Management of ashes from WtE: the path to the EoW status through an integrated approach

September 2024

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European regulatory framework for «End of Waste»

European production and recovery opportunities

Waste-to-Energy in Europe 2020

- WtE plants operating in Europe (not including hazardous waste incineraton plants): 504
- Waste thermally treated in WtE plants (in million tonnes): 101

Data supplied by CEWEP members and national sources; * icludes plant in Andorra and SAICA plant

CEWEP Confederation of European Waste-to-Energy Plants

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Focus on End of Waste status at european level

European production and recovery opportunities

- In 2020, around 101 million tonnes of waste (municipal, commercial and industrial) were treated in waste-to-energy plants in Europe.
- The combustion process produced about 20 million tons of bottom ash, which is the residual non-combustible part of the incinerated waste. Significant amounts of metals and minerals are present in these residues and offer many opportunities for recycling.
- After the metal is recovered, the bottom ash is stable and suitable for use and can be used to build roads or serve as aggregate for concrete.
- Many European countries use bottom ash as an alternative to virgin material such as gravel and sand.

20 million tons of bottom ash correspond to about 20% of the weight of waste treated in the plants. These are composed of

Mineral fraction
80-85%

Ferrous Metals
10-12%

Non-ferrous metals
2-5%
(of which 2/3 of aluminum))

Benefits of bottom ash recovery:

Iron recovery
An amount of iron equal to about 26 cruise ships can be recovered from European bottom ash

Aluminum recovery
In 2014, 17,000 tons were recovered in the Netherlands, which was mainly used in the automotive industry (engine block, etc.).

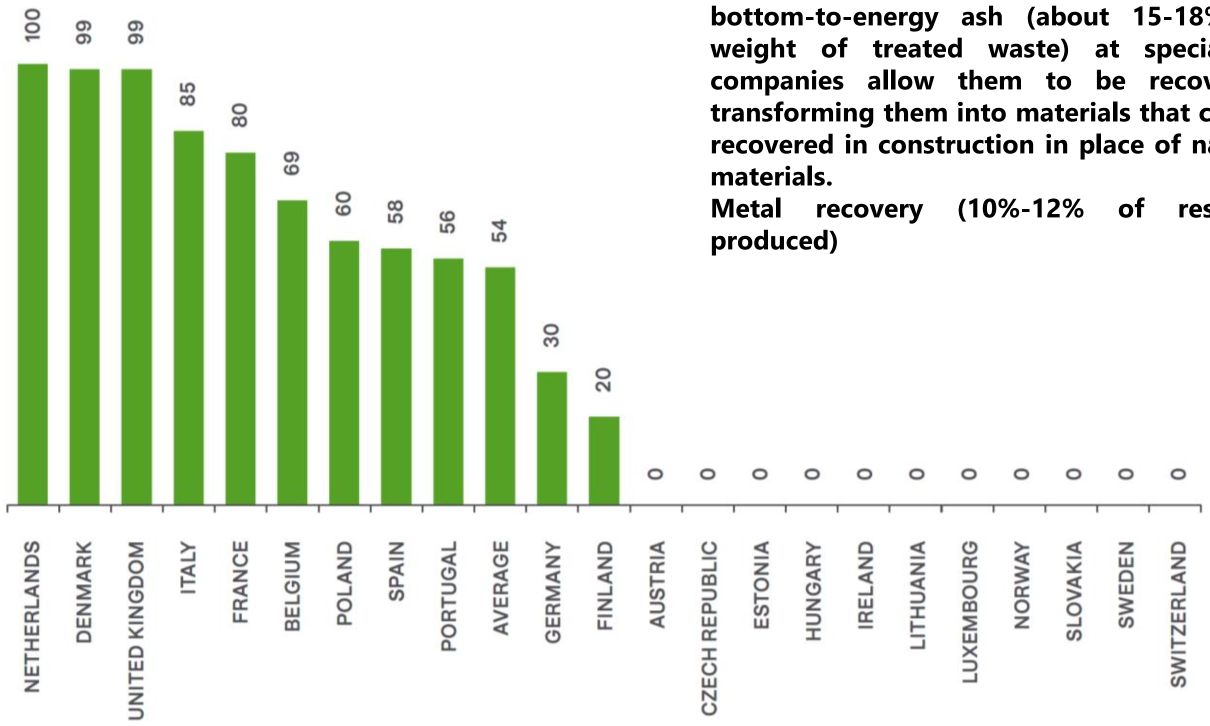
Reduction of CO_2 emissions
The recycling of metal avoids the emission of 3.9 million tons of CO_2eq

Using the non-ferrous component for the production of building materials

Bottom ash

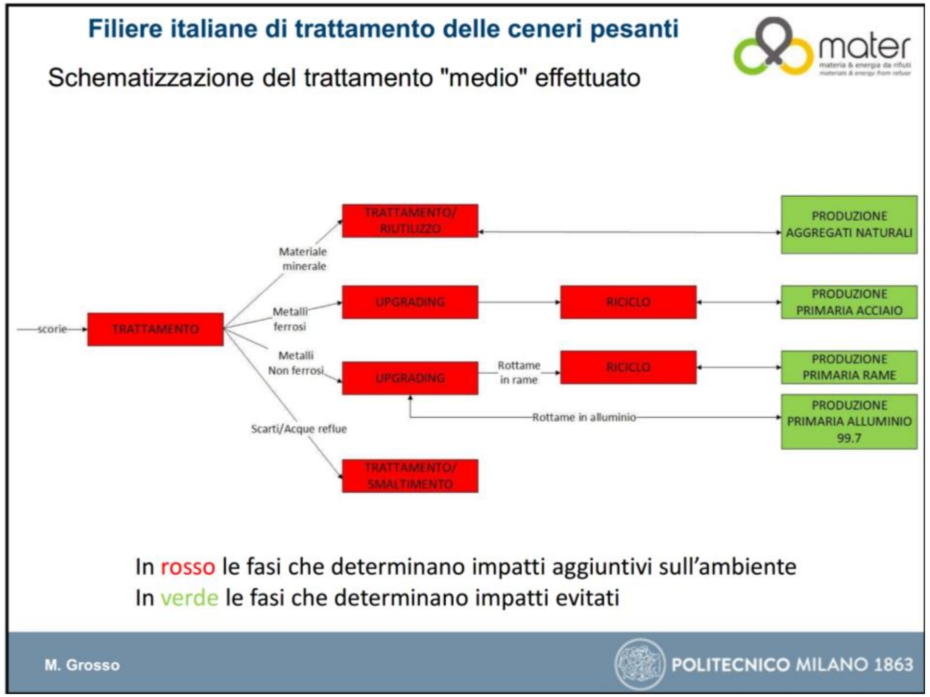
Residual waste from waste to energy treatment

The bottom ash is sent to recovery processes that allow new material to be obtained for traditional industrial processes: typically the treatments are mechanical for the selection and screening of the ash.



BOTOM ASH

Modern technologies for the treatment of bottom-to-energy ash (about 15-18% by weight of treated waste) at specialized companies allow them to be recovered, transforming them into materials that can be recovered in construction in place of natural materials.
Metal recovery (10%-12% of residues produced)



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Bottom ash

Residual from waste to energy

From the treatment of bottom ash, metals remain useful for subsequent reuse in the steel industries

MATERIALI FERROSI

INOX

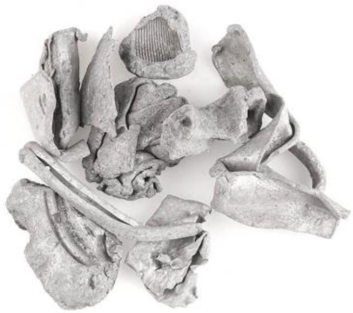
FERRO PROLER

OTTONE

RAME

ZAMA

ALLUMINIO GRANULARE



ALLUMINIO

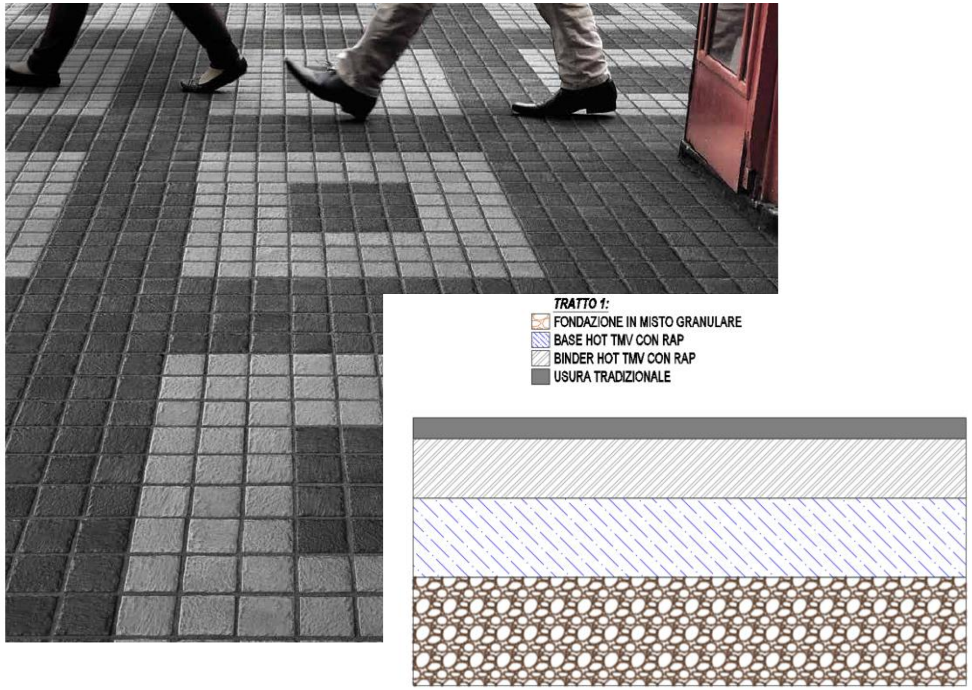
Bottom ash

Residual from waste to energy treatment

Mineral fraction and its uses.

The mineral fractions, based on their grain size, can be valuable in the replacement of aggregates and sands for use in concrete, bitumen, cemented (granular) mixtures, mortars and mixtures for the production of ceramics.

Scenario	Prodotto primario evitato	Additivo/prodotto di cui è richiesta l'aggiunta	Rapporto di sostituzione
Cemento	marna	calcare	1 : 3,2 in massa[a]
Calcestruzzo	ghiaia	-	1 : 1 in massa
Conglomerato bituminoso	sabbia	-	1 : 1 in massa
Strada	caso A (fondazione): ghiaia caso B (sottofondo): mistone naturale	cemento	1: 1 in massa[b]
Ceramica	Argilla	Argilla	30%



Focus on End of Waste status at european level

European Directive 2008/98 and amendment of 30/05/2018 : art. 6 "End of waste status"

1. Certain specific waste shall cease to be such within the meaning of Article 3(1) when it undergoes a recovery operation, including recycling, and meets specific criteria to be developed in accordance with the following conditions:
2. the substance or object is commonly used for specific purposes;
3. there is a market or demand for that substance or object;
4. the substance or object meets the technical requirements for the specific purposes and complies with existing legislation and standards applicable to products; and
5. The use of the substance or object will not lead to overall negative impacts on the environment or human health. The criteria shall include, where necessary, limit values for pollutants and shall take into account all possible adverse effects on the environment of the substance or object.
6. Measures designed to amend non-essential elements of this Directive by supplementing it, which relate to the adoption of the criteria referred to in paragraph 1 and specify the type of waste to which those criteria apply, shall be adopted in accordance with the regulatory procedure with scrutiny referred to in Article 39(2). Criteria for defining when end-of-waste should be considered, among others, at least for aggregates, paper and glass waste, metals, tyres and textile waste.

Member States shall take appropriate measures to ensure that waste that has undergone a recycling or other recovery operation ceases to be considered as waste if it fulfils the following conditions: (a) the substance or object is intended to be used for specific purposes;' '2. The Commission shall monitor the evolution of national end-of-waste criteria in the Member States and assess the need to develop criteria at Union level on that basis. To that end and where appropriate, the Commission shall adopt implementing acts to establish detailed criteria on the uniform application of the conditions set out in paragraph 1 to certain types of waste. These detailed criteria ensure a high level of protection of the environment and human health and facilitate the prudent and rational use of natural resources. They include: (a) incoming waste materials eligible for the recovery operation; b) permitted processing processes and techniques; (c) quality criteria for end-of-waste materials from the recovery operation in line with applicable product standards, including limit values for pollutants, where necessary; (d) requirements for management systems to demonstrate compliance with end-of-waste criteria, including quality control, self-monitoring and accreditation, where applicable; and (e) a requirement relating to the declaration of conformity. Those implementing acts shall be adopted in accordance with the examination procedure referred to in Article 39(2). When adopting those implementing acts, the Commission shall take into account the relevant criteria established by the Member States pursuant to paragraph 3 and shall adopt as a starting point the most stringent and environmentally protective criteria. 3. Where no Union-wide criteria have been established pursuant to paragraph 2, Member States may establish detailed criteria on the application of the conditions set out in paragraph 1 to certain types of waste. Those detailed criteria shall take into account all possible adverse effects on the environment and human health of the substance or object and shall meet the requirements set out in points (a) to (e) of paragraph 2. Member States shall notify those criteria to the Commission pursuant to Directive (EU) 2015/1535 where the latter so requires.

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Focus on End of Waste status at european level

European regulatory framework and in the various member states

Table 2
Overview on number and incineration capacity of MSWI plants, annually generated amount of IBA in the observed countries, information if utilisation is permitted and practiced, how much MIBA is utilised, respective documents regulating the utilisation of MIBA in the observed countries, type of legal document and references. (–)…no data available.

Country	MSWI plants No [–]	MSWI plants Capacity [Mt/a]	IBA mass [Mt/a]	MIBA utilisation permitted	MIBA utilisation practised	MIBA utilisation rate outside landfills [wt.%]	Reference for utilisation rates	Original title of document regulating MIBA utilisation outside of landfills	Type	Reference for documents
Austria	11	2.6	0.53	yes	no	0	(Republic of Austria, 2017a)	Bundesabfallwirtschaftsplan 2017; Technische Grundlagen für den Einsatz von Abfällen als Ersatzrohstoffe in Anlagen zur Zementerzeugung	guidance	(Republic of Austria, 2017a, b)
Belgium	15	3.3	0.47	Flanders: yes; Wallonia: yes (mandatory); Brussels capital region: not regulated	yes	69	(Bogush, 2018)	VLAREMA-2012 (Flanders); Arrêté du Gouvernement wallon, 14/06/2001 (Wallonia)	legislation	(Flemish Government, 2012; Government of Wallonia, 2001)
Czech Republic	4	0.65	0.2	yes	no	0	(Šyc, 2018)	Vyhláška č. 294/2005 Sb.	legislation	(Czech Republic, 2005)
Denmark	24	3.7	0.6	yes	yes	99	(Hykš, 2016)	Order N.1672 (2016)	legislation	(Kingdom of Denmark, 2016)
Estonia	1	0.25	0.058	not regulated	–	0	–	–	–	–
Finland	9	1.6	0.3	yes	yes	20	(Rantsi, 2018)	Government Decree on the Recovery of Certain Wastes in Earth Construction (843/2017)	legislation	(Government of Finland, 2017)
France	126	14.7	2.9	yes	yes	80	(Tegelbeckers et al., 2015)	Arrêté du 18 novembre 2011 relatif au recyclage en technique routière des mâchefers d'incinération de déchets non dangereux NOR: DEVP1131516A	legislation	(French Republic, 2011)
Germany	68	19.8	4.8	yes	yes	30	(Alwast and Riemann, 2010; Mesters, 2018)	LAGA M19 (annex 6) and LAGA M20 (for leachates)	guidance	(LAGA, 1994, 1995)
Hungary	1	0.42	0.12	not regulated	no	0	–	–	–	–
Ireland	2	0.8	0.14	not regulated	no	0 (partial export)	–	–	–	–
Italy	39	6.1	1.03	yes	yes	85	(Utilitalia, 2019)	Decreto 5 febbraio 1998 including its amendment Decreto 5 aprile 2006, n. 186	legislation	(Italian Republic, 1998, 2006)
Lithuania	1	0.28	0.075	yes	no	0	–	Įsakymas 2016 November 25 No. D1-805	legislation	(Lithuanian Government, 2016)
Luxembourg	1	0.17	0.028	not regulated	no	0 (full export)	–	–	–	–
Netherlands	12	7.6	1.9	yes (mandatory)	yes	100	(Born, 2018)	Regeling van 13 december 2007, nr. DJZ2007124397, houdende regels voor de uitvoering van de kwaliteit van de bodem (Regeling bodemkwaliteit)	legislation	(Government of the Netherlands, 2007)
Norway	18	1.8	0.25	not permitted	no	0	–	–	–	–
Poland	6	0.97	0.21	yes	yes	60	(Pająk, 2019)	Poz. 796 – Rozporzadzenie Ministra Środowiska z dnia 11 maja 2015 r. w sprawie odzysku odpadów poza instalacjami i urządzeniami	legislation	(Republic of Poland, 2015)
Portugal	4	1.3	0.22	yes	yes	56	(Valorsul, 2017)	Individual permit issued by independent national body (LNEC – Laboratório Nacional de Engenharia Civil))	individual permit	(Valorsul, 2017)
Slovakia	2	0.29	0.062	not regulated	no	0	–	–	–	–
Spain	10	2.4	0.44	Catalonia: yes; Rest of Spain: not regulated	yes	58	(Chimenos, 2018)	Ordre de 15 de febrer de 1996 (Catalonia)	legislation	(Generalitat de Catalunya, 1995)
Sweden	34	5.4	0.99	yes	no	0	(Fagerqvist, 2019; Van Praagh et al., 2018)	Återvinning av avfall i anläggningsarbeten Handbok	guidance	(Naturvårdsverket, 2010)
Switzerland	30	3.7	0.82	yes	no	0	(Holm and Simon, 2017)	Verordnung über die Vermeidung und Entsorgung von Abfällen (VVEA)	legislation	(Swiss Federal Council, 2015)
United Kingdom	45	12	1.5	yes	yes	99	(Lederer et al., 2018)	Guidance – Use of unbound municipal Incinerator Bottom Ash Aggregate (IBAA) in construction activities: RPS 206	guidance	(United Kingdom, 2019)
Total	463	90	17.6	16	11	54 (or 9.6 Mt/a)	–	–	–	–

D. Blasenbauer et al. / Waste Management 102 (2020) 868–883

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Focus on End of Waste status at european level

European regulatory framework and in the various member states

1

In Denmark, legislation has allowed the use of bottom ash in road construction for many years and increased the scope of its use for high-load roads in 2012. About 99% of the bottom ash produced in the country is recovered

2

In Switzerland, the finest fraction of bottom ash is used as a substitute for cement in the stabilization of fly ash.

3

In the Netherlands and Germany, bottom ash aggregates are also used in the construction of roads, motorway overpasses and noise barriers (they were the main material for the construction of more than 1 km of noise barrier along the A12 motorway in the Netherlands.)

.

Bottom ash aggregate is also present in road construction in Belgium, France, Portugal, the United Kingdom and Spain.

Focus on End of Waste status at european level

Case studies in some countries

- In the United Kingdom, the bottom ash aggregate was part of the construction of infrastructure for the London Olympics in 2012.
- In the Olympic village of Stratford, 30,000 tons of bottom ash were used:
- 2,000 tons as infill for structure and cover for flooring
- 5,000 tons as a sub-base for the expansion of the Excel Exhibition and Convention Centre car park, which hosted various competitions during the games

Focus on End of Waste status at european level

Case studies in some countries

- In the Netherlands, all waste-to-energy plant operators have signed a "Green Deal Bottom Ash" with the Dutch government. The main elements of this agreement:
- more than 75% recovery of all non-ferrous metals > 6 mm present in bottom ash
- From 2020 onwards, the granules must be so clean that they can be applied 100% for useful purposes
- With this green deal, which is a good example of a public-private partnership, the Dutch government and operators commit to turning bottom ash into a clean and 100% applicable secondary building material that can be used in the construction of roads, bridge and overpass embankments, sound walls or as a clean bottom ash granulate in concrete products such as bricks, curbs, etc.

Focus on End of Waste status at italian level

Italian production and recovery opportunities

- In 2020 in Italy – in waste-to-energy plants – about 6.24 million tons of waste (urban, commercial and industrial) were treated.
- The combustion process produced about 1.2 million tons of bottom ash, which were recovered mainly at activities authorized with IEA or, in some cases, with simplified procedures pursuant to Ministerial Decree 05/02/98.

- In Italy, the treatment of bottom ash takes place in medium-large plants located mainly in Lombardy and Emilia-Romagna, where the main waste-to-energy plants are concentrated.
- Among the main companies are RMB and Officina dell'Ambiente, which have been active in the sector for a long time now, characterized by a very strong treatment and oriented, in the first case, to maximize the recovery of metals, in the second to the enhancement of inert components. Of particular interest for the latter is the production of materials with numerous product certifications, not only of a performance type (Declaration Of Performance – DOP) but also environmental (Environmental Product Declaration – EPD), which allow an adequate enhancement even within sustainable building schemes (e.g. LEEDS certification), in terms of rewards for the use of recycled materials.

Focus on End of Waste status at italian level

Italian production and recovery opportunities

In the absence of specific criteria adopted through European regulations or national decrees, the authorizations for carrying out recovery operations (referred to in art. 208 – Single authorization for new waste disposal and recovery plants – and in Title III bis – Integrated Environmental Authorization – of Legislative Decree 152/2006) must be issued or renewed in compliance with the conditions established by art. 6 of Directive 2008/98/EC and on the basis of detailed criteria defined in the context of the same authorisation procedures, subject to the mandatory and binding opinion of ISPRA, if national permit or the territorially competent authority (Regione, Provincia) with the commitment of the local ARPA agency

In order for the competent authority to issue the authorisation to carry out recovery operations, the applicant must prepare a waste processing project that – recalling specific technical regulations and standards – certifies the efficiency of the recovery operations, i.e. the actual production of recovered products, according to the commercial characteristics of the market.
The reference parameters for the proceeding authority are represented by existing technical norms and standards and, in particular, by the UNI technical standards, technical documents which, although of voluntary application, constitute certain references for operators

Focus on End of Waste status at italian level

Italian production and recovery opportunities

- The regulatory references to be identified and applied in the field of end-of-waste status are not so much constituted by the legislation in force on the recovery of waste (with the ordinary procedure or through simplified procedures referred to in Ministerial Decrees 5 February 1998 and 12 June 2002, no. 161), but by specific technical standards that identify the minimum requirements and technical standards that the products deriving from recovery operations other than those codified in the two before mentioned decrees **BUT**

in fact, in several cases, in the absence of precise indications at national level, the local authorities have referred to the conditions set out in Ministerial Decree 05/02/98 "Identification of non-hazardous waste subject to simplified recovery procedures pursuant to articles 31 and 33 of Legislative Decree no. 22 of 5 February 1997", applying a criterion of end-of-waste status, most of the time simplistic and inadequate for the treatment activities authorized in the ordinary procedure (elution test referred to in Annex 3 of the Ministerial Decree 05/02/98, created at the end of the 90s to obviate the need to include a minimum analytical evaluation criterion in the context of the simplified authorization procedure)

Focus on End of Waste status at italian level

Italian production and recovery opportunities

01

Confusion

The lack of complete legislative clarity generates delays in the procedures for issuing/amending authorizations with the inclusion of criteria that are sometimes inadequate

02

Insecurity

Insecurity of the authorities for issuing EoW authorizations (both on a case-by-case basis for related to known supply chains), also given the possible criminal implications in the event of errors.

03

Uncertainty

Uncertainty generates less investment in research and development and new technologies because the reuse criteria to be applied are not clear

04

Social prejudice

The insufficient knowledge of the real possibilities of reuse and recovery of resources deriving from waste often leads to an oppositional and contrary social context regardless.

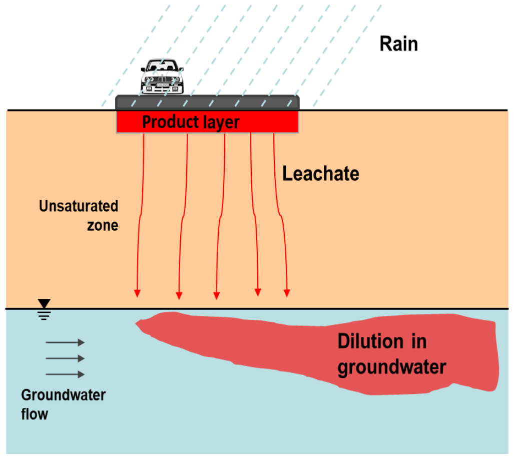
The lack of European EoW criteria does not mean that adequate solutions cannot be found at national level, see the experiences of other member states

What can we do, when an EoW regulation in missing especially in order to ensure a high degree of knowledge of environmental and health aspects ?

The «A2A Chain project and the integrated approach»

Multiple-evidence integrated approach developed by A2A Ambiente:

University of Rome Tor Vergata



Leaching behaviour

Risk assessment

Aquatic and terrestrial ecotoxicity

Technical performance

LabAnalysis Group

Collaboration with Product manufacturers and Environmental Protection Agencies

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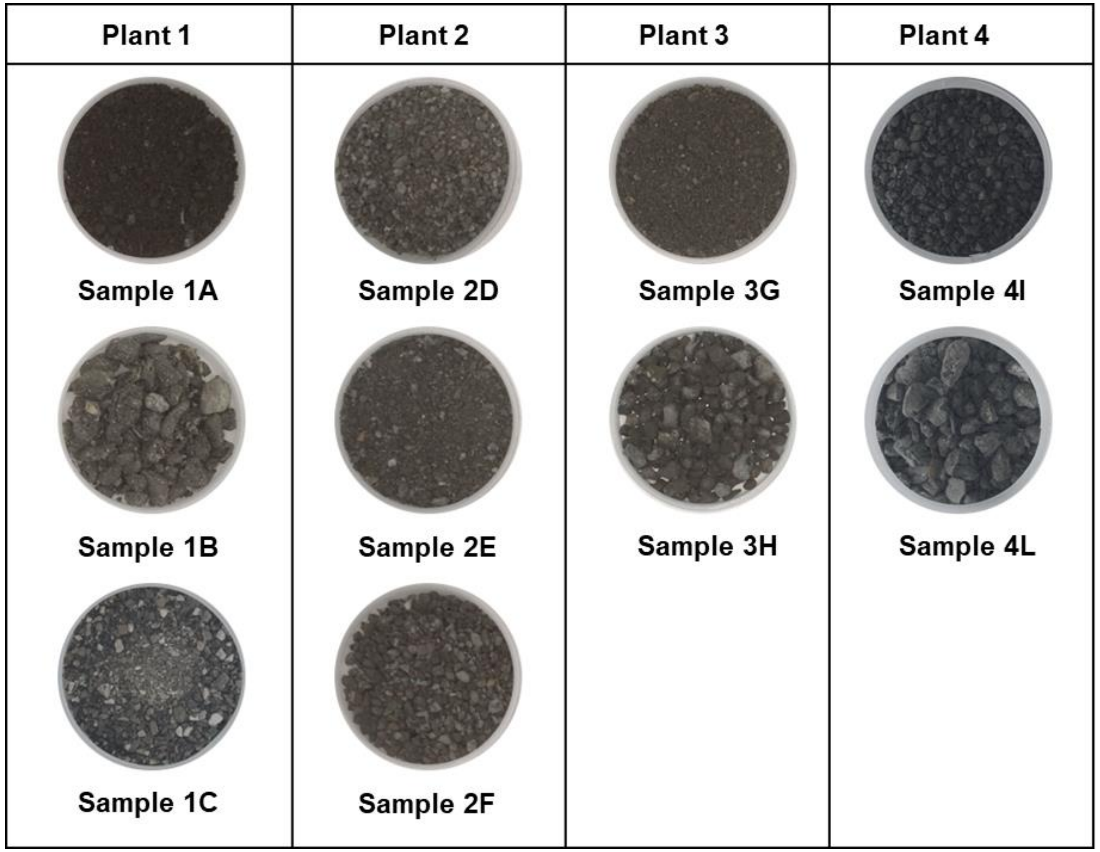
Analysed samples

Ten different products collected from some of the main Italian BA treatment plants



Plant	Sample	Utilisation
Plant 1	1A	cement/ceramics production
	1B	aggregates cement/ceramics production
	1C	aggregates cement/ceramics production
Plant 2	2D	cement/ceramics production
	2E	aggregates cement/ceramics production
	2F	aggregates cement/ceramics production
Plant 3	3G	aggregates
	3H	aggregates
Plant 4	4I	aggregates
	4L	aggregates

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Methodology applied was defined togheter with all the partecipants.

Sampling:

- 1st November 2020-January 2021
- 2nd March-April 2021
- 3rd September-October 2021

Tests performed:

✓ **Chemical composition analysis**

✓ **Leaching test**
→ Characterization tests (L/S and pH) – 1st sampling
→ Compliance leaching test – all 3 samplings

✓ **Ecotoxicological test**
→ Aquatic organisms – 1st sampling
→ Terrestrial organisms – all 3 samplings but only products used as aggregates

✓ **Risk assessement on the basis of the results of the leaching test**

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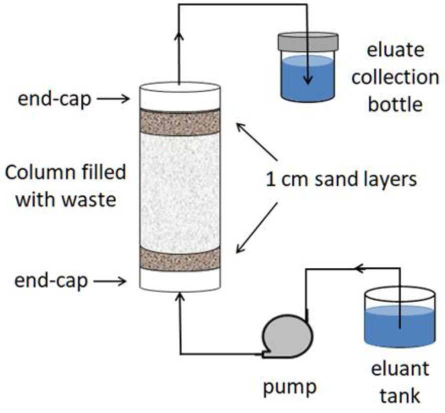
Leaching test performed

✓ ***Solubility and release as a function of the L/S ratio***

Up-flow percolation test (EN 14405 - 2017) on samples ground to < 4 mm (triplicate); L/S = 0.1, 0.2, 0.5, 1, 2, 5 and 10 L/kg of dry sample

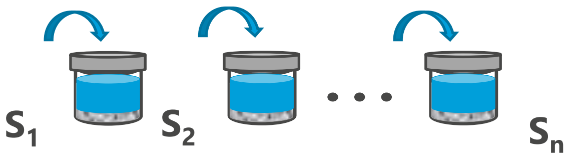


Average flow rate of eluent: 12 ml/h

✓ ***Solubility and release as a function of pH***

pH dependence test (CEN/TS 14429 - 2015) on samples ground to < 1 mm (duplicate); L/S = 10 L/kg; t = 48h

different acid/base additions



Compliance leaching test:

✓ ***Leaching at natural pH and L/S=10 L/kg*** (EN 12457-2) on samples ground to < 4 mm (triplicate); L/S = 10 l/kg; t = 24h

Analysis of the eluates: Ca, Al, Fe, K, Mg, Na, Si, As, B, Ba, Be, Cd, Co, Cr, Cu, Mn, Mo, Ni, Pb, Sb, V and Zn chlorides, sulfates, nitrates and fluorides and DOC - pH and EC

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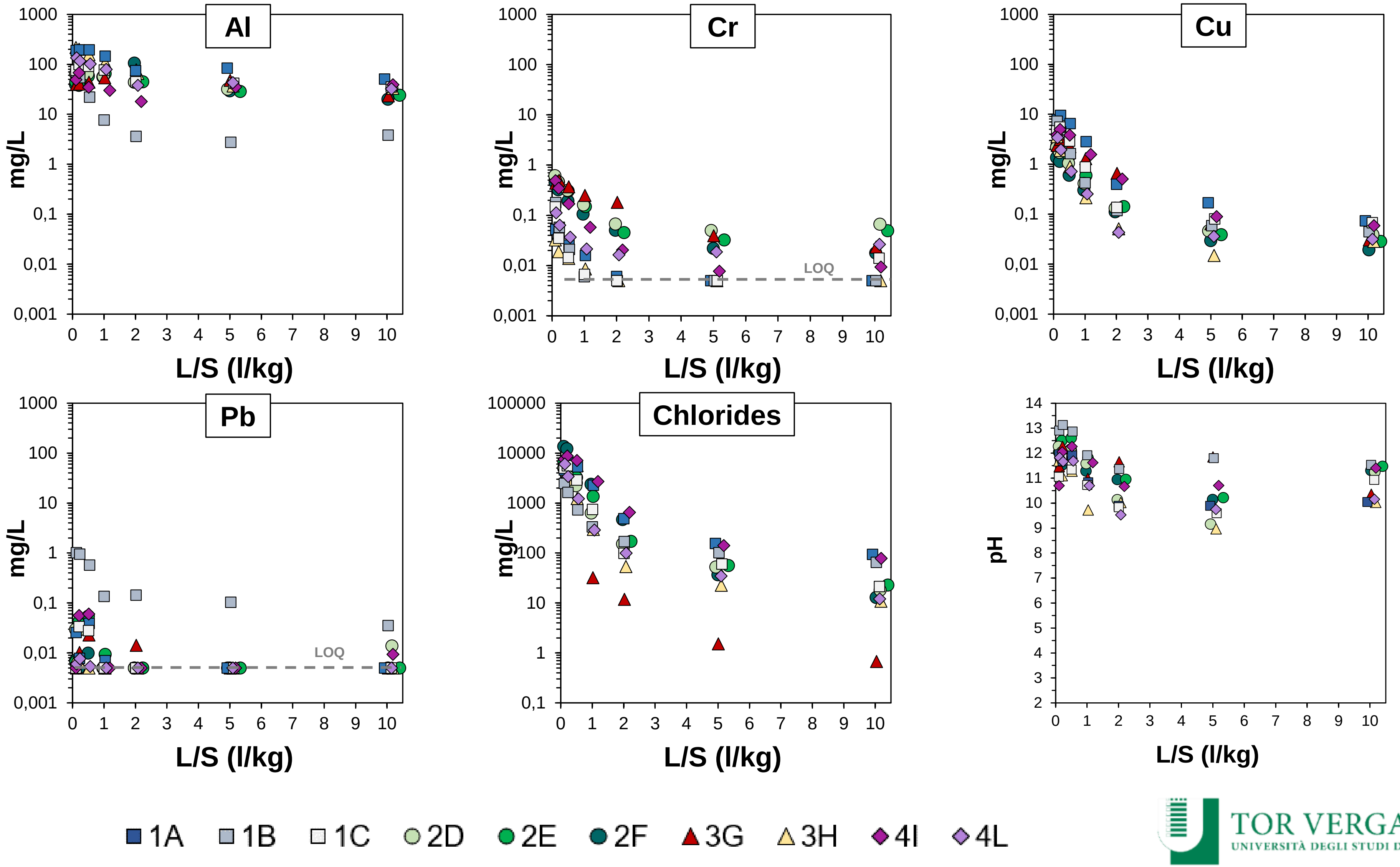
Results obtained for the 10 samples-percolation test



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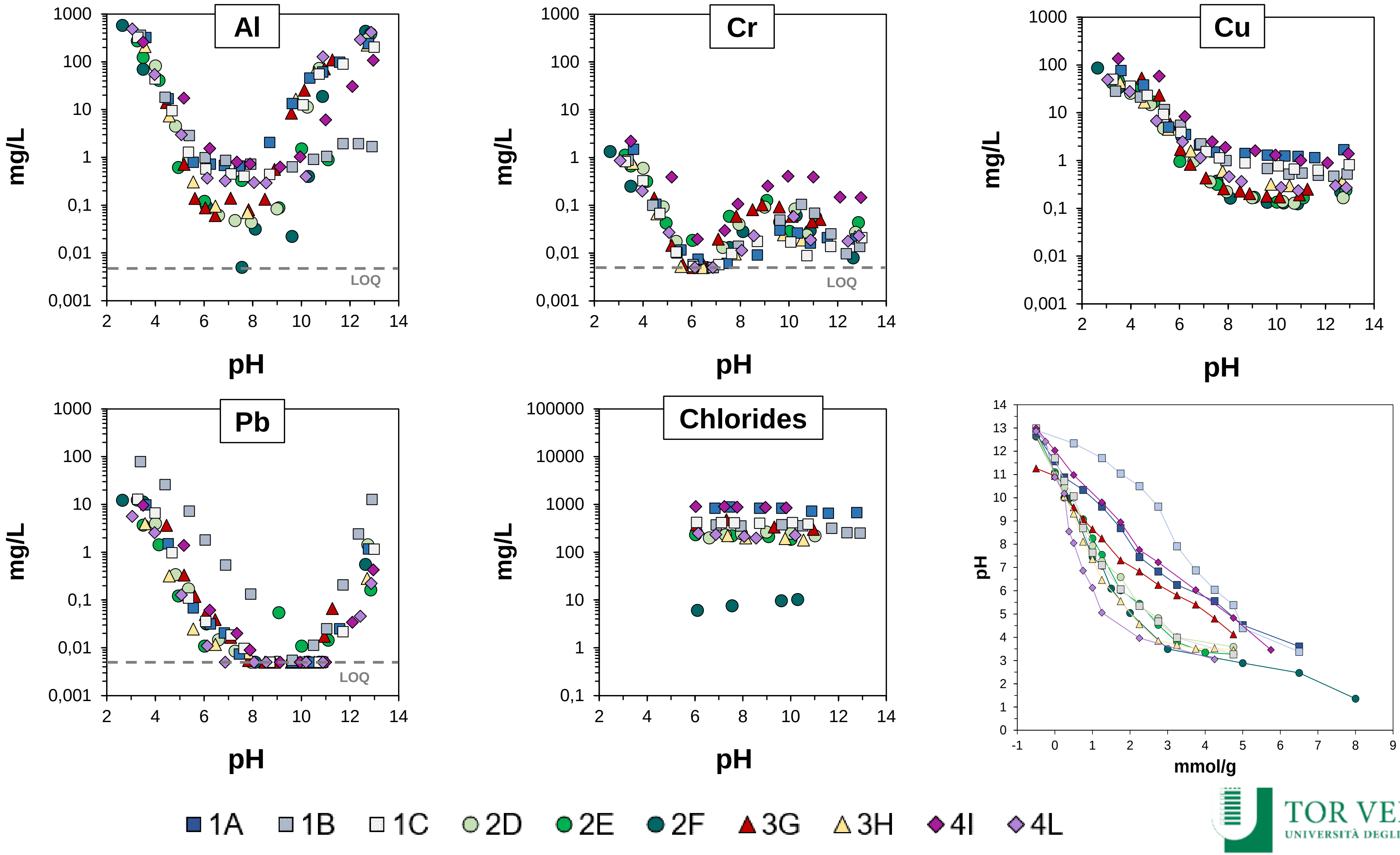
Results obtained for the 10 samples-Ph dependence test



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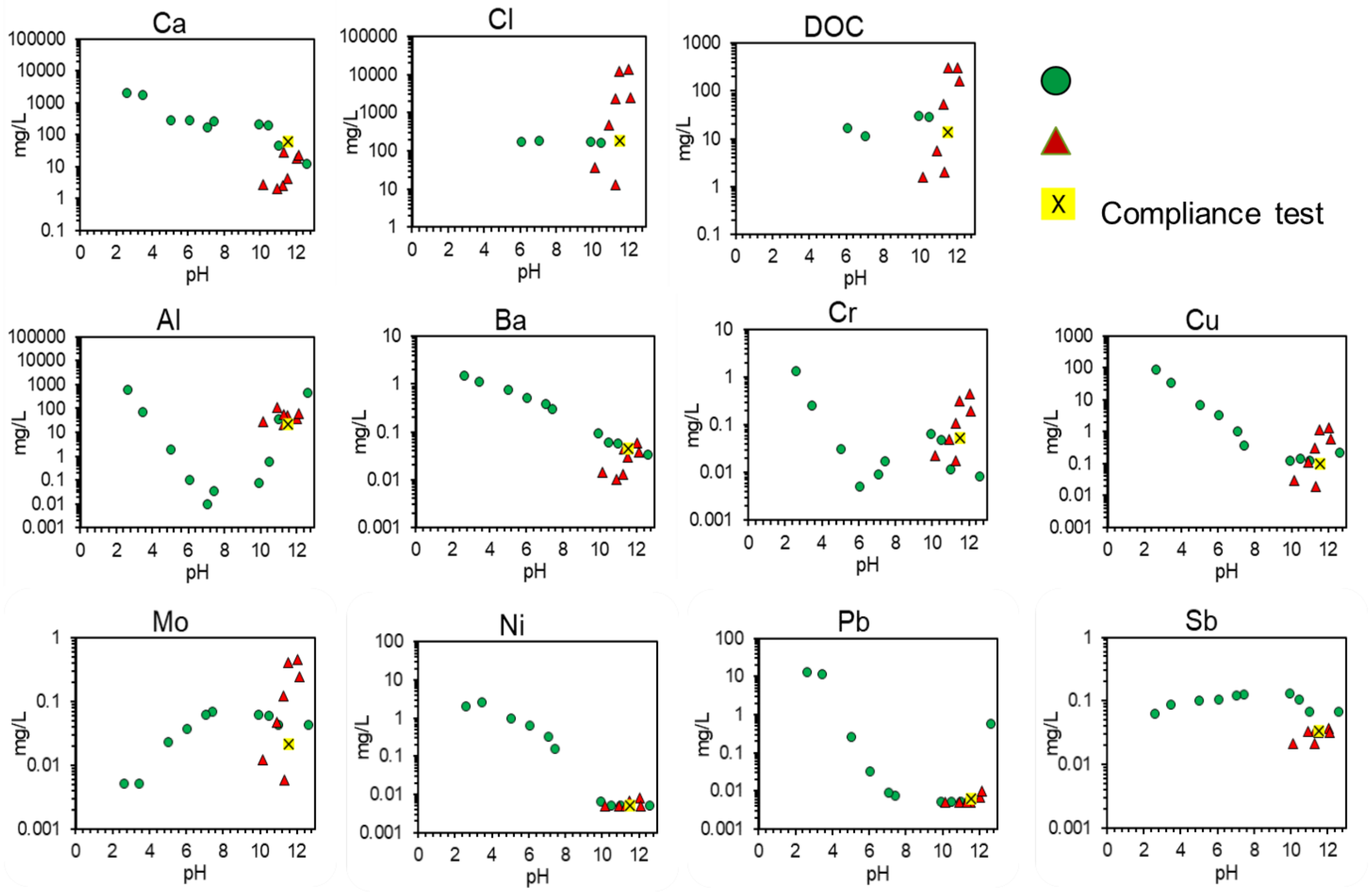
Results mechanism

governing release (sample 2°)

Availability controlled

Solubility controlled



■ 1A ■ 1B □ 1C ● 2D ● 2E ● 2F ▲ 3G △ 3H ◆ 4I ◇ 4L

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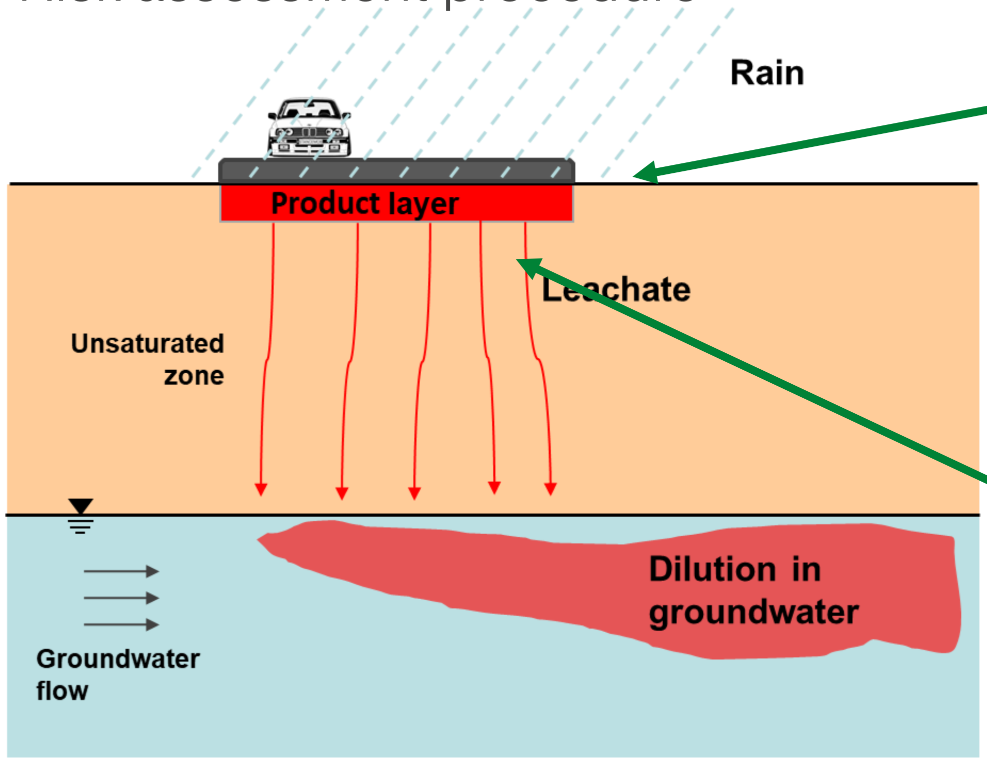
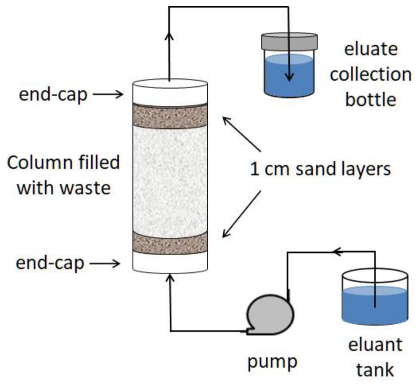
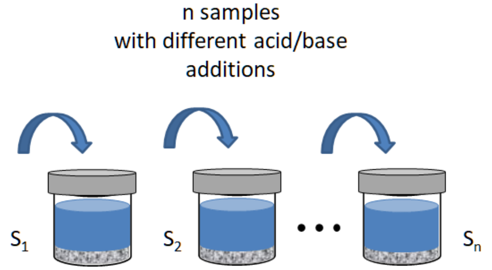
Risk assessment procedure



Column test (washout)



pH-dependence tests (solubility controlled)



Hp: Utilization as unbound filler or aggregate (conservative)

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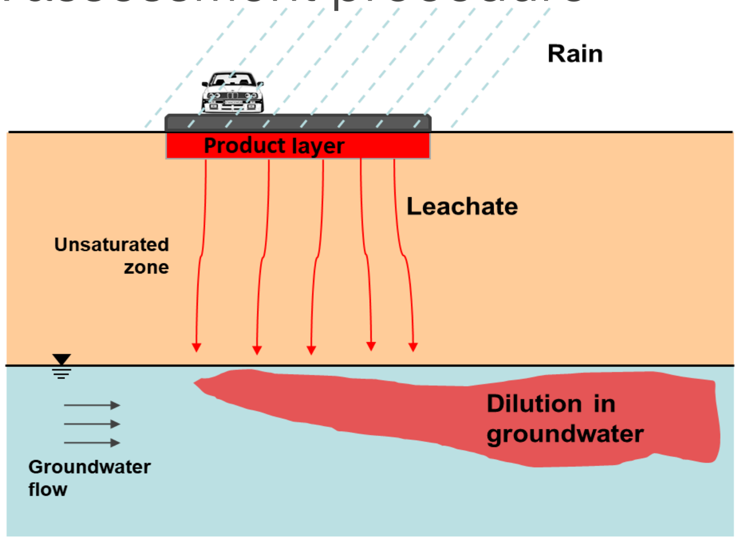
Risk assessment procedure



$$C_{POC} = \frac{C_{eluate}}{LF} = \frac{C_{eluate} \cdot SAM}{LDF}$$

Concentration at the point of compliance

SAM = Soil Attenuation model
LDF = Leachate dilution factor

Compliance (acceptable risk) if $C_{POC} < C_{lim\ GW}$

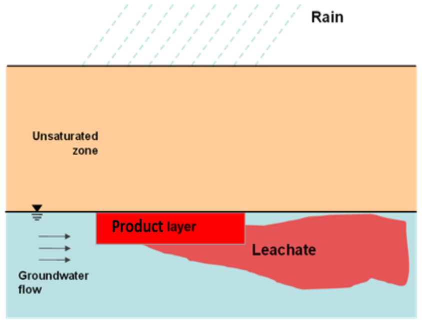
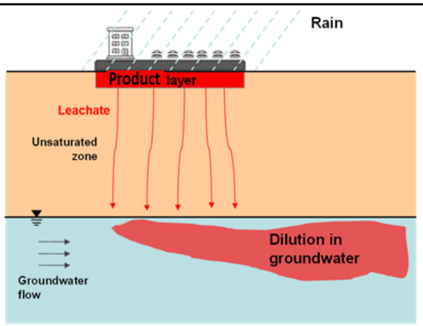
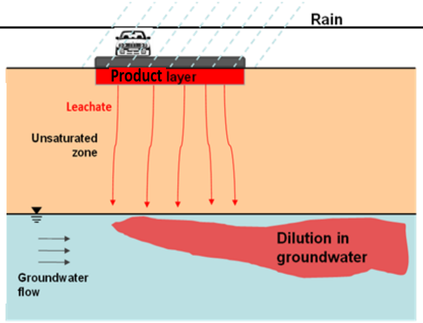
GW quality criteria

- Water quality criteria set by specific legislation (e.g. CSC Italian Lgs. 152/06)
- Risk threshold concentrations calculated for the water ingestion pathway using the equations proposed by ASTM (2000) with ISS-INAIL toxicological parameters and using the Risk- net 3.1 software.

The equation can be inverted to calculate the maximum concentrations in the eluate in order to ensure meeting the groundwater quality criteria

The «A2A Chain project and the integrated approach»

Risk assessment procedure

Scenario	Assumptions
Scenario 0: groundwater application ("no restrictions") 	**Assumption**: direct contact of the material with the groundwater. **Simulation**: no attenuation in the unsaturated zone and no dilution in the groundwater. **LF** = 1
Scenario 1: large scale applications ("Worst Case") 	**Assumption**: unbound fillers or aggregates in large scale applications (parking lots). **Simulation**: attenuation in the unsaturated zone and low dilution in the groundwater. **LF** ~ 39
Scenario 2: Typical applications («Worst Resonable Case») 	**Assumption**: unbound fillers or aggregates in road sub-base layers. **Simulation**: moderate attenuation in the unsaturated zone and groundwater. LF ~ 1400

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Risk assessment procedure: leaching data

Sample	Percolation column test (all L/S ratios)			pH dependence test (7<pH<12)		
	Scenario 0	Scenario 1	Scenario 2	Scenario 0	Scenario 1	Scenario 2
1A	Al; B; Cr; Cu; Mo; Pb; Sb; Cl; F	-	-	Al; B; Cd; Co; Cu; Cr; Mn; Mo; Ni; Pb; Sb; Cl; F; SO_4	-	-
1B	Al; B; Cr; Cu; Mo; Pb; Sb; V; Cl; F	Pb	-	B; Ba; Co; Cr; Mn; Mo; Ni; Pb; Sb; Cl; F; SO_4	-	-
1C	Al; Cr; Cu; Mo; Pb; Sb; Cl; F	-	-	Al; Cd; Co; Cr; Cu; Mn; Mo; Ni; Pb; Sb; Zn; Cl; F; SO_4	-	-
2D	Al; Cr; Cu; Mo; Pb; Sb; Cl; F	Cr	-	Al; Cd; Co; Cr; Mn; Sb; Cl; F; SO_4	-	-
2E	Al; As; Cr; Cu; Mo; Pb; Sb; Cl; F; SO_4	Cr	-	As; Co; Cr; Mo; Pb; Sb; V; SO_4	-	-
2F	Al; As; Cr; Cu; Mo; Sb; Cl; F	Cr; Cl	-	Al; As; Co; Cr; Mn; Sb; F; SO_4	-	-
3G	Al; Cr; Cu; Mo; Pb; Sb; Cl; F; SO_4	Cr	-	Al; As, B; Cd; Co; Cr; Mn; Mo; Pb; Sb; Cl; F; SO_4	-	-
3H	Al; B; Cr; Cu; Mo; Sb; Cl; F; SO_4	-	-	Al; As; Cr; Mo; Sb; F; SO_4	-	-
4I	Al; Cr; Cu; Mo; Pb; Sb; Cl; F	Cr; F	-	B; Cd; Co; Cr; Cu; Mn; Mo; Sb; Zn; Cl; F; SO_4	Cr	-
4L	Al; Cr; Cu; Mo; Sb; Cl; F	-	-	Al; Cr; Sb; F; SO_4	-	-

Scenario 0 (no restrictions) = direct contact of the material with the groundwater;
Scenario 1 (worst case) = unbound fillers or aggregates in large parking lots;
Scenario 2 (worst reasonable case) = unbound fillers or aggregates in road sub-base layers.

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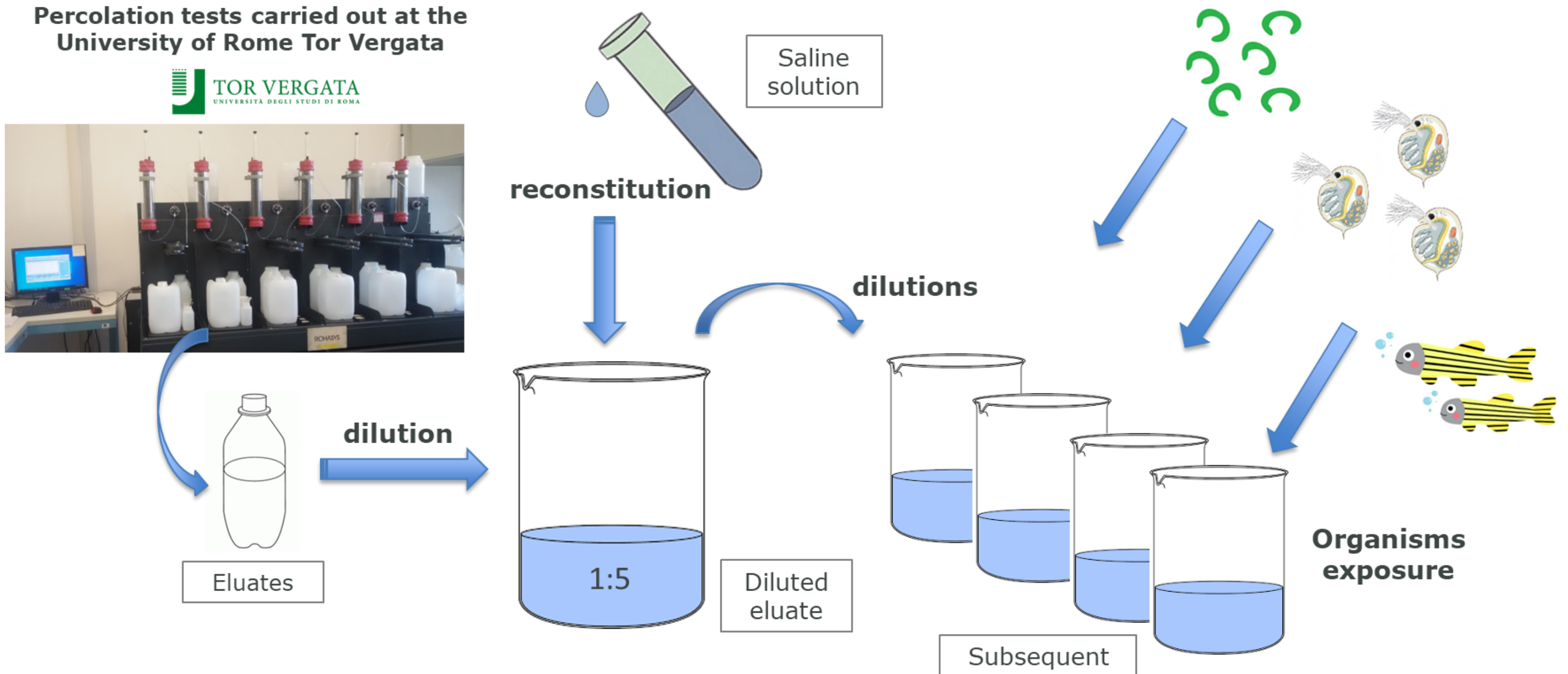
Ecotoxicological test performed

Aquatic tests
OECD 201 Freshwater Alga and Cyanobacteria Growth Inhibition Test
OECD 202 *Daphnia* sp. Acute Immobilisation Test
OECD 203 Fish Acute Toxicity Test
OECD 211 *Daphnia magna* Reproduction Test

Tests typically employed for waste classification according to the EU's CLP regulation



5 concentration tested, starting from **1:5* (20%) dilution**

*based on preliminary calcluation of dilution from soil to water body

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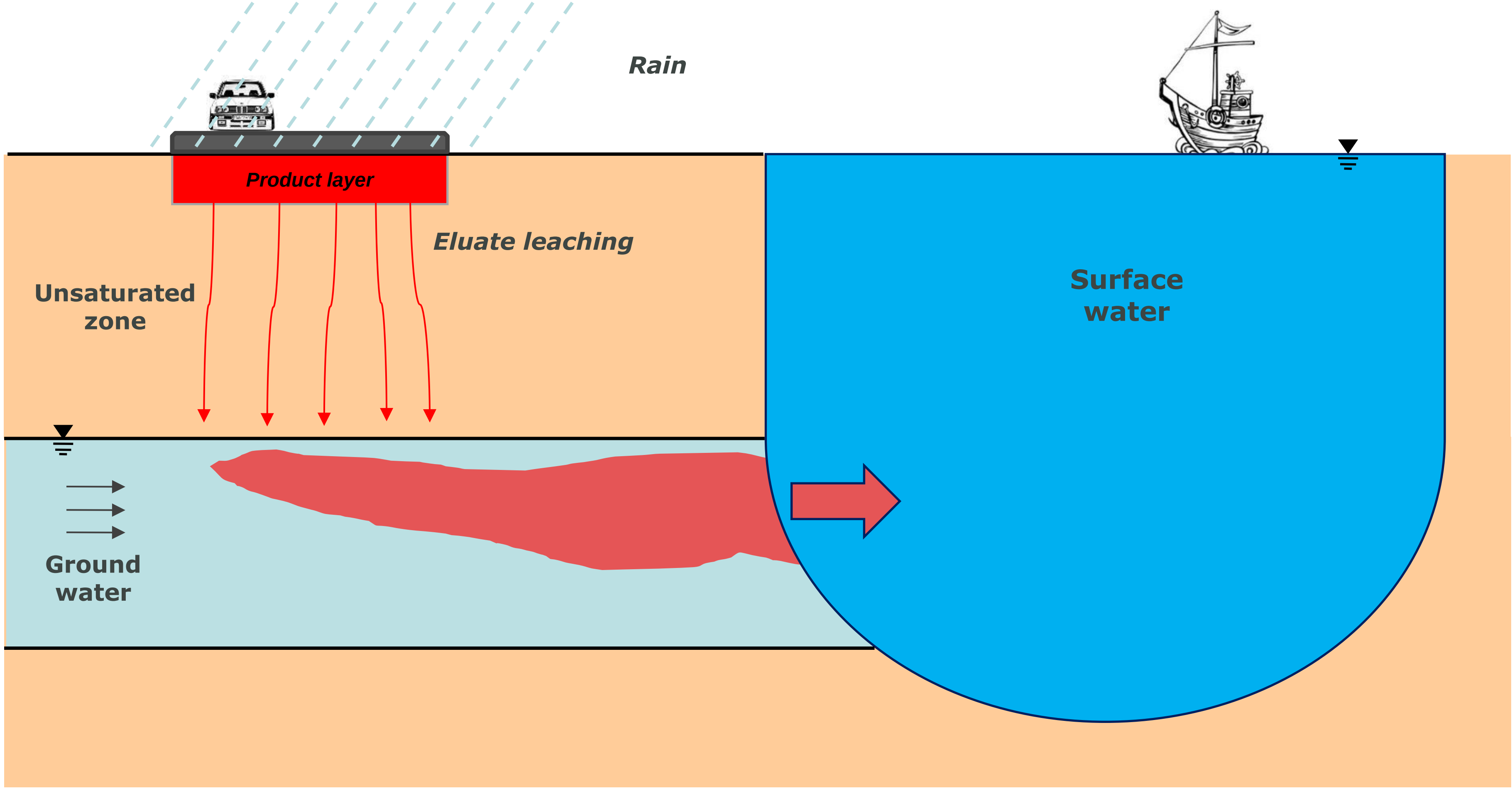
Risk assessment modelling : acquatic ecotoxicity



Assumption:

Factor of 10 dilution from groundwater to surface water

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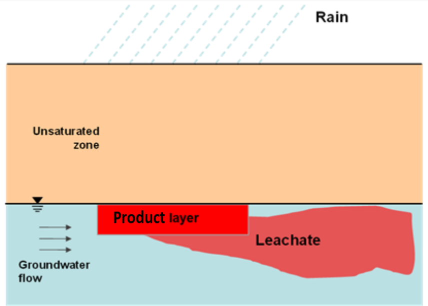
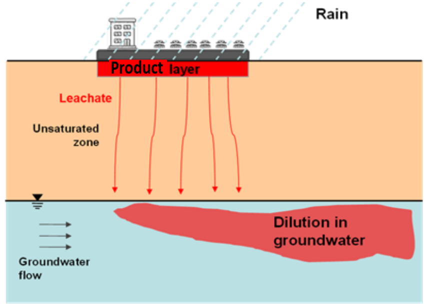
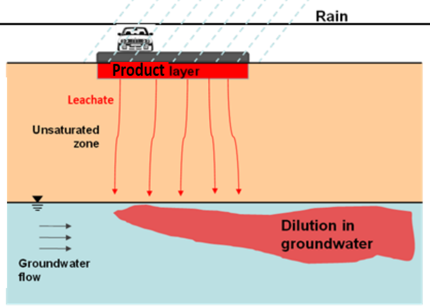
Risk assessment scenarios : acquatic ecotoxicity

Scenario		Assumptions
Scenario 0: groundwater application ("no restrictions")		**Assumption**: direct contact of the material with the groundwater. **Simulation**: no attenuation in the unsaturated zone and no dilution in the groundwater. **LF** = 1
Scenario 1: large scale applications ("Worst Case")		**Assumption**: unbound fillers or aggregates in large scale applications (parking lots). **Simulation**: attenuation in the unsaturated zone and low dilution in the groundwater. **LF** ~ 39
Scenario 2: Typical applications («Worst Resonable Case»)		**Assumption**: unbound fillers or aggregates in road sub-base layers. **Simulation**: moderate attenuation in the unsaturated zone and groundwater. LF ~ 1400

Dilution factor 1→ x10 = 10

Dilution factor 39 → x10 = 390

Dilution factor 1400 → x10 = 14000

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Risk assessment scenarios : acquatic ecotoxicity

	Scenario 0 - Dilution factor of 10				
Sample	**Fish**	**Daphnia acute**	**Daphnia chronic**	**Algae acute**	**Algae chronic**
1A	10	124	417	44	146
1B	8	7	38	7	12
1C	9	71	196	24	105
2D	6	55	323	64	143
2E	5	41	208	26	92
2F	8	79	217	31	90
3G	5	55	385	72	153
3H	10	56	556	43	141
4I	9	51	263	45	152
4L	10	62	251	34	103

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Risk assessment scenarios : acquatic ecotoxicity

	Scenario 1 – Dilution factor of 390					
Sample	Fish	Daphnia acute	Daphnia chronic	Algae acute	Algae chronic
1A	10	124	417	44	146
1B	8	7	38	7	12
1C	9	71	196	24	105
2D	6	55	323	64	143
2E	5	41	208	26	92
2F	8	79	217	31	90
3G	5	55	385	72	153
3H	10	56	556	43	141
4I	9	51	263	45	152
4L	10	62	251	34	103

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Risk assessment scenarios : acquatic ecotoxicity

	Scenario 2 – Dilution factor of 14000				
Sample	**Fish**	**Daphnia acute**	**Daphnia chronic**	**Algae acute**	**Algae chronic**
1A	10	124	417	44	146
1B	8	7	38	7	12
1C	9	71	196	24	105
2D	6	55	323	64	143
2E	5	41	208	26	92
2F	8	79	217	31	90
3G	5	55	385	72	153
3H	10	56	556	43	141
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Risk assessment scenarios : terrestrial ecotoxicityand how to express results

	Molto tossico	Tossico	Pericoloso
Organismo terrestre	Categoria Acuto 1/Cronico 1	Categoria Acuto 2/Cronico 2	Categoria Acuto 3/Cronico 3
Organismi del suolo e piante (acuto)	$EC_{50} \leq 10$ mg/kg d.w.	$10 < EC_{50} \leq 100$ mg/kg d.w.	**$100 < EC_{50} \leq 1000$ mg/kg d.w.**
Organismi del suolo (cronico)	NOEC ≤ 1 mg/kg	1 < NOEC ≤ 10 mg/Kg	10 < **NOEC ≤ 100 mg/kg**
Microflora	$EC_{50} \leq 1$ mg/kg	$1 < EC_{50} \leq 10$ mg/Kg	**$10 < EC_{50} \leq 100$ mg/kg**

UN (United Nations - Committee of Experts on TDG and GHS). 2006. Sub-Committee of Experts on the Globally Harmonized System of Classification and Labelling of Chemicals Twelfth session, 12 (p.m)-14 July 2006, Item 2 (c) of the provisional agenda, Environmental hazards, Classification criteria for the terrestrial environment.

LC_{50}/EC_{50} — Tossicità acuta (mortalità/sopravvivenza)

NOEC — Tossicità cronica (riproduzione)

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Risk assessment scenarios : acute hazard (1)

		Test acuti (EC50 > 1000 mg/kg d.w. = No Risk)				
		Verme	Folsomia	Hypoaspis	Microflora	Piante
1B	1° giro	> 1000	> 1000	> 1000	> 1000	> 1000
	2° giro	> 1000	> 1000	> 1000	> 1000	> 1000
	3° giro	> 1000	> 1000	> 1000	> 1000	> 1000
1C	1° giro	> 1000	> 1000	> 1000	> 1000	> 1000
	2° giro	> 1000	> 1000	> 1000	> 1000	> 1000
	3° giro	> 1000	> 1000	> 1000	> 1000	> 1000
2E	1° giro	> 1000	> 1000	> 1000	> 1000	> 1000
	2° giro	> 1000	> 1000	> 1000	> 1000	> 1000
	3° giro	> 1000	> 1000	> 1000	> 1000	> 1000
2F	1° giro	> 1000	> 1000	> 1000	> 1000	> 1000
	2° giro	> 1000	> 1000	> 1000	> 1000	> 1000
	3° giro	> 1000	> 1000	> 1000	> 1000	> 1000

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Risk assessment scenarios : acute hazard (2)

		Test acuti (EC50 > 1000 mg/kg d.w. = No Risk)				
		Verme	Folsomia	Hypoaspis	Microflora	Piante
3G	1° giro	> 1000	> 1000	> 1000	> 1000	> 1000
	2° giro	> 1000	> 1000	> 1000	> 1000	> 1000
	3° giro	> 1000	> 1000	> 1000	> 1000	> 1000
3H	1° giro	> 1000	> 1000	> 1000	> 1000	> 1000
	2° giro	> 1000	> 1000	> 1000	> 1000	> 1000
	3° giro	> 1000	> 1000	> 1000	> 1000	> 1000
4I	1° giro	> 1000	> 1000	> 1000	> 1000	> 1000
	2° giro	> 1000	> 1000	> 1000	> 1000	> 1000
	3° giro	> 1000	> 1000	> 1000	> 1000	> 1000
4L	1° giro	> 1000	> 1000	> 1000	> 1000	> 1000
	2° giro	> 1000	> 1000	> 1000	> 1000	> 1000
	3° giro	> 1000	> 1000	> 1000	> 1000	> 1000

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Risk assessment scenarios : cronical hazard (1)

		Test cronici (NOEC > 100 mg/kg d.w.) = No Risk		
		Verme	Folsomia	Hypoaspis
1B	1° giro	1000	1000	1000
	2° giro	1000	1000	1000
	3° giro	1000	1000	1000
1C	1° giro	1000	1000	1000
	2° giro	1000	1000	1000
	3° giro	1000	1000	1000
2E	1° giro	1000	1000	**562**
	2° giro	1000	1000	**316**
	3° giro	1000	1000	1000
2F	1° giro	1000	1000	1000
	2° giro	1000	1000	1000
	3° giro	1000	1000	**562**

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Risk assessment scenarios : cronical hazard (2)

		Test cronici (NOEC > 100 mg/kg d.w.) = No Risk		
		Verme	Folsomia	Hypoaspis
3G	1° giro	1000	1000	1000
	2° giro	1000	1000	1000
	3° giro	1000	1000	1000
3H	1° giro	1000	1000	**177**
	2° giro	1000	**316**	1000
	3° giro	1000	1000	1000
4I	1° giro	1000	1000	1000
	2° giro	1000	1000	**316**
	3° giro	1000	1000	1000
4L	1° giro	**562**	1000	1000
	2° giro	1000	1000	1000
	3° giro	1000	1000	1000

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Conclusions and perspectives

Aquatic ecotoxicity

For all the eluates tested, fish was the least susceptible species, while the Daphnia reproduction test was the most sensitive. Evaluating the hypothetical examples, it can be concluded that: Scenario "0" (direct contact with groundwater) is not acceptable. Scenario "1" (large-scale applications) in most cases did not present any critical issues. Scenario "2" (typical applications), in which the most usual conditions of application fall, is always acceptable.

Terrestrial ecotoxicity

No significant acute effects (mortality) were observed at the selected concentrations (EC50>1000 mg/kg d.w.). Some effect on reproduction (mainly of Hypoaspis) was observed, but still with NOEC > 100 mg/kg d.w.

By applying the table "Classification criteria for the terrestrial environment", the samples tested are classified as NON-hazardous.

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Conclusions and perspectives

- A combined methodology to assess the environmental compatibility of the utilisation of mineral fractions obtained by BA treatment was proposed and tested for 10 samples produced by industrial plants.

- The procedure can be used to identify utilisation scenarios that may lead to acceptable risks to human health and aquatic and/or soil ecosystems

- But also to identify the critical contaminants to be treated or managed before utilisation of the product, in order to achieve acceptable risk-based levels

- The results of the different evaluations carried out: leaching tests + human health-based risk assessment, and aquatic and terrestrial ecotoxicological tests + risk-based interpretation were in good agreement

  -> robust methodology

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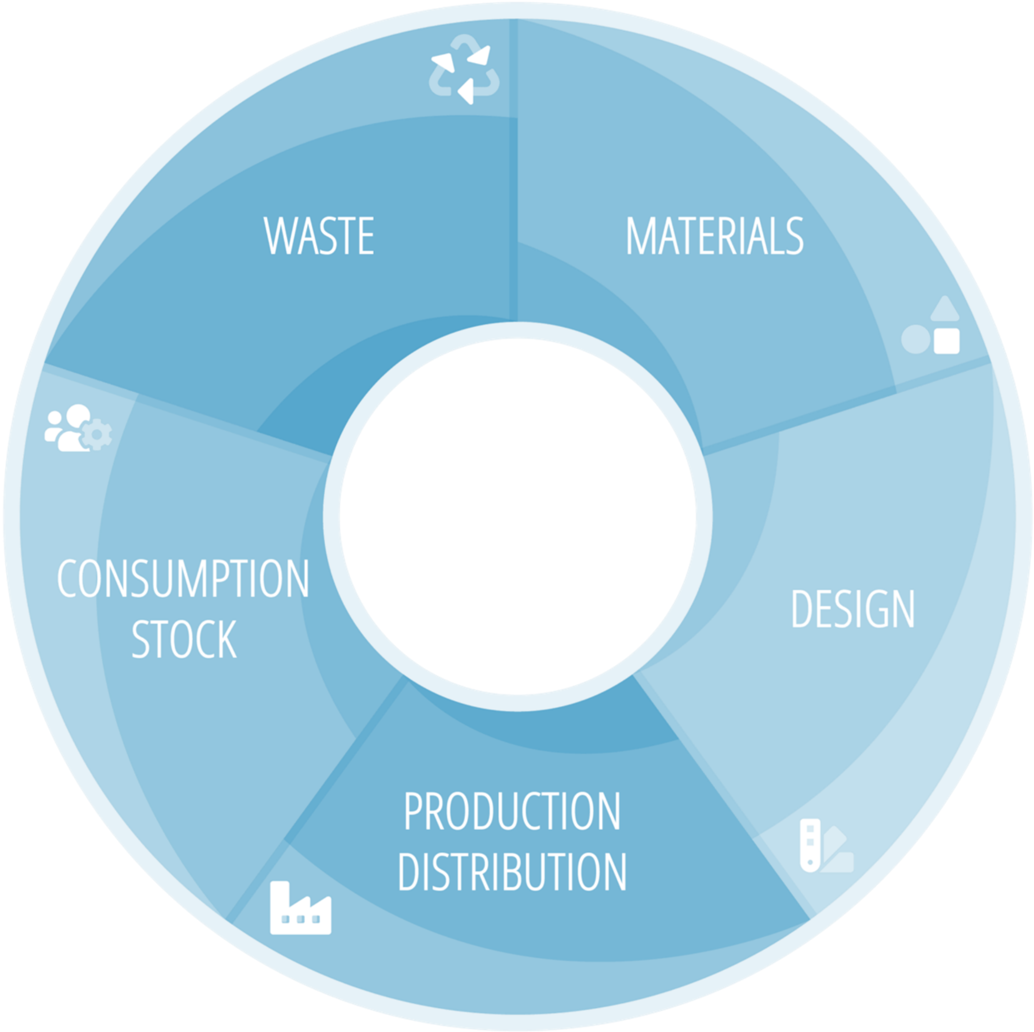
What can the Authorities do?

1. Consider the development of national guidelines for the bottom ash recovery sector also based on the approach and results obtained from this study of the combustion ash supply chain;
2. Use a similar approach also for the study of other possible supply chains from which new resources can be generated



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Thank you for your kind attention!