheeks on inadmissible waste and mixing, and documentation, followed by a quality requirements investigation are common. Quality assurance system differs for recycling companies that follows standard procedure, mobile system adopts a single batch procedure.

Recycling Material Ordinance aims to the conservation of natural primary material trying to achieve the highest recovery rates of high-quality recycled construction materials; as well to ensure legal certain in the use of recycled construction materials o recycled construction material products and the reduction of the remaining substances to landfill. The ordinance also contains quality specification for recycled construction materials and prescribe the ranges of application for recycled construction materials. The Ordinance also prescribes that only the highest quality for EoW status, subject to compliance with specific requirements.

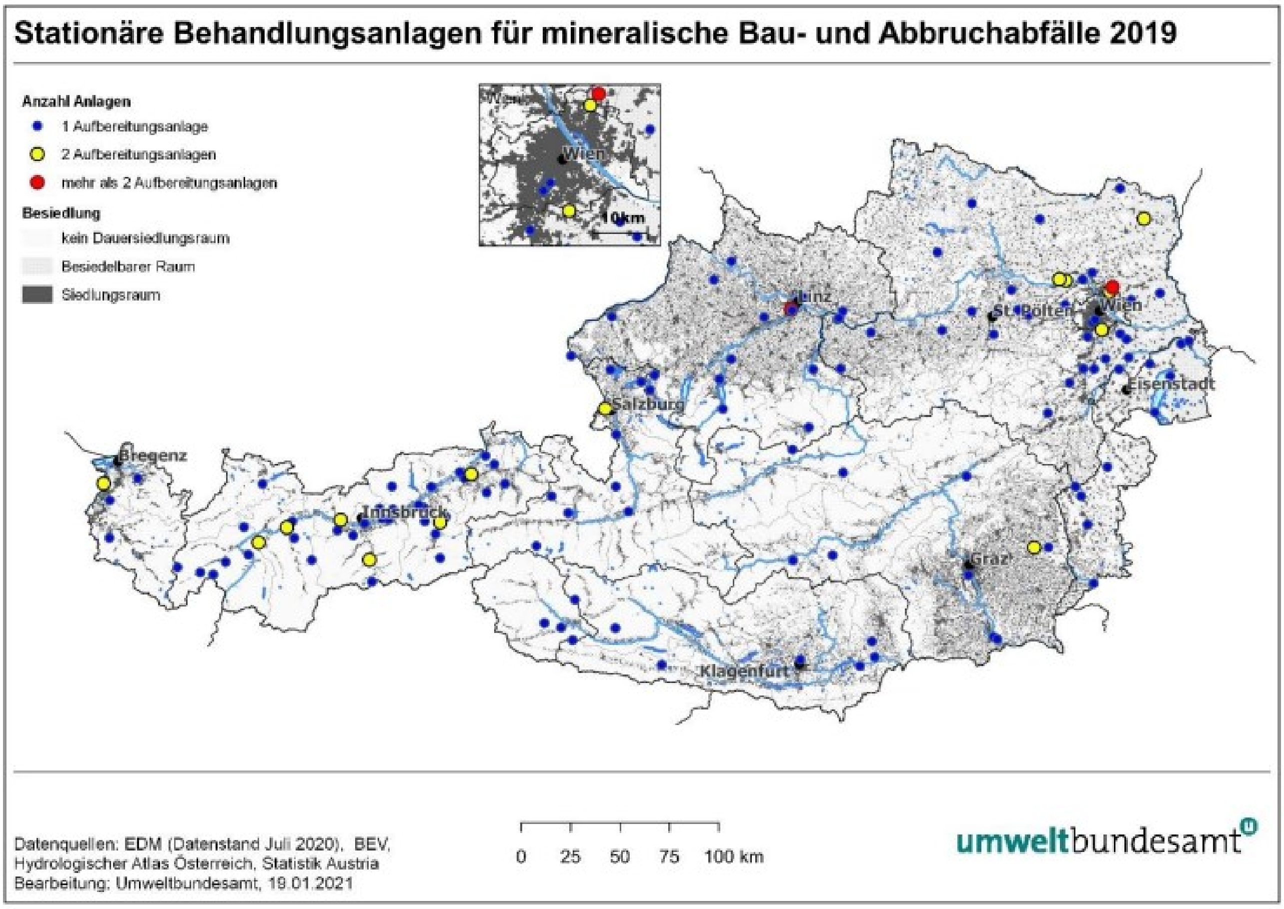


Figure 17: Stationary treatment plants for mineral construction and demolition waste in 2019.

As a result of quarrying for sand, gravel, marl, clay, or a result of building activities, cavities arise. In Austria those can be backfilled with waste on grounds of technical and environmental usefulness and taking into consideration specific quality criteria. The constrain are: substitution of other materials for a concrete purpose (structural engineering), ensuring a quality comparable to that of the substituted product by a quality assurance system and limitation of the use to an extent absolutely necessary for reaching the goal of backfilling (CDWM Austria). Depending on whether backfilling is done following a dry or wet extraction will determine the quality of the materials employed. It is expected that below this operation a new construction project will be arise, therefore the material used provide stability meeting construction criteria. In any case backfilling operation are regulated under another legislation the soil ordinance.

Austria is now thought of Gypsum and aerated concrete recycling, because they can break down in hydrogen sulphide in landfills and therefore became a possible source of pollution if not properly managed and because they can be used as construction material in a closed loop at the same material and technical level (FWMP, 2017). From the prospective of the RBV Ordinance to produce recycled aggregates however, gypsum and aerated concrete are considered as impurities, in line with demolished technical standard ÖNORM B 3151, and therefore collected apart. Gypsum could be collected for a fee from building site, for example in special bags and its scraps handle in a treatment facility, at a comparatively low cost for landfill but with a higher collection quota.

In Austrian federal state care must be posed to build in a resource-conserving and efficient manner as required in Annex 1 point 7 of Regulation EU No. 305/2011, no legally requirement applies on amount of secondary raw materials use (Steiermak).

4.1.2 Italy

Italy is divided in 20 regions, the national legislative plan for construction and demolition waste regulates the relevant provisions at national level, on the basis of the national plan, regions develop their own management plan. This aspect represents pros and cons; the system allowed a better administration designed for suiting each region to every different need but offer data difficult to compare because of the different parameters considerd. Italy land consumption density account for 2,1 m2/ha (35) with a doble population density compared to Austria.

At national level the following regulation concerning mineral fraction of CDW applies:

- D. lgs n.152/2006 Code on the environment, part IV defines CDW, and hazardous waste,
- D. lgs n.152/2022 "Regulation governing the cessation of the waste status of inert construction and demolition waste and other inert waste of mineral origins" lays down specific environmental criteria in accordance with which inert construction and demolition waste ceased to be consider a waste and qualified as recovered aggregates.
- DM n.69/2018

In Italy CDWs are considered as special waste, accounting the larger share. These have increased in recent years, a factor due to a considerable state incentive on the renovation of buildings for energy upgrading. The total production of CDW excluded soil, rocks and dredging spoil stands at 59,4 million t. Of this 47,6 million t are sent for material recovery, meaning that the recovery rate of waste from demolition and construction operations is 80.1%, above the European target (37). The generation of such waste is not to be considered uniformly distributed throughout the country, it must be considered also that material recovery plants and production plants performing material recovery are not evenly distributed throughout the territory; most are located northern Italy (35). Mean material flow composition is represented in table 11.

Table 11: production and preparation for re-use and other forms of recovery of CD waste excluding excavated soil and rocks (ISPRA).

Waste fraction	**Production**	**Prepare for reuse/recycling**
	t	**t**
Ferrous metal	4952316	4411731
Non-ferrous metal	432660	314966
Glass	104216	91430
Plastic	53985	3832
Wood	293117	264428
Minera CDW	53340326	42270588
Tot	59195643	47400333

Before a project of demolition or construction of one structure at the expense of another, also for Italy a stepwise logical procedure applies. At first a preliminary audit of the structure to be demolished aimed at understanding the typologies of structure, the year of manufacture and eventual renovation, the previous activities conducted in the structure, characteristics on the site and presence of any criticism. The audit can be conducted by analysing drawings and photographic documentation of the building, calculating the quantities and types of materials that would be obtained through demolition and identifying the management alternatives for the different wastes. The executive project identifies the dismantling and demolition methods and the waste resulting from them, ensure separation between hazardous and non-hazardous waste, organize on site deposit and transport. Waste management plant should be write based on this, it will form a database as an organic list of materials produced, in qualitative and quantitative terms. In case in the site of the demolition project are present abandon waste, those before demolition must be removed and properly sent to recovery or disposed (Bernardis, 2016).

Before to proceed to masonry and foundation structures demolition, is necessary to remove asbestos components, underground tank, hazardous substances, and removal of materials that can be reusable.

To identify any hazardous substances present, a chemical profile must be assessed based on information gathered on the past use of the demolition object and therefore in the case of demolition of industrial buildings, the analytical characterisation shall also cover the substances typical of the activity carried out (relevant substances). Otherwise, there are no standardized specifications that oblige the search for hazardous substances (Workshop, 2023).

The material intended for re-use applies for those historical value and for building elements that can be dismantled such as structural elements of wood or metal, bricks or stone blocks, tiles, roof tiles, steps, thresholds, tiles and majolica tiles, windows, doors, fireplaces in natural stone, etc. such materials, if the owner does not intend to dispose of them, evaluating their possible re-use and ensuring the absence of hazardous substances, are not classified as waste, and should therefore be considered as any other building material/component and as such must be handled as such.

Selective demolition is highly recommended and strategic in the awarding of tenders. (PVC forum). Undifferentiated demolition occurs on small demolition work, in emergency interventions such as unsafe buildings and in emergency event. This strategy is used as the more economic. In this case, the undifferentiated waste is delivered in sorting plants, obtaining at least three different product categories at the output as mineral fraction, metals, and light fraction. In recent years, the development of plant design for the treatment of C&D waste has found a considerable impetus thanks to the increase in landfill cost.

For the purpose of selective demolition, certain materials used as cladding (bituminous sheathing) and/or insulation in buildings (e.g. glass wool and rock wool) must be removed prior to demolition of the structure to avoid contaminating the inert demolition waste with unsuitable waste.

Safety operation of buildings must be realized preliminarily and independently from the demolition activities. On site storage on temporary storage zone must ensure safe conditions for workers and the environment according to D.Lgs 152/2006

Therefore, material derive from demolition activities generate since their production, it must be divided in homogeneous categories where possible and classified according to European Waste Code CER to be sent to treatment facilities. Any waste produced and managed have to be produced a FIR waste identification form, then registered in national base.

For the mineral part of waste from construction and demolition waste, the main form of recovery is transformation into fine or coarse aggregates that can be used in the production of concrete or asphalt or in road construction.-Treatment plant for inert recovery can be mobile or fix. The last are designed with a high technological content, different crushing system allow a wide granulometry of homogenous material. A "mobile facility" is defined as a single technological structure a single piece of machinery or a single body that performs substantially an operation or a phase of a disposal and/or recovery operation or, in particular cases a set of facilities technological facilities, which can be transported and installed at a site to carry out campaigns of activities of time-limited duration not exceeding 120 days. Those plant are economically convenient in large demolition site, usually allow the simple volumetric reduction of the individual elements fed into the system.

Each step for each waste-to-treatment stage quality criteria ensure the environmental performance of the finished product.

Table 12: Quality criteria for each step of treatment stage.

Phase	**Objective**	**Modality**
Drain of waste	Warnings presence of non-identic waste at treatment	Verification of conformity
Storage of waste	Guarantee a constant power to the grinding system	Storage areas of incoming waste
Mechanical crushing	Reduction of predetermined granulometry	Mill
Metal separation	Recovery of ferrous metals and not	Eddy current/ Electromagnet
Separation of light fraction	Eliminate residual materials	Ballast/floating separator, manual separation
Granulometric separation	Dimension selection	Screen

In Italy a purchase constrains exist for public office and predominantly public capital companies that have to fulfil the annual requirement of manufactures and goods with an amount of secondary recycled material at minimum of 30% of the requirement itself, Ministerial Decree 203/2003. As far as the construction sector is concerned, the manner in which this requirement is carried out is based on the recycled aggregate Ministry of the Environment (Circular 5205/2005). Public administrations provide for the use of recycled materials in the formulation of tender specifications. Criterion for which the recycled aggregate may be used by the applique company is that it must be priced appropriately, in the sense that its value must not exceed that of the corresponding raw materials or goods. Italy was the first country, among the EU Member States, to impose the obligation to apply a minimum environmental criteria for public contracting stations (Javer).

4.2 Reuse criteria and Recycling, EoW criteria and Backfilling Legislation for inert CDW

EoW criteria is a tool of particular interest for the boost of the circular economy. Material is put back in circle if they didn't pose any detrimental effect to the environment. If the material does not pass the criteria for the envisaged material class, it may be subject to further treatment before undergoing renewed tests or it may be classified in a different material class with less strict conditions.

4.2.1 Austria

4.2.1.1 Recycling Building Materials Ordinance - RBV n. 290/2016

The purpose of the recycled Construction Material Ordinance is to promote the recycling of mineral waste from CD activities and ensure that the recycled construction materials produced are of high quality. This Regulation apply to production through the treatment of certain waste and use of recycled building materials as recycled aggregates; environmental compatibility criteria with limit values and condition for the EoW status. Also, this ordinance set out obligations for construction and demolition activities as the separation and treatment of the resulting detritus. The objective is to promote preparation for re-use of components and to ensure the high quality of recycled building materials. Lastly the law makes clear the responsibilities/mansions of the different participants.

Only certain types of waste are admissible for recycled building materials production. In table a list of waste from which secondary material can be recovered is reported as in RBV. We have selected the waste interesting for this study. The incoming waste must be me avoided to be contaminated by the following contaminants: Asbestos, artificial mineral fibres, (H) CFCs (e.g. in extruded polystyrene (XPS), polyurethane (PU)), PAHs (eg tar), PCB, Phenols, Mineral oil, Plaster, magnesite and cementitious wood wool insulation boards, cement-bonded wood chipboard, Fire protection panels and Faux marble.

Table 13: admissible CDW for the Austrian Recycling Building Material Ordinance.

SN	Waste designation	Specification
31409	Construction waste (no construction site waste)	
31409 18	Construction waste (no construction site waste)	only mixtures of selected waste from construction and demolition measures
31410	Road construction	
31427	Concrete demolition	Also concrete (e.g. faulty batches) from production
31427 17	Concrete demolition	only selected waste from construction and demolition measures
31467	Track ballast 1	
54912	Bitumen, Asphalt	

Incoming waste must be checked at the manufactured of recycling building materials for quality assurance plan by means of visual inspection to its suitability for the production of recycled building materials; the material must undergo an examination for inadmissible mixing, inadmissible waste or impurities e.g. asbestos, artificial mineral fibres, HCFCs, etc, and the correlated documentations (audit document, the deconstruction concept and the confirmation of the approval state). Only waste considered accepted can be processed in the plant.

At the end the processed recycled building materials must be checked for its environmental compatibility before to be used. Criteria on environmental quality requirement are set according to the limit values for total contents and leachate test, in Annex 2 of the aforementioned directive. In the event of a suspicion of contamination arising from the incoming inspection the eluate parameters in accordance with Annex 2 to include that of the inert waste landfill in accordance with Annex 1 Table 4 of the Landfill Ordinance 2008 (DVO 2008),Federal Law Gazette II No. 39/2008. For each of these parameters, an eluate limit of 0.3 mg/kg DM is imposed.

Recycled construction materials produced as aggregates in recycling plants are classified into quality classes according to their composition. The classes are defined by means of a list of parameters and associated limit values. Recycling building materials must be assigned to the relevant quality class and must comply with the structural engineering requirements in accordance with the state of the art. A recycling building material must also correspond to the provisions of the EU Building Products Directive. There are eight quality classes: U-A, U-B, U-E, H-B, B-B, B-C, B-D and D. For each class a preferable use application is suggest; the first classes are used for the most ambitious project. The quality class D is out of our interest because those are aggregates coming from steel mill slag production. In order to regulate the environmentally sustainable use of recycled construction materials, it is necessary to determine the type of application with regard to hydrogeological application areas. Fundamentally, the use of recycled construction materials of quality class lower than U-A is not permitted in water-source preservation areas and in areas with set conditions for water management.

For some kind of waste, the quality class for which they can be classified is fixed. Recycled building materials of quality class U-E may only be produced from track ballast material or technical bulk material.

By way of derogation, no compliance with the required limit values, a recycled building material made of reclaimed asphalt (RA) can be assigned to quality class B-D if the reclaimed asphalt doesn't contain any impurities or pollutants e.g. with tar. The investigation of the contaminants is made by individual samples, as explain below, before the demolition activity. Therefore, pure reclaimed asphalt can be directly reused respecting the limits of applicability and areas of use of the quality class B-D. Non-recyclable residues resulting from the production of recycled building materials must be properly disposed of.

In the Austrian legislation only recycled building material of quality class U-A could seek its EoW status, the end of its waste status is reached when it is handed over by its manufacturer to a third party. For recycled building materials of all other quality classes, an end to the waste characteristic can only be achieved through the permitted use. Therefore U-A could be used without restriction for different purposes, for other quality classes prohibition in the use's area exist.

Recycling building materials are partially restricted in their application areas. Depending on the quality class, the areas of application are limited or there are prohibitions on use for example in water conservation areas. Permissible areas of application and prohibitions of uses are specified in the Annex 4.

Table 14: Leachate limit values for quality classes

		Quality class		
Parameter	**Unit**	**U-A**	**U-B**	**U-E**
Eluate L/S=10				
pH		7.5-12.5	7.5-12.5	7.5-12.5
El. Conductivity	mS/m	150	150	150

Cr total	mg/Kg DM	0.6	1.0	0.60
Co	mg/Kg DM			1.0
Cu	mg/Kg DM	1.0	2.0	1.0
Mo	mg/Kg DM			0.5
Ni	mg/Kg DM	0.40	0.60	0.4
Ammonium-N	mg/Kg DM	4.0	8.0	4.0
Chloride	mg/Kg DM	800	1000	800
Fluoride	mg/Kg DM			10
Nitrite-N	mg/Kg DM	2.0	2.0	2.0
Sulphate	mg/Kg DM	2500	6000	2500
TOC	mg/Kg DM	100	200	100
KW-Index	mg/Kg DM			5.0
Anionenak. Surfactants MBAS	mg/Kg DM			1

Table 15: total content limit values for quality classes.

Total content	Unit	U-A	U-B	U-E
As	mg/Kg DM			50/200
Pb	mg/Kg DM	150	150/500	150/500
Cd	mg/Kg DM			2.0/4.0
Cr total	mg/Kg DM	90/300	90/700	300/700
Co	mg/Kg DM			50
Cu	mg/Kg DM	90/300	90/500	100/500
Ni	mg/Kg DM	60/100	60	100
Hg	mg/Kg DM	0.70	0.70	1.0/2.0
Zn	mg/Kg DM	450	450	500/1000
TOC	mg/Kg DM			30000
KW-index	mg/Kg DM	150	200	150
Benzo(a pyrene	mg/Kg DM			1.2
Sum 16 PHA (EPA	mg/Kg DM	12.0	20	12.0
Contamination	Unit	U-A	U-B	U-E
FL	cm^3/Kg	≤4	≤5	≤5
Rg+X	M-%	≤1	≤1	≤1

Table 16: Use application for quality classes.

Quality class	Description	Unbound application without low-permeability, bonded surface or base course	Unbound application under low-permeability, bonded surface or base course	Production of concrete from strength class C 12/15 or strength class C 8/10 from exposure class XC1	Production of asphalt mixes
U-A	Aggregates for unbound as well as for hydraulically or bituminously bonded use	yes	yes	yes	yes

U-B	Aggregates for unbound as well as for hydraulically or bituminously bonded use	no	yes	yes	Yes
U-E	Aggregates for unbound as well as for hydraulically or bituminously bonded use	yes	yes	yes	Yes
H-B	Aggregates exclusively for the production of concrete from strength class C 12/15 or strength class C 8/10 from exposure class XC1	no	no	Yes	No
B-B	Aggregates (especially reclaimed asphalt) for the production of asphalt mixes	no	yes	no	Yes
B-C	Aggregates (especially reclaimed asphalt) for the production of asphalt mixes	no	no	no	Yes
B-D	Aggregates (especially reclaimed asphalt) for the production of asphalt mixes	no	yes	no	yes

Recycled building material product of quality class U-A can be used unbound and used unbounded for the production of concrete under strength class C12/15 or in the case of strength class C 8/10 under exposure class XC1 and asphalt mixes production without any restriction on its application. Therefore, it is an aggregate for both unbound and hydraulically or bituminous bound use.

Recycling building materials of quality class U-B and U-E is admissible for unbound uses and may also be used unbound for concrete production under strength class C12/15 or in the case of strength class C 8/10 under exposure class XC1, only under a low permeable, bound surface or base course. Exceptions to this are building construction measures and the trapezoid of a traffic area. The low-permeability, bonded surface or base course must be applied immediately after installation, considering structural requirements. They cannot be used in the following areas, unless a water permit has been granted for the use or recycled building materials:

- in protected areas pursuant to the Water Rights Act 1959 (WRG 1959);

- in the designated core zone of protected areas or in the designated narrower protected area in accordance WRG 1959, with the exception of protected areas for the protection of thermal water resources

- in and immediately above groundwater, and

- in surface waters.

The recycling building materials of quality class U-B and U-E may be also used as aggregates to produce asphalt mixture therefore those quality class allow unbound and hydraulically or bituminous bound use. The quality class U-E can also be used unbound in the body of the track, thus serving as a base layer. Therefore, no upper low-permeable, bonded top, or base course is necessary. Therefore, UE are mainly used for these aims.

Recycling building material of quality class H-B can used exclusively in hydraulic bound for concrete production from strength class C12/15 or strength class C8/10 from exposure class XC1, according to ONORM B 4710-1.

Recycled building material of quality classes B-B, B-C and B-D can be used as recycled aggregates for bituminous bounding. In particular recycled building material of quality class B-B and B-C may be used in asphalt production plant to produce asphalt as a product; recycled building materials of quality B-D may be used in the asphalt production to produce asphalt as a waste, this means that for the latest prohibition on uses and possible areas of applications apply. Recycling building material of quality class B-B and quality class B-C infect may only be used for the production of asphalt mixture of quality B-B, for which no prohibition on use apply, begin a product. Recycling building material of quality class B-D may only be used to produce asphalt mix of quality B-D, for the following uses: bituminous bound surface courses or bituminous bonded base courses used in the construction and maintenance of all public traffic areas. The use must be carried out in accordance with RVS 08.16.01 "Requirements for asphalt layers", issued on 1 February 2010, and RVS 08.16.06 "Requirements for asphalt layers - use-behaviour-oriented approach", issued on 1 April 2013.

Asphalt mix of quality class B-D may not used in the following areas:

in protected areas in accordance with §§ 34, 35 and 37 WRG 1959

in protected areas; if a core zone of protected areas or a narrower protected area is designated in accordance with §§ 34, 35 and 37 WRG 1959, the prohibition of use is limited to this area; the ban on the use of the entire protected area does not apply if a water law permit for this construction measure has been obtained

- in and immediately above groundwater, and
- in surface waters.

Recycling material of quality class B-B and B-D made of asphalt obtained by milling (milled asphalt) may also be used in road construction for the production of unbound upper base courses of federal highways A and S and state roads B and L, in accordance with RVS 08.15.02 "Unbound base courses with asphalt granules". In this case, restrictions for quality class U-B apply.

In the case of a recycled building material of quality class B-C or quality class B-D, which has a total PAH content (16 PAHs according to EPA) of more than 20 mg/kg DM, the processing into asphalt mixture may only be carried out in enclosed hot mixing plants with vapor collection and treatment from the mixing process. Vapour capture and treatment must prevent the release of pollutants, in particular TOC, HC and PAHs, in accordance with the state of the art. The final items, asphalt mixture shall be demanded to have been complied with the limit value for the total PAH content (16 PAHs according to EPA) of 20 mg/kg DM., provided that no other materials containing PAHs are used.

For the assignment of quality class for secondary raw materials is used a focused chemical composition analysis. In the leaching test, the parameter searching in the eluate are different depending on the quality class: heavy metals for all classes Cu are searched, Mo for the quality class U-E, B-B, B-C, B-D; Ni for U-A, U-B, and U-E; quality class U-E look also to Co. PH, electric conductivity, ammonium-N, chloride, nitrate-N, sulphate is a common search. The classes B-B, B-C and B-D search also Fluoride. Quality class U-E is the ones with a higher characterization, KW-Index, anionenak. Surfactants – MBAS, TOC are searched too. A methylene blue active substances or MBAS assay is a colorimetric analysis test method that use methylene blue to detect presence of anionic surfactants, such as s detergent or foaming agents. KW-Index (C10-C40) must be read more carefully if the limit is exceeded due to bituminous fractions, this value shall not be relevant for the assessment of the material, provided that the (more volatile) fraction of C10-C17 does not exceed 75 mg/kg DM for quality class U-A and 100 mg/kg DM for quality class U-B for the carbon dioxide index. In this case, the test report shall indicate the result for C10-C17 and the asphalt content in M%. Alternatively, in the case of a recycled building material RA (recycled crushed asphalt granules) with an asphalt content of more than 90 M%, the KW index parameter is not to be applied. Instead, a KW index in the eluate of 2 mg/kg DM applies to quality class U-A and a KW index in eluate of 5 mg/kg DM to quality class U-B.

In the total content analysis, the searched chemical characterisation is also different depending on the quality class desired. For each quality classes the parameters searched for are floating materials (FL), glass and other materials (Rg+X), KW-Index and ∑16PAK (EPA). The other parameter testes are HM, of those the class U-E is the ones more characterised. ∑16 EPA-PAH is a list of 16 PAH which have been classifies as priority pollutants by the US Environmental protection Agency and are commonly analysed in environmental samples as representatives of the whole group of PAH, it collect: Acenaphthene, acenaphthylene, anthracene, benzo[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, benzo[g,h,i]perylene, benzo[k]fluoranthene, chrysene, dibenzo[a,h]anthracene, fluoranthene, fluorene, indeno[1,2,3-cd]pyrene, naphthalene, phenanthrene and pyrene. Benzo[a]pyrene is also analysed as single parameter for the class U-E.

Quality assurance with regard to environmental compatibility of recycled building material is detected by leaching test and total content analysis. With regard to digestion, leaching and determination methods for chemical-analytical analysis, all requirements of Annex 4 Part 1 Chapter 5 DVO 2008 apply. The test results of the individual field samples must be within the tolerance range according to Annex 4 Part 1 Chapter 7 DVO 2008.

The manufacturer of recycled building materials must ensure the environmental compatibility of the recycled building materials produced, by an assessment report for each batch. It also has to clearly identify the new material, by means of a designation that indicate the quality class with specification of the permissible areas of applications and the prohibitions of use. In accordance with the Waste Balance Ordinance the producer shall keep record of the type, quantity origin and whereabout of waste for the production of recycled material. If several recycled building materials are produced simultaneously from one starting material, which differ only in grain distribution, it is sufficient to limit quality assurance to the batch with the finest grain distribution, the corresponding quality class is assigned to all of them, considered the extreme condition for the relise of substance in the leaching test (JRC).

The quality assurance procedure of recycled building material follows a standard procedure: a declaration check by an external authorised specialist and in-house production control (by the manufacturer).

On the basis of the test results in the scope of declaration checks, the batch to be assessed shall be assigned to a corresponding quality class providing that all limit values are complied with. For all repetitions of the declaration test and the FPC the limit values of the applicable tables for the declared quality class of the respective recycled building material for the batch examined must be complied with, otherwise the batch tested is either:

- after removal of the corresponding pollutants or contaminants within the framework of a declaration test and to assess compliance with the respective limit values, or
- to be assigned to another quality class – provided that all limit values are complied with, or
- to be discharged from production and handled properly.

In addition, if one or more limit values are exceeded in the course of the repetition of the declaration test, at least one further batch of a maximum of 50 production hours of this recycled building material must be immediately examined and assessed by an external authorised specialist or specialist institution in accordance with the provisions of this chapter.

In specific cases a different quality assurance procedure is necessary: Recycled building materials made of bituminous or hydraulically bonded surface or base courses from the dismantling or rehabilitation of traffic areas, and Recycled building materials consisting of track ballast material and technical bulk material from the substructure of track structures, and recycled building materials made from technical bulk material.

In the first case quality assurance for recycled building materials made of bituminous or hydraulically bonded surface or base courses (e.g. reclaimed asphalt) from the dismantling and rehabilitation of traffic areas can be carried out by means of sampling by individual samples (e.g. drill cores, milling samples) and their analytical examination before the start of the demolition or milling activity (in-situ). On the basis of the test results, the material milled from the respective asphalt surface is of a corresponding quality class. As a result the investigated site will be subdivide in different area corresponding to a different quality classes.

In the second case quality assurance can also be carried out by means of a basic characterisation in accordance with Annex 4 Part 2 Chapter 1.6 DVO 2008 before the start of the excavation or clearing activity by an external authorised specialist or specialist institution. The scope of parameters for the initial examination shall be at least all parameters limited to quality class U-E. In any case, a detailed examination of all proportions or partial quantities must be carried out for all parameters relevant to the limit value and, in any case, for the parameters ∑16PAH (EPA), KW index and Benz(a)pyrene (each as total content). The tested masses are to be assigned to quality class U-E – provided that all limit values are complied with. If the limit values of quality class U-E are complied with, if another quality class is also complied with, the investigated mass can be assigned to this other quality class. In the last case quality assurance can be reached as in the previous case and the same consideration count.

In the end, for each process, the investigation must be carried out by an authorised specialist institute and the parameters of the RBV can be used for classification. The respective use is made according to these quality classes, or prohibitions of use apply.

In Austria is possible to use natural aggregates in subordinate quantities as a mixing component with recycled aggregates for its the technical improvement, in particular to supplement the grading curve, in accordance with the prohibition mixing in accordance with section 15 (2 AWG 2002).

4.2.2 Italy

4.2.2.1 D. lgs n.152/2022 “Regulation governing the cessation of the waste status of inert construction and demolition waste and other inert waste of mineral origins”.

This recent Legislative Decree No. 152/2022 lays down specific environmental criteria in accordance with which inert construction and demolition waste ceased to be consider a waste and qualified as recovered aggregates. The inert waste from construction and demolition activities accepted, for the production of the recovered aggregates, consider only a part of the non-hazardous waste of the chapter 17 of the EU list of waste (LoW) as all subchapter 17 01 concrete, bricks, tiles and ceramic; the waste code 17 03 02 of the subchapter bituminous mixtures, coal tar and tarred products; the code 17 05 04 soil and stones and 17 05 08 track ballast don’t containing hazardous substances. And the 17 09 04 mixed waste from construction and demolition other than those mentioned in headings 170901, 170902 and 170903 (don’t containing hazardous substances). Only specified waste code can be allowed to enter the production process. The table describe the waste accepted at the plant entrance.

Table 17: Eligible waste code list in recycling plant

EU code	Description
17 01 01	Concrete
17 01 02	Bricks
17 01 03	Tiles and ceramics
17 01 07	Cement mixtures or slag, bricks, tiles and ceramics other than those mentioned in 170106
17 03 02	Bituminous mixtures don’t containing coal tar
17 05 04	Excavated earth and rock, other than those mentioned in 170503
17 05 08	Crushed stone for railway ballasts, other than that referred to in 170507
17 09 04	Mixed wastes from construction and demolition other than those mentioned in headings 170901, 170902 and 170903

Incoming waste, accepted for the production of recovered aggregates must by checked. To that end, the producer of recovered aggregate must have a system for checking the acceptance of waste. The system must ensure at least compliance with the following obligation:

examination of the documentation accompanying the loading of incoming data;
visual inspection of the incoming waste load;
weighing and recording of incoming waste loading data;
separate storage of waste that doesn’t comply with the criteria of the regulation in a separate area;
storage of compliance waste in the area dedicated exclusively to it which is structured in such a way as to prevent even accidental mixing with other types of waste not accepted
to additional checks including analytical checks;
on a sample basis or whenever the analysis of the documentation or the visual inspection indicates this need.The producer needs a the system also presupposes the preparation of a procedure for the management, traceability and reporting of non- conformities found.

For undertakings registered under Regulation (EC) No 1221/2009 of the European Parliament and of the Council, of 25 November 2009, and for companies in possession of the environmental certification UNI EN ISO 14001, the aforementioned system is integrated into the environmental management system.

Handling of waste sent to the production of recovered aggregates must be carries out by personnel with training and updating at least two years in order to prevent contamination of the same with other types of waste don’t accept.

The process of treatment and recovery of inert waste from construction and demolition activity takes place through mechanical and technologically interconnected phases as grinding, screening, particle size selection, separation of metal fraction and unwanted fractions, etc. The recovery process depends on the type of material entering the system, and it must allow compliance with the final EoW criteria. Adequate space, at the manufactured plant, must ensure for storage of aggregates during the conformity verification, and while waiting for transport to the site of use. Storage and handling at the producer are organize in such a way that the individual produced batches are not mixed.

The producer of recovered aggregates should have a quality management system in according to the UNI EN ISO 9001 standard capable to demonstrating compliance with the criteria set out in this regulation.

Recycled aggregates are sampled for conformity analysis according to UNI 10802 “Rifiuti - Campionamento manuale, preparazione del campione ed analisi degli eluati”.

Quality requirements for aggregates recovered is assessed by composition and by means of a release test, for each batches produced. The latter is not mandatory to those aggregates intended for the packaging of concrete referred to in UNI EN 12620 with resistance class Rck / leq ≥ 15 Mpa.

A batch portion represent a quantity not exceeding 3 000 m^3 of aggregate recovered.

Table 18: Total content

Parameters	Unit of measurement	Limit concentration
Asbestos	mg/Kg dry matter	100
AROMATIC HYDROCARBONS		
Benzene	mg/Kg dry matter	0.1
Ethylbenzene	mg/Kg dry matter	0.5
Styrene	mg/Kg dry matter	0.5
Toluene	mg/Kg dry matter	0.5
Xilene	mg/Kg dry matter	0.5
Aromatic organic summation (20 to 30)	mg/Kg dry matter	1
POLYCYCLIC HAROMATIC HYDROCARDONS		
Benzo(a)anthracene	mg/Kg dry matter	0.5
Benzo(a)pyrene	mg/Kg dry matter	0.1
Benzo(b)fluorantene	mg/Kg dry matter	0.5
Benzo(k)fluorantene	mg/Kg dry matter	0.5

Benzo(g,h,i)perilene	mg/Kg dry matter	0.1
Crisene	mg/Kg dry matter	5
Dibenzo(a, e) pyrene	mg/Kg dry matter	0.1
Dibenzo(a,l) pyrene	mg/Kg dry matter	0.1
Dibenzo(a, i) pirene	mg/Kg dry matter	0.1
Dibenzo(a, h) pirene	mg/Kg dry matter	0.1
Dibenzo(a,h)anrtacene	mg/Kg dry matter	0.1
Indenopirene	mg/Kg dry matter	0.1
Pirene	mg/Kg dry matter	5
Polycyclic aromatics summation (25 to 34)	mg/Kg dry matter	10
Phenol	mg/Kg dry matter	1
PCB	mg/Kg dry matter	0.06
C>12	mg/Kg dry matter	50
Cr VI	mg/Kg dry matter	2
Floating materials	cm^3/Kg	<5
Foreign fraction	% by weight	<1%

Table 19: Leachate limit values.

Parameters	Unit of measurement	Limit concentrations
Nitrates	mg/l	50
Fluorides	mg/l	1.5
Cyanides	µg/l	50
Ba	mg/l	1
Cu	mg/l	0,05
Zn	mg/l	3
Be	µg/l	10
Co	µg/l	250
Ni	µg/l	10
V	µg/l	250
As	µg/l	50
Cd	µg/l	5
Total chromium	µg/l	50
Pd	µg/l	50
Se	µg/l	10
Hg	µg/l	1
COD	mg/l	30
Sulphates	mg/l	750
Chlorides	mg/l	750
pH		5.5-12,0

Composition test on the recovered aggregate is assessed for asbestos, Cr VI, C> 12. For the determination of asbestos, the officially recognized methodology for the whole national territory must be used.

Organic parameters are also checked for all BTEX, Styrene, aromatic organic summation (20 to 23), some Polycyclic aromatic hydrocarbons, summation of the polycycle aromatic from 25 to 34, and PCB.

Floating materials and foreign fraction should be searched where defined by applicable technical standards, otherwise must be checked.

Leaching test follows the method provided by UNI EN 12457-2. In cases where the sample to be analyzed has a very fine particle size should an ultracentrifuge (20000 *G)* be used for at least 10 minutes without proceeding to the natural sedimentation phase. Only after this phase can the next filtration phase be carried out according to point 5.2.2 of the UNI EN 12457-2 standards. The searching parameters are Nitrates, Fluorides, Cyanides, Sulphates, Chlorides and Be. COD and Ph; also, HM are tested ad exclusion of Al, Mn, Fe, Mo and Sb.

The legislation reports the technical reference standards for the specific use of the recovered aggregates in a certain manufacturing process, in Table 4 of the Annex 1; the compliance with those standards allows CE certification. The finished recovered aggregates shall be used, in accordance with the technical standards for:

- the realization of the body of embankments of civil engineering earthworks;
- the construction of road, railway, airport and civil and industrial yards;
- the construction of layers of foundation of transport infrastructures and civil and industrial yards;
- the realization of environmental recovery, filling and filling;
- the realization of accessory layers having, by way of example, anticapillare, antifreeze, draining function;
- the packaging of concretes and mixtures bound with hydraulic binders (such as, for example, cemented mixtures, batchable mixtures).

For all uses, with the exception of environmental recovery, filling and filling*,* the CE marking shall apply as provided for in Regulation (EU) No 305/2011 of the European Parliament and of the Council of 9 March 2011.

For the uses referred to mixtures bound with hydraulic binder, Cement and cement-containing preparations may not be marketed or used if they contain, when mixed with water, more than 0.0002 % of water-soluble chromium VI on the total dry weight of the cement (Regolamento CE n. 1907/2006 del Parlamento Europeo e del Consiglio.

Compliance with criteria to reach EoW is certified by the producer of aggregate recovered by mean of a declaration draw up for each batch of recovered aggregate produced. The declaration must send to the competent authority and to the territorially competent Regional Environmental Protection Agency. In the DDC for each batch of recovered aggregates a composition by volume is requested and the purpose of use.

4.2.2.2 DM n.69/2018

This legislation regulates the EoW of conglomerate bituminous. Set the use of the granulate of conglomerate bitumen. At the end of the productivity process for each batch certificate of quality compliance with the end-of -waste criteria. The certificate must be sent to the competent authority and the Environmental and land protection agency. The Italian regulation n.69/2018 governs the cessation of waste status (end of Waste) of bituminous conglomerate. The only acceptable mineral CDW research the EoW status is the one under the European waste code n. 17 03 02, coming from the demolition of bituminous conglomerates and from cold milling operations of pavement layers made of bituminous conglomerate.

Table 20: Admissible kind of bituminous conglomerate.

EU code	Description	Restriction
17 03 02	Bituminous mixtures other than those mentioned in 17 03 01	Coming from: the demolition of bituminous conglomerate pavements or from cold milling operations of pavement layers made of bituminous conglomerate

Bituminous conglomerates reach the EoW status, and it is classified as granulate of conglomerate bitumen if it meets the technical standards laid down in UNI EN 13108-8 (series 1-7) or UNI EN 13242 depending on the specific intended purpose, meaning that it complies the appropriate technical standard, and the recycled material fully satisfied environmental test limit values on composition and leachate test.

Sample are gained for the environmental test of bituminous conglomerate on composition and realise test following the sampling method UNI 10802, with a frequency of sampling of 1 sample every 3 000 m^3, the quantitative of a batch.

Parameters to searching for composition test are asbestos and the sum of the following PAHs: benzo (a) anthracene, benzo (a) pyrene, benzo (b) fluoranthene, benzo (k) fluoranthene, benzo (g,h,I) perylene, chrysene, dibenzo (a,e) pyrene, dibenzo (a,l) pyrene, dibenzo (a,i) pyrene, dibenzo (a,h) pyrene, dibenzo (a,h) anthracene. The methodology officially used at national level must be used for chemical determination.

For release behaviour, compliance test according to the method prescribed by UNI EN 12457-2. Only in cases where the sample to be analysed has a very fine particle size, an ultracentrifuge (20000 G) must be used, without proceeding to the natural sedimentation step, for at least 10 minutes. Only after this phase can one proceed to the subsequent filtration phase as described in point 5.2.2 of standard UNI EN 12457-2.

The parameter to looking for are nitrates, fluorides, cyanides, chlorides, sulphates, Be, COD and heavy metals excluding Al, Mn, Fe, Mo, Sb.

Table 21: Substance to be analysed

Parameter	Unit of measure	Concentration limit
Sum PAH	mg/Kg	100
Asbestos	g/Kg	1000

Table 22: Total concentration limit values.

Parameter	Unit of measure	Concentration limit
Nitrates	mg/l NO_3	50
Fluorides	mg/l F	1.5
Sulphates	mg/l SO_4	250
Chlorides	mg/l Cl	100

Cyanides	µg/l Cn	50
Ba	mg/l	1
Cu	mg/l	0.05
Zn	µg/l	3
Be	µg/l	10
Co	mg/l	250
Ni	µg/l	10
V	µg/l	250
As	µg/l	50
Cd	µg/l	5
Total chromium	µg/l Cr	50
Pb	µg/l	50
Se	µg/l	10
Hg	µg/l	1
COD	mg/l	30

Also, the Presence of foreign matter are analysed and should be at max 1% by mass, therefore it should be reclaimed asphalt of category F1. The number of samples for the determination of foreign materials is described in the EN UNI 13108-8. The content of foreign matter shall determine according to EN 12697-42 (7). Foreign matter comprises materials others then natural aggregates, not derived from asphalt and is describes and subdivided in two groups as: group 1: cement concrete, including cement concrete products; bricks; subbase material (excluding natural aggregate); cement mortar; metal; group 2: synthetic materials; wood; plastics.

The specific uses of application of the granulate of conglomerate bitumen are defined in the regulation:

for bituminous mixtures produced with a hot mixing system in accordance with UNI En 13108 (1-7

or for bituminous mixtures produced with a cold mix system

for the production of aggregates for unbound and hydraulically bound materials for use in road construction, in accordance with the harmonised Uni En 13242 standard, excluding environmental recovery.

The Uni En 13108-8: 2016 standard specifies requirements for the description of reclaimed asphalt as a constituent material for asphalt mixtures. Infect the use of recycling in asphalt production make it necessary to specify reclaimed asphalt as a constituent material for asphalt production, after being tested, assessed, and classified according to this technical standard. Reclaimed asphalt (RA may be used as a constituent material for bituminous mixtures manufactured in an asphalt plant, in accordance with the specifications for those mixtures. In the asphalt production standards EN 13108-1 up to and including EN 13108-7 and EN 13108-9 the use of reclaimed asphalt is permitted with requirements related to the percentage addition (7. Since the requirements for the asphalt mixtures are the same for mixtures with and without reclaimed asphalt, a set of properties of the reclaimed asphalt are of importance. The particle size and properties of the aggregate, the binder content, the properties of the binder and foreign matter in the reclaimed asphalt are relevant to the quality of the product. The particle size of the RA shall be determined according to EN 933-1 and the number of samples to be testes according to UNI EN 13108-8. This European standard specifies the specific bituminous binders to be used with RA, such as: paving grade bitumen, modified bitumen or hard grade bitumen; and its content shall be determined according to EN 12697-1. A feedstock quantity shall be defined, and sampling shall be carried out on sample increments as defined in EN 932-1.

Reclaimed asphalt contaminated with coal tar or other additives or components above hazardous levels is not covered by this standard and will need to be considered under Member State Environmental, and Health and Safety Regulations.

For feedstock of reclaimed aspalth is intended a defined quality of reclaimed aspalth with declared properties, suitable and ready to be used as constituent material.

At the end of the productivity process for each batch a declaration of conformity is necessary. The certificate must be sent to the competent authority and the Environmental and land protection agency.

4.2.3 Comparison

The different approach for Italy and Austria on management of inert CDWs are summarized in Table 18.

Table 23: Comparative summary table regarding inert CDW management in Austria and Italy.

Member State	**Legislation on EoW criteria?**	**Input waste requirement?**	**Regulation on the use?**	**Permissible area of application?**	**Criteria on total content?**	**Criteria on leaching?**	**Material quality class**
Austria	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Italy	Yes	Yes	Yes	No	Yes	Yes	No

In both case in Austrian and Italy, the use of wase-derived aggregates is governed by waste legislation. Italy has produced a recent specific legislative decree for the acquisition of the title of EoW, in Austria a unique ordinance governs waste management and the seek of the EoW status. In stable recycling facility only permitted waste are accepted in entrance. Environmental criteria for the output material to be used are based on leaching behaviour of inorganic substances and the total content of organic and inorganic substances. Italy specified that the recycling plant authorized for this kind of recycling must have a quality management system in accordance with UNI EN ISO 9001.

In Austria the recycled building material of quality class U-A, the only class achieving the EoW status, may be freely used unbound without any kind of restrictions, as it is considered a product. The other class end to be defined as waste when handed by a third party, but there are some constrain on its area of applications. It should be noted that these criteria have been developed using pathway scenarios that take some degree of attenuation of realised substances into account (17. Meaning a reduction on concentrations of chemical species in the leachate by means of chemical, physical and biological reaction as it migrates trough a solid medium. Italy, on the other hand, does not divide products into quality classes, and all outputs that comply with the quality verification system obtain the EoW status and no restrictions exist on the area of application.

Austria imposes a list of quality classes of recycled material, based on the environmental compatibility of the recycled aggregates, which means that the parameters and limit values to be sought are less restrictive going down the list. Restrictions are placed on the use of recycled aggregates for each quality class, this restriction in the development of the limit values and substance to be regulated, those restriction can be taken into account in the development of limit values in the choosing of source and pathway scenario less conservative and lead to less stringent EoW limit values. Austria comparing to Italy have more than one set of substances threshold of leaching criteria, reflecting the different condition use.

By categorizing recycled aggregates into several classes, each with their own set of screening values, the methodology provides limits in accordance with the foreseen use of the aggregates. On the one hand, it is more flexible than a single set of strong but extremely rigorous "all-purpose" limits that most waste aggregates would not be able to fulfil and may therefore allow for more materials to be given end-of-waste status. On the other hand, once established, it provides for a simple approach to the wide variety of aggregate materials and applications that exist, always ensuring adequate protection of the environment and human health.

The fact that Austria impose conditions on use means that in the assessment principle based on source-pathway-receptor, leading to relatively low stringent leaching limit values; Italy instead apply stringent limit values because in the source-pathway-receptor a near worst case approach is required, leading to a relatively stringent leaching limit value. The adoption of certain limit values allows more moderate leaching values. Infect if no restriction on the use of recycled aggregates is placed the in the risk base approach the worst case should be considered, for the set of limit values.

Neither Austrian nor Italy set requirements on the taken back by the user/owner at the end of its service life, as for example Germany require in its soil quality decree.

The new Italian legislation on seek for EoW status, has set very stringent limit values, it must be monitored to take into account, where necessary, the evidence that emerged during the application phase. High limit values imply sufficient proof of absolute compliance with the criteria up front and effective subsequent quality control measures.

4.3 Sampling method Protocol

Obtaining a "representative" sample of the item to be tested is always the first step in evaluating waste materials or products. This sample should accurately reflect any differences in the overall quality of the sample. Making sure that the little sample of material that is ultimately examined is accurately representative of the community from which it was sampled is never easy.

Several sampling protocols and pre-treatment guidelines for recovery of aggregates have been developed by European standardisation committees CEN and product technical committees TC. The standard on sampling in the field and the connected Technical Reports provide the tools to define the scale of production for which the sampling is representative and the number of increments and samples to take (and how to take them) to get a result that is representative for the population with a certain reliability.

In general, every step of the process for carrying out an analytical environmental test is standardized, from planning the sampling to sampling in the field to formally transferring the sample to the lab. This includes subsampling in the lab for the preparation of the test portion and a second sampling domain for evaluating the analytical test results.

4.3.1 Austria

We have already analysed the quality system procedure adopted in Austria to ascertain environmental compatibility for recycled material environmental, now we are interested in standardized Austrian sampling methods to gain sample to test the material. In recycling plant in the scope of FPC all batches, corresponding to a production quantity of no more of a weekly production, must be analytically examined and evaluated separately. For third party check, the first batch produced (maximum 50 production hours, minimum quantity 200 t) must be sampled and chemically analytically exanimated. The frequency of this test is at least one a year. At least 10 samples, evenly distributed, shall be taken from the batch to be assessed and combined into a qualified sample (field sample). A field sample is a sample from which the laboratory sample is prepared for subsequent examination; the field sample may be either a single sample, a qualified sample or an aggregate sample. About the performance of sampling, the minimum sample quantity of a sample and the documentation of sampling, the requirements of ÖNORM EN 932-1 "Test methods for general properties of aggregates - Part 1: Sampling methods", issued on 1 January 1997, apply for both declaration and FPC. Instead, the environmental compatibility within the scope of the factory production check must be analytically proven for all batches (maximum 50 production hours) that are not examined as part of the declaration test. Austria as sampling method use the European standard, specified by the CEN product technical committee on aggregates, CEN/TC 154.

For direct installation (mobile treatment plant), individual batches of a recycled building material can also be tested for environmental compatibility within the specification of ÖNORM S 2127 "Basic characterization of waste heaps or solid waste from containers and transport vehicles", by an external authorised specialist or specialist institution with a maximum assessment scale of 500 t. The same analytical environmental criteria for secondary raw materials produced in recycling stationary facilities applies.

For the preparation of the test portions from the laboratory samples in laboratory are covered by the Eu standard, adopted also in Austria EN 15002:2015 “Characterization of waste - Preparation of test portions from the laboratory sample”.

As we mentioned above, in some cases it is necessary to use an alternative quality control method. Referring to reclaimed asphalt from dismantling or rehabilitation of traffic areas sampling by individual samples (e.g. drill cores, milling samples) and their analytical examination may be performed before the start of the demolition or milling activity (in-situ). The individual sample must be obtained at a point that is as representative as possible for the respective area, and the sampling must be carried out over the planned milling depth. If, on the basis of the optical/olfactory assessment of the drill cores before the analytical examination, different qualities are to be expected in the stratification, then these must also be analysed separately and also removed separately. For the examination of samples, the respective drill cores must be cut vertically in half (reserve sample), one half must be cut, broken and examined in the intended milling thickness, the other shall be conserved.

At maximum 1 elementary sample must be proved for an area of 2000 m^2; for project with a higher area each line must be sampled separately. Generally, for each project individual sample are pick up and analysed. In case of the following requirement a from individual samples a unique mixed collective sample is obtained.

- A maximum of five dismantling projects are combined into one collective sample,
- In total, no more than 20 000 m^2 are represented by the aggregate sample,
- Each of these dismantling projects is represented by at least two individual samples (e.g. one sample per lane) and
- No pollutant loads (especially tar) in the layer to be milled are known or were detected in the course of sampling.

In the case of federal highways, A and S, a sampling grid of a single sample per maximum 5 000 m^2 is sufficient if there is a corresponding homogeneity of the road structure.

Sampling planning, sampling, assessment and documentation must be carried out by an external authorised specialist or specialist institute. Each sampling of a single sample must be documented in a sampling protocol based on the sampling protocol, which must be signed on site by the sampler.

4.3.2 Italy

In the case of analytical characterisation of the waste on-site derived from a of selective demolition (to be attested by the producer by means of a declaration), since the waste can be considered homogeneous, the, analysis must be carried out on a sufficiently significant mass of waste (this analysis must be repeated every 3,000 cubic metres of waste produced for civil or commercial buildings and every 1,500 cubic metres for artisan and industrial buildings). In the case of non-selective demolition, since the waste cannot be considered homogeneous, the totality of waste produced shall be characterised analytically by batches of a maximum volume of 500 cubic metres for artisan or industrial buildings and 1000 cubic metres for civil or commercial buildings (SNPA De Bernardis, 2016). The sampling standard is UNI 10802: “Rifiuti - Campionamento manuale, preparazione del campione ed analisi degli eluate”. The norm explains how to define a sampling plan;

techniques for manual sampling of granular, coarse, monolithic wastes; procedures to reduce the size of waste samples taken in the field in order to facilitate their transport to the laboratory; sample size reduction procedures for laboratory analysis; - eluate preparation and analysis procedures and guidelines on the transport and storage of samples. The norm must be read in accordance with the European EN 14899: 2005 "Characterisation of waste – Sampling of waste materials – Framework for the preparation of a sampling plan".

The same sampling standard applies for gain a representative sample of a produced batch of recovered aggregate that reach EoW status to use in lab for analysis tests. In this case the frequency of sampling is 1 sample every 3000 m^3(Decreto Ministeriale Ambiente n. 69, 2018).

4.3.3 Comparison

Table 24: comparative sampling protocol between Austria and Italy.

Member State	**FPC**		**Mobile Plant**	
	Standard sampling	**Frequency**	**Standard sampling**	**Frequency**
Austria	EN 932-1	Weekly production	ONORM S 2127	Each batch at max 500 t
Italy	UNI 10802	3000 m^3	UNI 10802	1500 m^3

Austria adopts a FPC sampling protocol for recycled aggregates based as part of the product standards provided by CEN/TC 154 CEN product technical committee on aggregates, Italy instead standard for waste aggregates, produced from CEN/TC 292, characterisation of waste.

Austria makes use of different sampling procedure one for FPC and one for Mobile plant. In the context of recycling treatment plant an external quality certification is provided an authorized company; the first batch produced (> 200 t and < 50 production hours) must be sampled with the same national standard and analysed.

In case of is situ verification sampling methods in Italy remain the same but with a frequency of 1500 m^3. Austria make use of its National standard ONORM S 2127, for which each batch (max 500 t) is assessed.

4.4 Environmental testing analysis

Leaching tests must be used to assess the risks related to the release of chemicals from an aggregate and their subsequent transport in an aqueous phase. In order to compare the concentration of inorganic and organic compounds to current limit values associated to health risk, a standardized test procedure at the national level will also be needed.

The determination of inorganic and organic substances as content requires digestion/extraction methods and subsequent quantification by analytical methods. As for leaching test, exist a wide range of methods to assess content of harmful substances in the material to be tested. A possible method for determination of inorganic substances is aqua regia digestion followed by quantification using ICP-OES; for organic substances different separate methods are used for individual organic substances or substance groups, consisting on extraction, clean-up and quantification by GC-MS (JRC).

A hierarchical test structure has been designed based on a thorough initial characterisation, which serves as a guide for the future recurrent routine testing. This is done to make it easier to employ test techniques as part of legislative systems and prevent overly redundant testing. Due to their ability to compare the outcomes of various leaching tests with one another, several instruments can be utilized for the mutual comparison of leaching test data and regulatory leaching screening values. A statistical approach based on the calculation of a so-called k-value is used with the purpose of assessing the compliance of test results with test limit values.

The test should be reproducible by different technician/workers; must has adequate accuracy e.g. balance accuracy, and the test procedure of execution well defined.

At European level some problems exist in the evaluation of PCB content. For the organic compounds defines as Polychlorinated biphenyls (PCB) EU legislation does not provide any detailed definition on its limit values in waste. In the Regulation (EC) No. 850/2004 of the European Parliament and of the Council on persistent organic pollutants as regards Annexes IV and V" – "the POP Regulation" and its amendment there is a reference to the measurement content of PCBs, the EN 12766-1 and EN 12766-2. The two methods apply different determination method the first: determine all congeners analytically and sum them; the second determine the sum of 6 congeners PCB 28, 52, 101, 153, 138 and 180 and multiply the result by 5 to get an estimate of the total content of PCB. If we consider also the Council Decision 2003/33/EC on criteria and procedures for acceptance of waste at landfills, things get even more confusing, it specifies under limit values on content of PCB only "polychlorinated biphenyls, 7 congeners" and a limit values, not mentioning any factor to the estimation of the total content, and not being clear on what parameter the limit apply. Therore for this substance it is not easy to have a term of reference.

4.4.2 Austria

Quality assurance with regard to environmental compatibility of recycled building material is detected by leaching test and total content analysis. With regard to digestion, leaching and determination methods for chemical-analytical analysis standardized standard apply.

To detect leaching behaviour or recycled materials in Austria is used the standard ÖNORM EN 12457-4 "Characterization of wastes – Leaching – Compliance test for leaching of granular wastes and sludges – Part 4: Single-stage shaking method with a liquid/solids ratio of 10 l/kg for materials with a grain size of less than 10 mm (with or without grain size reduction)". Crushing shall be carried out if it is necessary for sampling or testing, or if the grain size of the waste is greater than 10 mm, as request by the specification. Waste must not be ground. This European standard has been developed to investigate mainly inorganic constituents from waste, it does not take into account the particular characteristics of organic substances. This test procedure specified procedure an eluate which shall subsequently be characterised physically and chemically according to appropriate standard methods.

ÖNORM S 2117 "Preparation of an eluate from unground waste samples with a grain size of less than 10 mm for the investigation of aquatic ecotoxicity and organic parameters" applied for the determination of organic parameters in the eluate deriving leachate test. To avoid the need to perform tests on two different eluates the same eluate deriving from the leaching test EN 12457-4 is used for organic parameter determination. This standard report the preparation of test mixture for the ecotoxicological tests. The same standard applies for organic total content determination.

For total content determination of inorganic substances, the following standard applies ÖNORM EN 13657 "Characterization of wastes – Digestion for the subsequent determination of the fraction of elements in wastes soluble in aqua regia". This standard specifies methods of digestion with aqua regia. Solution produced by the methods are suitable to be analysed.

For chemical analysis determination method according with the state of the art are used. EU proposed methods are atomic absorption spectrometry (FLAAS, HGAAS, CVAAS, GFAAS), inductively coupled plasma emission spectrometry (ICP-OES) and inductive coupled plasma mass spectrometry (ICP-MS).

The floating materials, glass and other materials shall be determined in accordance with the state of the art.

For some recycled building material quality is assured before the start of the excavation by authorised specialist or externa specialised institution. Quality assurance for recycled building materials made of track ballast material and technical bulk material from the substructure of track structures can be carried out by means of a basic characterisation in accordance with ÖNORM S 2126 "Basic characterization of excavated material before the start of excavation or clearing activity". According to this standard each defined excavation areas should be separately characterized. The chemical investigation must be done for the scope of the quality class U-E the sample must be conform with all parameters limit values. In case the limit values of quality class U-E are complied with, if another quality class is also complied with, the investigated mass can be assigned to this other quality class.

Quality assurance for recycled building materials made of technical bulk material can also be carried out before clearance activities as a basic characterisation in accordance with the same standard ÖNORM S 2126. For the initial investigation according to ÖNORM S 2126, the following table in Annex 4 Part 2 Chapter 1.2 DVO 2008 defines the maximum assessment scale, the minimum number of qualified samples to be obtained, depending on the respective excavation category. And the same consideration applies (U-E class research).

4.4.3Italy

For total content determination the standard UNI 10802 applies for eluate preparation and the nation recognise methodologies applied for the chemical determination.

Leaching test method follow the standard UNI EN 12457-2: “Caratterizzazione dei rifiuti - Lisciviazione - Prova di conformità per la lisciviazione di rifiuti granulari e di fanghi - Parte 2: Prova a singolo stadio, con un rapporto liquido/solido di 10 l/kg, per materiali con particelle di dimensioni minori di 4 mm (con o senza riduzione delle dimensioni)”. In cases where the sample to be analysed has a very fine particle size should an ultracentrifuge (20000 *G)* be used for at least 10 minutes without proceeding to the natural sedimentation phase. Only after this phase can the next filtration phase be carried out according to point 5.2.2 of the UNI EN 12457-2 standard (JRC).

In the Ministerial Decree n. 69, 2018 the procedure for the preparation of eluate for IPA and asbestos analysis is UNI 10802. For the determination method look the state of the art.

4.4.4 Comparison

Table 25: Comparison standardised test methods for leaching behaviour and total content composition.

Member state	Standard composition test	Standard leching test
Austria	EN 13657 ONORM S 2117	EN 12457-4 (L/S = 10 l/kg) ONORM S 2117
Italy	UNI 10802	EN 12457-2 (L/S=10 l/kg)

Austria and Italy for leachate test both use a batch leaching test methodology submitted by the European Community the EN 12457; a one stage batch test at liquid to solid ratio of 10 l/Kg Austrian for materials with particle size below 10 mm, Italy for materials with particle size below 4 mm. This European standard specifies a compliance test providing information on leaching of granular waste material. Leaching limit values for Italy are express under eluate concentration, for Austria as substance realised for Kg of granular material.

Austria for determination of organic parameters in eluate adopt its own national methodology the ONORM S 2117. The main reason for this is that whereas there are standardised and well proven leaching tests for inorganic substances at EU level, leaching tests for organic substances are much less developed, and at present, the experience with leaching tests for organic substances is probably not sufficient for these to be applied in general to regulatory systems.

For total content assessment Austria use a standard EN 13657 for inorganic substance, the ONORM S 2117 for organics. Italy adopts the standard 10802.

5 Discussion and recommendations

The safe recirculation of secondary raw materials implies a decrease in the exploitation of natural resources; to this end, it is necessary to develop environmental quality certificates for materials that prove the protection of the environment and human health. The establishment of environmental criteria in the reuse of recycled aggregates should be scientific base, transparent and traceable process. Stakeholders must also be consulted frequently, and their needs taken into account. Stakeholders can offer suggestions for the choice of use scenarios, but regulatory decisions on environmental protection standards should be made in cooperation with environmental specialists.

Under circular economy concept, the aim is to close high-quality material cycles. If raw materials are to be used in several cycles, significant quantities of pollutants will have to be removed. Preventing contamination due to excessive recovery initiatives is a central concern. The challenge lies in determining the degree of acceptable impurities with no higher environmental impact (compared to the primary raw materials). The precautionary principle ranks above the conservation of resources.

It is therefore necessary to impose quality limits for responsible use in a circular economy. On the other hand, quality limits must be proven to be met. Screening values must be cautious but at the same time allow the industry to function. A single classification of recycled aggregates, and thus a single list of limit values, provides a simpler approach to the wide variety of existing aggregate materials and applications. By dividing recycled aggregates into different quality classes, different limit values are assigned according to the preferred application of each class. It is thus more flexible than a single set of strong but extremely strict 'all-purpose' limits that most waste aggregates would not be able to meet. A classification of aggregates may therefore allow more materials to be given final waste status. Compliance tests for leaching behaviour and total content allow to evaluate if the desired waste can be reused in the construction.

It is also important to regulate the previous phase to the generation of waste and their management before entering the treatment plants. The quality at the entrance to the material treatment plants to have a good output material must be high. To obtain high quality materials result effective a pre demolition audit, a demolition and waste management plan that includes a selective demolition, a on-site collection of the different types of material. Improving the quality of waste promotes the acceptance of secondary materials among construction companies and a more intensive circular economy.

Italy and Austria can be considered two leading countries in the management of inert CDWs, as they satisfactorily exceed the European targets on the recovery of such waste. In view of future changes and new European targets for material recovery, new legislative and economic instruments are needed to promote the flow of these materials in a circular economy.

We can observe how the two countries have a solid legislative framework especially for the status of EoW, in Austria the use of the selective demolition process as a basis for recovery activities is mandatory, in Italy it is indispensable to win tenders.

At the legislative level, re-use should be wider in terms of reused materials and require a specific regulatory section for those materials that retain their full value.

6 Conclusion

Recycling rate can be high only if EoW criteria will be fulfil. This work if the transformation capacity matches the local demand, and the final product is economically competitive with the respect of first raw materials. Encouraging the adoption of recycled products through quality certificates and/or waste end criteria, may increase the confidence of companies on these materials. Manufacturing of roadbed, asphalt, concrete, composite materials, and creation of civil engineering structures are common EOW.

Circular economy in the narrow sense of multiple recirculation requires high-quality waste. Single-origin fractions are comparatively easy to recycle, so preferable. Lower grades can, however, be fed at best into downcycling, although the number of useful recycling loops will inevitably be fewer. This is why pre-demolition investigation, selective demolition and separate collection on site play a central role in the management of such waste. All regulatory basis for a proper high-quality management of this strategic flow, and the correct dissemination and application of GPP in the construction sector seem to have been developed. However, to date the use of recycled aggregates in the construction sector is not able to close the material loop, as many recycled materials are used in infrastructure works. The proposed low-quality recycling powering the expansion of city and land use, producing all the negative effect of urbanisation. A change in the choice of materials could lead to make cities less climate altering.

Major technological developments in this area are expected as more complex products and new composite materials leading to greater diversity and less concentration in individual groups of substances. From a logistical and technical point of view, this trend results in huge challenges when it comes to recovering materials. Further research will be required.

Design for high-quality recycling, easy handling, reuse and long-lasting building structure should be encouraged.

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