

EUROPEAN CONSTRUCTION IN SERVICE OF SOCIETY

ECOserve NETWORK

CLUSTER 1

**Alternative raw materials in cement production
and environmental aspects related to impact on
soil and groundwater**

Network Activities

*Integrated evaluation of environmental
properties extending beyond concrete*

1. INTRODUCTION

In Cluster 1 of the ECO-Serve project the following objectives had the following specific objectives were pursued (Cluster 1 deliverables 1-5):

- the data collation from public studies and through the Network contacts and evaluation of the current status of the use of alternative fuels and raw materials in cement production, of the trace element contents in cements and of the binding mechanisms of trace elements in the hardened cement paste to assist in defining the best available technologies (BAT) under economical aspects,
- collection of existing leaching tests, leaching test data and field data from public studies and through the Network contacts and collection of regulations in European member states related to the environmental behaviour of construction products as input to define an the environmental baseline,
- synthesising the collected information and the development of a proposal for the valuation of existing leaching tests (environmental tools) with regard to environmental quality criteria (environmental indicators) using a scenario approach for different utilization options and life cycle stages (database/expert system) and measures to promote and facilitate the use of alternative fuels and raw materials in the clinker production,
- dissemination of the proposals for testing, interpretation of data and environmental quality criteria through the Network to gain endorsement by the industry to comply with requirements stipulated in the Construction Products Directive (CPD, 1989).
- organisation of a workshop in co-operation with the ECO-Serve Management Cluster with stakeholders from industry, regulatory agencies and the research community.

2. ALTERNATIVE FUELS AND RAW MATERIALS IN CEMENT PRODUCTION

The environmentally sound utilization of alternative fuels and raw materials in the cement industry is an important development in most parts of Europe. In cement kilns at the very high temperatures possible organic contaminants in alternative fuels or raw materials are completely destroyed, thus eliminating potentially harmful situations in alternative management options for these materials. Alternative raw materials help to save the use of virgin materials.

2.1 Fuels and raw materials used

Example materials used as alternative fuel or raw material in Europe are:

Alternative fuels	Alternative raw materials
Spent solvents	Iron ore
Used tyres	Waste streams from iron and steel works
Waste oil	Foundry sand
Scrap wood	Ashes from burning processes
Fractions from municipal, industrial and commercial waste e.g. plastics and paper	Coal fly ash
Automobile textiles	Oil shale

Paper sludge	Poultry litter
Sewage sludge	Alum earth
Bone meal	Drinking water sludge
Cocoa shells	
Biomass ash	
Refuse Derived Fuel	

2.2 Possible side effects

Dust - Dust emissions have been sharply reduced in the past decades by the use of electrostatic precipitators and fabric filters.

Trace elements - Trace elements are contained in the raw materials and fuels and thus may be incorporated in the cement and become enriched in the dust. Trace elements such as arsenic, cadmium, lead, nickel or vanadium, are practically completely combined in the clinker. Elements that are volatile at moderate temperature may not be retained in the dust and be emitted. Mercury and thallium are examples of elements of concern and may require input to be limited in individual cases. Trace elements in cement will be addressed separately.

Nitrogen oxides - The clinker burning process is a high-temperature process with temperatures in the sintering zone at around 1450 °C and flame temperatures of about 2000 °C. These high temperatures result in the formation of nitrogen oxides (NO_x). Therefore, the generation of nitrogen oxides is inherent to the process and not influenced by the use of alternative fuels, unless nitrogen-rich alternative materials are used.

Total carbon, CO, SO₂, NH₃ - The raw material composition is decisive for the content of total carbon and carbon monoxide in the exhaust gas. The raw materials can effect the emissions of sulfur dioxide and ammonia and ammonium compounds. The SO₂ emissions can be lowered by adding hydrated lime or by application of wet scrubbers, which is often not economically feasible.

Dioxins and furans - Dioxin and furan emissions and other organic constituents in the feed materials are completely destroyed at the extremely high temperatures and the residence time in the rotary kiln firing system. Almost no dioxins and furans are newly formed in the exhaust gas of rotary kiln plants.

2.3 Composition changes

The content of cement in worldwide cements is given in Table 1 and 2 for respectively major and minor elements and trace elements. The variability in major and minor elements is quite small. Trace elements show a rather limited range in spite of the use of alternative fuels and alternative raw materials. However, the content does not correlate with possible release during service life and material recycling, as trace elements can not be eliminated.

Table 1. Summary statistics of major constituents in ECRICEM World wide cements.

	SiO ²	Al ² O ³	Fe ² O ³	CaO	Na ² O	K ² O	MgO	SO ³	Mn ² O ³	TiO ²	P ² O ⁵
N	56	56	56	56	56	56	56	56	56	56	56
Mean	23.2	6.1	3.0	57.4	0.30	0.79	2.7	3.0	0.20	0.37	0.17
Median	21.8	5.2	3.0	60.7	0.24	0.79	2.5	2.9	0.13	0.29	0.13
X min	15.3	2.8	1.3	40.5	0.04	0.00	0.6	1.9	0.05	0.15	0.04
X max	36.2	10.9	5.9	64.9	1.40	1.8	7.4	4.7	1.48	1.11	0.74
Standard deviation	4.58	2.11	0.91	7.19	0.26	0.41	1.54	0.62	0.23	0.19	0.15

Table 2. Summary statistics of trace constituents in ECRICEM World wide cements in comparison to VDZ data.

	Arsenic (As)		Lead (Pb)		Cadmium (Cd)		Zinc (Zn)	
	VDZ	Ecricem	VDZ	Ecricem	VDZ	Ecricem	VDZ	Ecricem
N	415	25	415	25	415	25	415	25
n < d.l.	4	0	0	0	49	0	0	0
Mean	7.0	11.25	16.86	25.16	0.34	0.55	191.6	116.5
Median	4.3	5.87	13.3	14.1	0.29	0.47	150	82.1
X _{min}	0.5	1.28	1.67	2.67	0.05	0.1	9	15.9
X _{max}	96.7	71.9	105	169	1.52	1.91	1023	372
Standard deviation	9.30	15.60	14.28	32.30	0.25	0.43	155.7	95.2

3. AVAILABLE LEACHING TEST INFORMATION

Worldwide many different leaching tests are used to assess release from materials, which leads to widely different end results for the same material. This incomparability of data is an important limitation. Based on an extended evaluation, a much smaller set of tests would suffice to provide the necessary information (Van der Sloot et al, 1997).

In the context of the Construction Products Directive Essential requirement no 3 on Health and Environment it must be ensured that no adverse health and environment effect result from the use of alternative fuels and raw materials. Adequate tools to judge such effects were not or insufficiently available for construction materials. In the CEN Technical committees on environmental aspects, methods of judgment have been developed and these have been evaluated for use in connection with construction materials. In the environmental TC's of CEN a process of horizontal standardisation (across different fields) was been initiated (Horizontal, 2003). The benefits of such a process were recognised as being of high importance for the construction field as well.

On March 16th 2005 the European Commission published mandate M/366 "Development of horizontal standardised assessment methods for harmonised approaches relating to regulated dangerous substances under the Construction Products Directive (CPD)". M /366 deals with the subject of emissions of regulated dangerous substances from construction products as defined in the CPD that may have harmful impacts on human health and the environment in relation to Essential Requirement No. 3 of the CPD. The mandate is intended to provide harmonised European

measurement/test standards that are needed in order to bring about the “approximation” of laws, regulations and administrative provisions of the Member States. The measurement/test standards will have to provide results that can be expressed in performance terms and be suitable for addressing the emission of regulated dangerous substances in harmonised European Technical Specifications (ETS). In 2006 CEN TC 351 “Construction products: Assessment of release of Dangerous Substances” has been established for the implementation of M/366 and the elaboration of the necessary harmonised measurement/test standards.

For the attestation of conformity in M/366 a multistage concept is prescribed. This is to ensure that conformity attestation is only required when it is actually necessary upon assessment of the potential hazards which the respective building material may cause to the environmental media water, soil and air. In detail the three following options for conformity assessment have been provided for:

- Attestation of conformity without testing, so-called “WT-products”
- Attestation of conformity without further testing, so-called “WFT-products”
- Attestation of conformity with further testing, so-called “FT-products”.

3.1 Standards

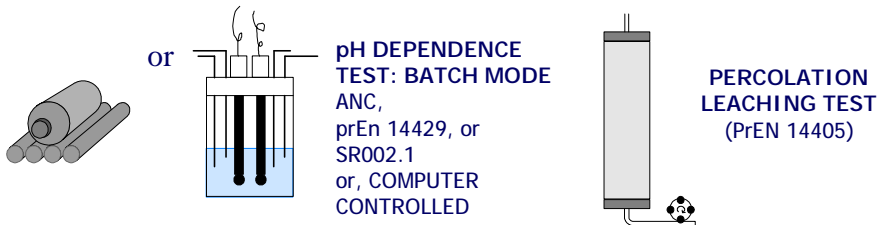
For characterisation of materials a set of procedures has been defined that will cover the information needs to describe the release from granular (e.g. aggregates) and from monolithic materials (such as construction products) in different scenarios.

3.1.1 Characterisation

In figure 1 the characterisation methods are highlighted covering chemical speciation aspects as obtained from the pH dependence test on size reduced materials (providing information on release conditions other than those observed during testing, e.g. resulting from carbonation) and time dependent release from a monolithic material. The first fractions of a percolation test on size reduced monolithic material provides insight in pore water concentrations, which are relevant for a proper description of long term release predictions.

An illustration of the application of these tests to more than 50 OPC (Ordinary Portland Cement) and blended cement mortars from worldwide origin is given in figure 2. It shows very consistent release behaviour of Cr and Zn (information on more than 25 major, minor and trace elements available; van der Sloot et al, 2000; Ecricem, 2001) pointing at the same release controlling mechanisms for all mortars. In case of Cr, the distinction between chromate and trivalent Cr is important. In OPC at pH > 7 all leachable Cr is present as chromate. In cements blended with blast furnace slag the proportion of chromate is small to non-existent as a result of the imposed reducing conditions in the mortar by the sulfide present in the slag. For Zn the release behaviour as a function of pH is dominated by the same solubility controlling phases. Carbonation leads to lower release of Zn. For Cr, however, carbonation leads to a substantial increase in leachability. This is the same for all oxyanions (e.g. As, Sb, Se, Sulphate, V). From a long term release point of view and certainly in recycling of construction debris as aggregate, the oxyanions are of greater importance for possible environmental impact than metals like Pb, Cd, Cu and Zn

GRANULAR MATERIALS



MONOLITHIC MATERIALS



Chemical speciation aspects

Time dependent aspects of release

Figure 1. Characterisation leaching test methods for granular and monolithic materials.

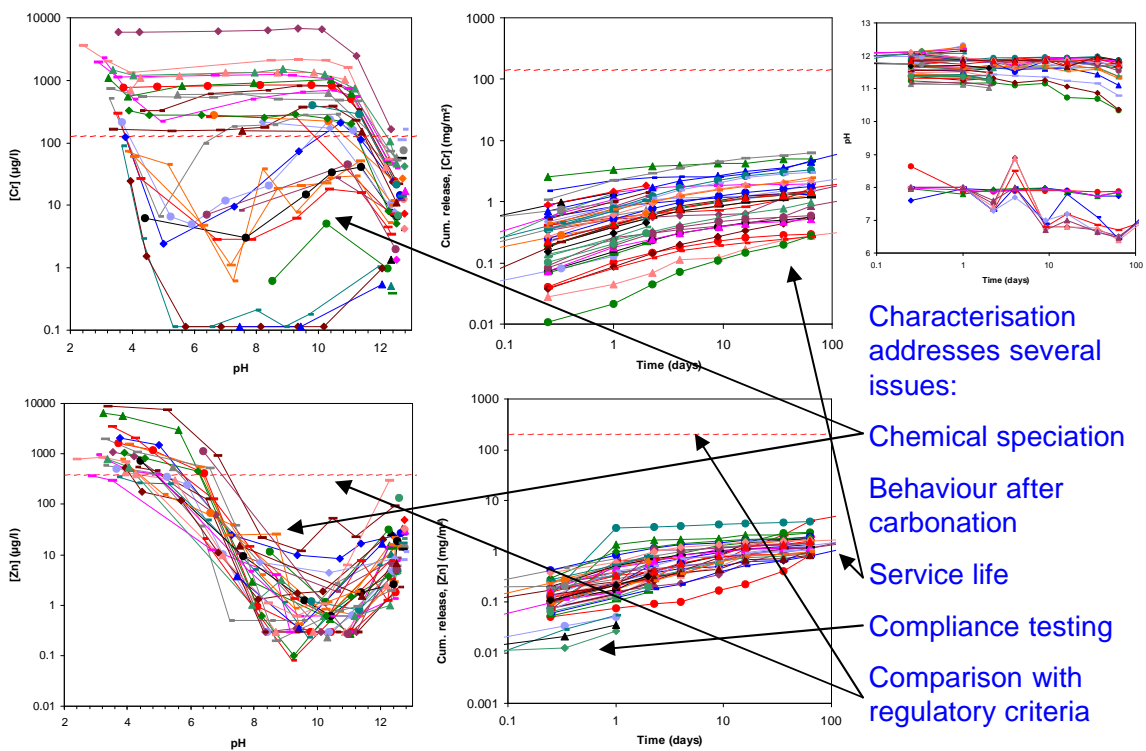


Figure 2. Characterisation test results (TS 14429 and DMLT renewal) for > 50 worldwide OPC and blended cement mortars with and without carbonation for Cr and Zn.

3.1.2. Compliance

Once the release behaviour has been established, much simpler compliance testing will suffice to show that a new type of cement mortar will behave similarly as the already characterised materials. Only in case of significant deviation from the observed ranges a need for more detailed characterisation will arise. In figure 2 compliance test data are inserted consisting of the first fractions of a tank test or possibly even one step. The need for compliance or conformity testing depends on the difference between the concentration levels observed in a test and regulatory criteria derived from impact evaluation in an intended use scenario.

3.2 Unified data format

To facilitate data comparison a unified data format has been developed, which allows mutual comparison of almost any leaching test result, pilot scale test or field verification experiments. Standardisation of a limited set of adequate test methods helps to facilitate that process.

3.3 Comparison of data within an installation and between installations worldwide.

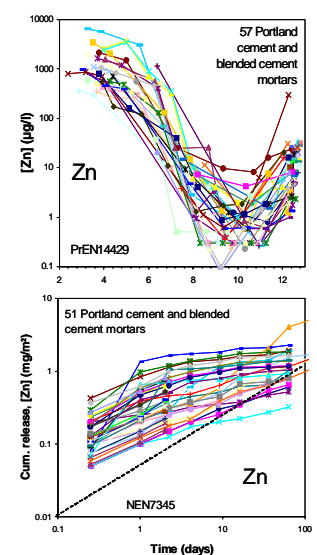
An issue of importance in relation to standards is the repeatability/reproducibility aspect of testing. This is covered by the performance characteristics of standard test methods as produced in CEN. In table I results of repeatability testing of a cement mortar (10 fold in one lab), variability within one plant and variability among different plants world wide is given for Zn. Reproducibility testing has not yet been performed for these methods and will be necessary by organising a validation study with European laboratories (action in the context of CEN TC 351).

Table I. Repeatability, variability in one plant and world wide variability of Zn of a tank leach test.

Cement mortar (from world-wide sources)

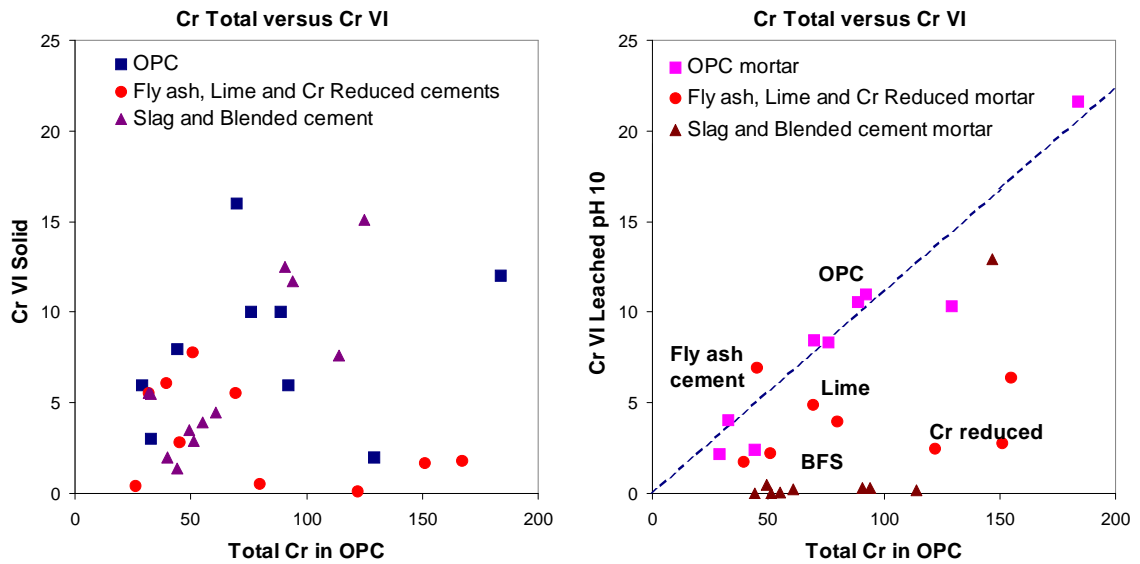
	Individual (n = 10)		One cement plant (n=3)		more cement plants (n = 29)	
	Average	SD (%)	Average	SD (%)	Average	SD (%)
Al			271	35	209	65
Ba	39.6	6.4	26	23	29	106
Ca	26035	4.8				
Cd	0.59	3.8			0.08	157
Cr			1.56	40	1.94	85
Cu			0.73	62		
K	34112	2.1	11898	31	13454	58
Mo	0.48	7.4	0.08	33	0.47	155
Na	22131	2.4	3909	29	3300	60
Ni					1.25	89
Pb*	4.8	55	0.14	123	1.84	172
Si	489	5.5				
SO4 as S	425	5.1	431	30		
V	163	5.2	0.21	146		
Zn*	6.9	26	1.12	41	1.63	57

* Pb and Zn are close to the detection limit and therefore show a higher SD.



3.4 Difference between OPC and blended cements.

In figure 3 one of the main difference between OPC and blended cements is shown, which is the release behaviour of Cr. For OPC only a direct correlation between total Cr and chromate was found, which requires further verification on a larger number of samples. Obviously, Cr reduced cements as required now by EU regulation on occupational exposure show low leachability relative to content.



$$\text{Leachable Cr (L/S=10, pH 9 - 10, 24 hrs) mg/kg} = 0.11 (\pm 0.02) * \text{Total Cr (mg/kg) (Portland cement only)}$$

Figure 3. Comparison of Cr VI in solid and leachable Cr against total Cr in cement.

3.5 Chemical speciation and binding aspects

Based on the pH dependence leaching test data chemical speciation modelling (here LeachXS-Orchestra, 2006; Meeussen, 2003) can be applied to identify the solubility controlling phases and the binding mechanisms for elements in the cement matrix. In figure 4 this type of modelling is shown for Cr illustrating the partitioning in solution as well as the partitioning in the solid phase. In the solid phase, the role of Cr(OH)₃, BaSO₄-BaCrO₄ solid solution and incorporation of Cr in ettringite is of relevance. It is also clear that different phases control solubility in different pH domains, which is important to assess the consequences of carbonation after long term exposure to field exposure conditions. The potential for this type of modelling for new development in cement application may prove an interesting spin-off of this environmental evaluation work.

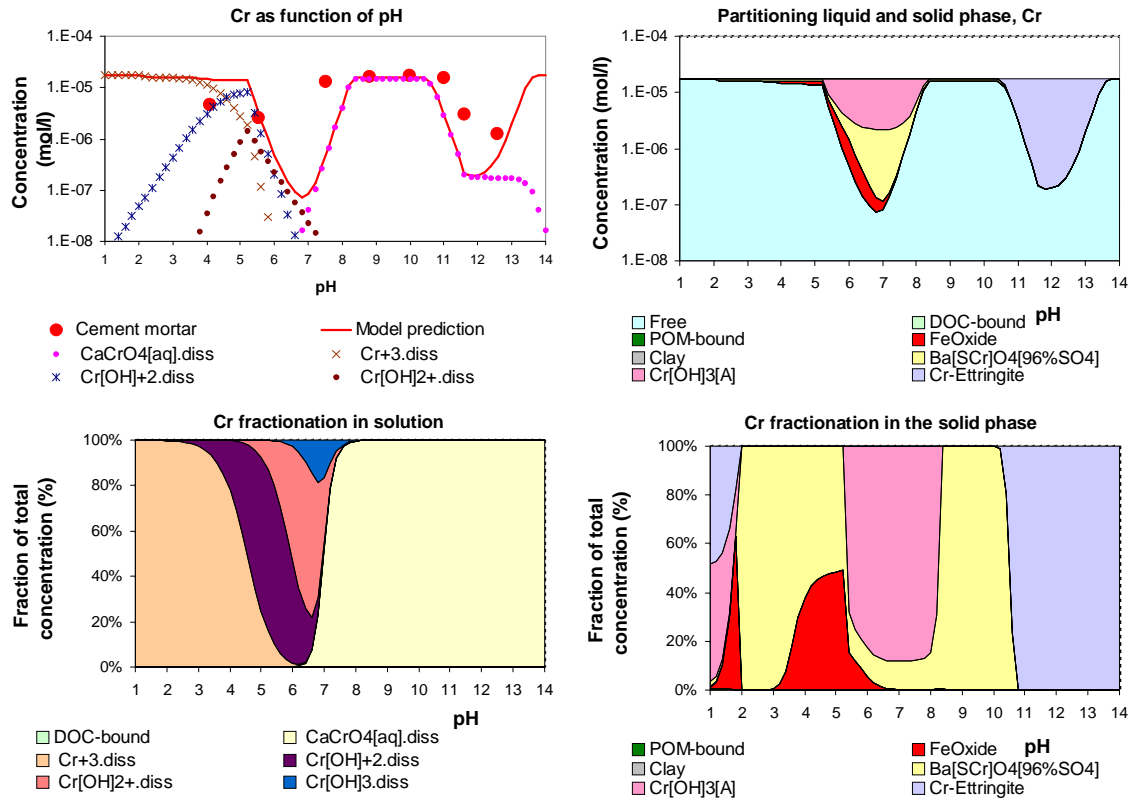


Figure 4. Chemical speciation of Cr in cement mortar leaching in both solid and liquid using the LeachXS-Orchestra model environment.

3.6 Release modelling tank test

The same modelling environment has been used to carry out a full mechanistic modelling approach involving all major, minor and trace elements to describe release of constituents in a tank leach test with leachant renewal cycles. In figures 5 and 6 the results for respectively pH (rather complex due to the many phases affecting pH), a relatively inert salt (here K, showing the role of product tortuosity), sulphate and Zn. The agreement between model and measurement is very promising and holds potential for long term release predictions under changing exposure conditions in practice, whereas empirical descriptions will fail rapidly under such imposed conditions.

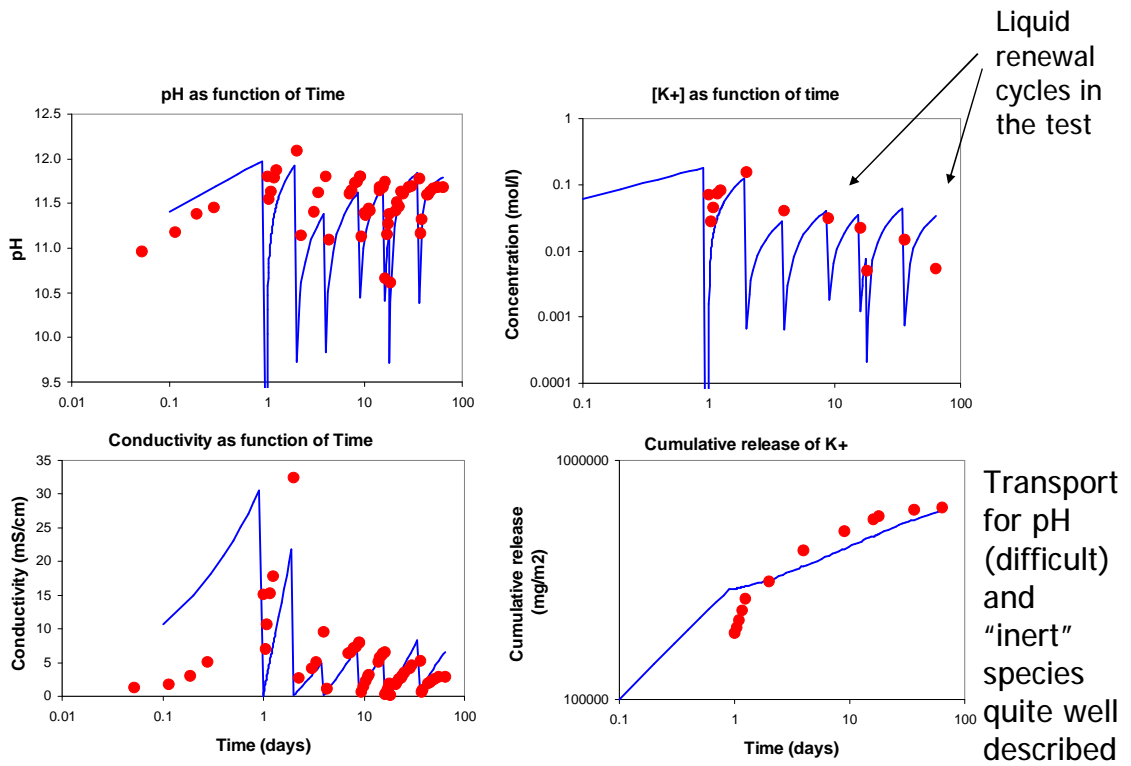


Figure 5. Model prediction for pH and an inert salt by a full mechanistic modelling approach

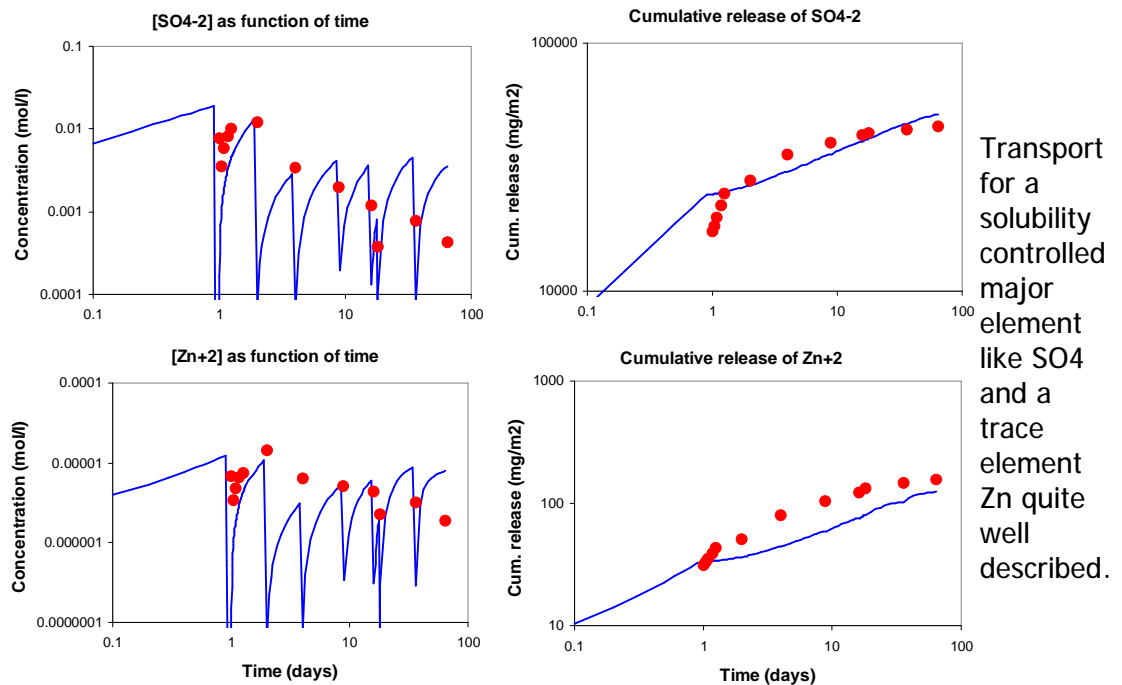


Figure 6. Model prediction for sulphate and Zn by a full mechanistic modelling approach.

3.7 Test use in relation to recycling

In the CPD the release during service life is addressed. This may lead to a situation, where a material will meet environmental requirements under service life conditions, but may fail to do so under recycling conditions. Not necessarily or unlikely under recycling as a bound aggregate, but in applications as an unbound aggregate. To prevent such delayed surprises of incompatibility a full material cycle evaluation is proposed. In fact the testing as described above will allow such a preliminary evaluation beforehand. In figure 7 the material cycle of construction materials is shown with the testing moments and testing types inserted. Again need for testing and frequency of testing depends on the concentration levels encountered for substances defined by regulators.

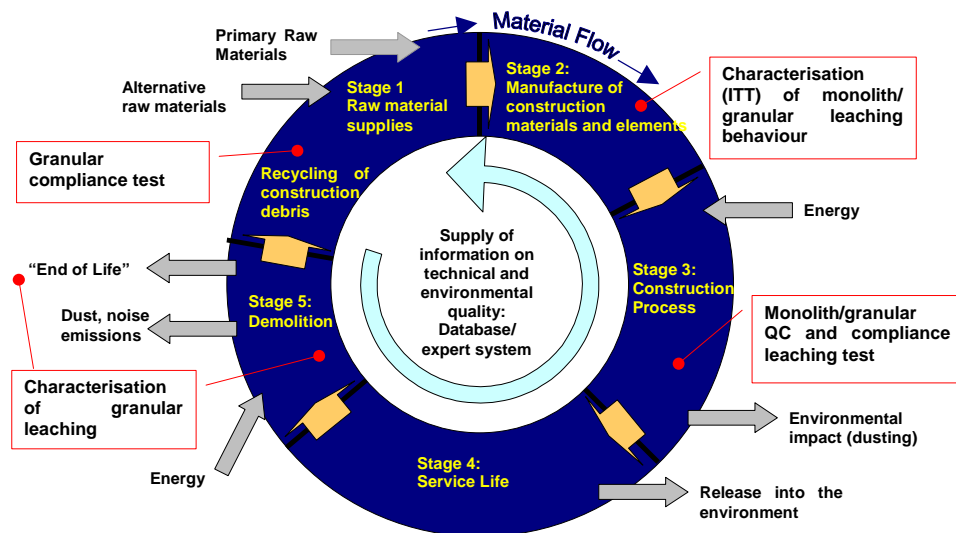


Figure 7. Life cycle stages in construction and environmental testing aspects identified.

3.8 Test use for different questions

In discussion with stakeholders (end-users, regulators, consultants, researchers) the different information needs were identified. For a proper evaluation of long term impact regulators need sufficient information on short and long term release to be able to judge release of substances of concern for soil and groundwater quality. A single step leaching test is not going to provide the necessary information to judge this. In the development of new products, particularly, when alternative materials are used, industry needs to know what the boundaries of the playing field are. Too simple tools are not suitable for that purpose. End-users in daily practice want a situation without any testing requirement or as minimal as possible and as simple as possible. Consultants and research need to provide the tools and methodology to address these conflicting requirements. Only a tiered approach, which implies a hierarchy in testing, will solve these conflicting requirements. In figure 8 the different test uses from the different perspectives are indicated. Developing a database for common construction materials with anonymous data, which can be used EU wide or possibly even worldwide, will provide a reference basis against which the industry can justify to classify a construction product e. g. as WT-product and verify new products in terms of their environmental performance.

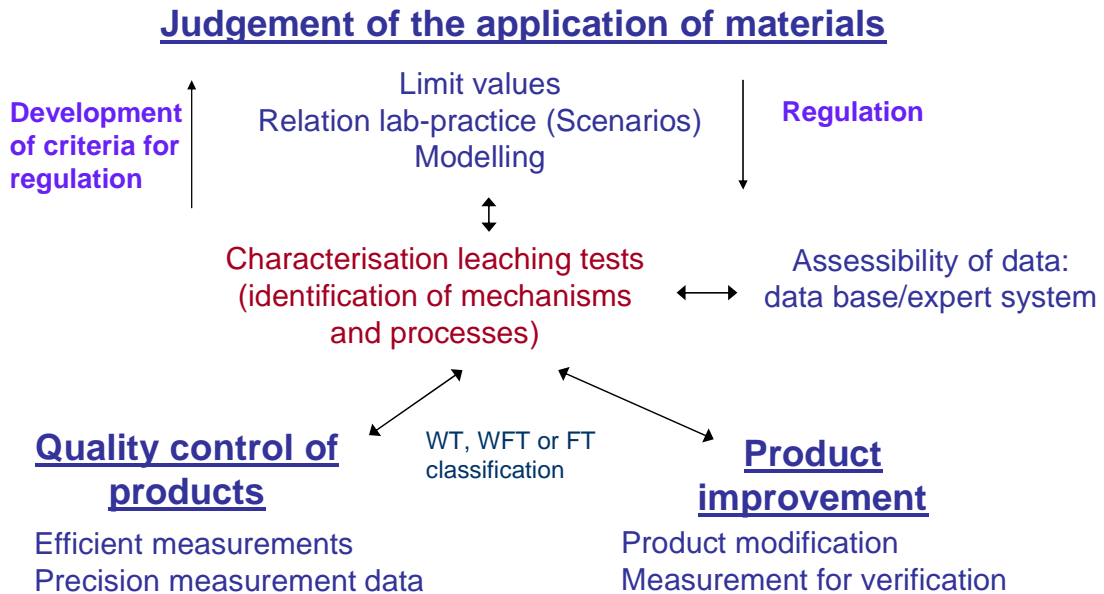


Figure 8. Role of characterisation and compliance leaching tests in environmental judgement.

4. SOIL & GROUNDWATER IMPACT APPROACH

In figure 9 the complexity of the soil & groundwater impact problem for regulators dealing with protection of environmental quality is illustrated. With the use of alternative materials in construction applications and similar activities in other fields (biofuels, alternative fertilisers, etc) the regulatory activities start to overlap more and more, as the same material may be judged by different regulations depending on the purpose of intended use.

The chance of double testing is increasing, when there is no interaction between the different regulatory fields. Within the construction field similar situations occur as jurisdictions may be split between land and water applications. As rules of chemistry and physics governing release of substances from granular or monolithic materials are not dependent on the material type, but that the relevance of certain parameters or properties may prove more relevant in one case relative to another, a generic approach to material characterisation seems very feasible. From the characterisation simple testing means for conformity evaluation can be derived. From the basic material characterisations conclusions on behaviour under a variety exposure conditions can be made.

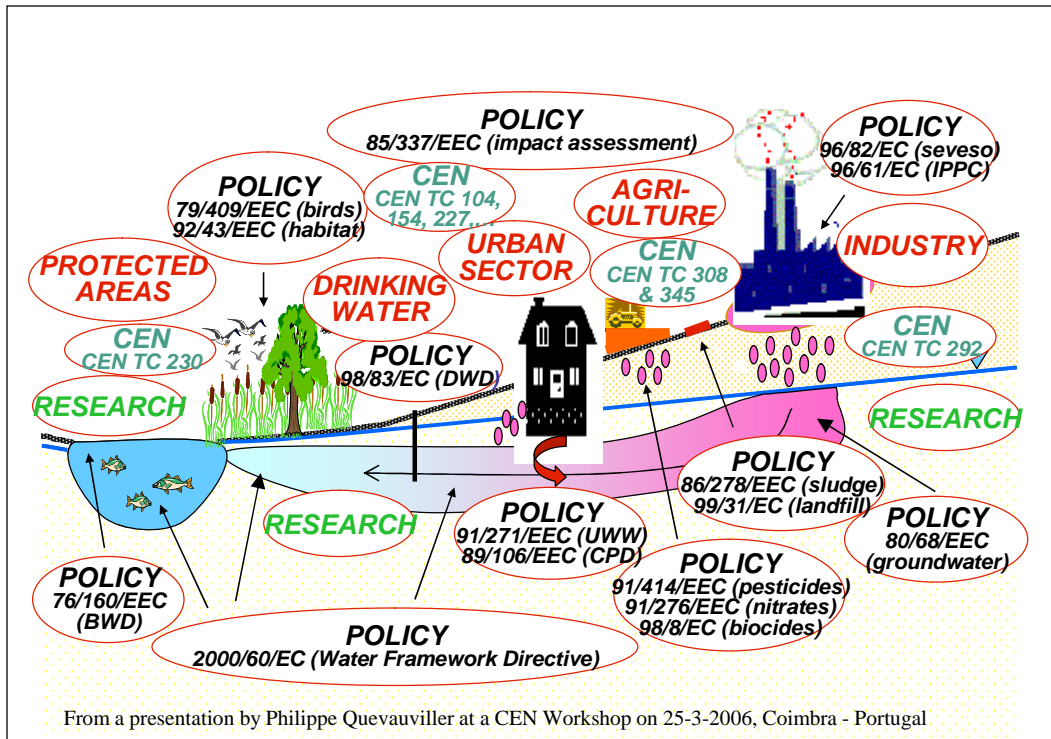


Figure 9. Policy framework and related standardisation activities.

4.1 Service life

For the evaluation of release, simple and more sophisticated models can be used. The larger the uncertainty implied in a model in relation to actual behaviour in practice, the larger the safety margins will be in setting criteria. The higher the validity of a model to address real impact, the more realistic the limit values can be. Obviously, this is to a large extent determined by the state of the art in modelling and verification of model output with practice. When realistic release predictions fall well below any critical limit, then simple models may suffice to come to a conclusion. For more complex or more critical situations, more sophisticated evaluations may be called for.

4.1.1 Simple models

Simple release models only take one-dimensional diffusion into account to project long term release. This can in several cases overestimate release by significant factors, as release may decrease due to carbonation of the surface (Al, Zn, Pb).

In figure 10 the projected release of Al under conditions where initially high pH dominates release and subsequent carbonation leads to a decrease in release. Leaching data for a range of cement mortars with and without carbonation provide the background information for this prediction. When the carbonation source disappears, the high pH may come back again and then the concentration of Al might increase again, as the remaining buffer within the cement mortar is still present.

For other elements the release may actually increase after carbonation (oxyanions like Mo, Cr, V), but may be limited to the rate of progression of the carbonation front. This then becomes an evaluation which makes use of more sophisticated knowledge and leads to a relatively simple rule of thumb. The carbonation front is assumed to progress according to a square root of time relationship. For a carbonation front of 2 mm in 10 years that allows calculation of the progression. From this information, the layer thickness by carbonation can be assessed and with the availability for leaching of the anion of concern, the release at a specified time can be estimated.

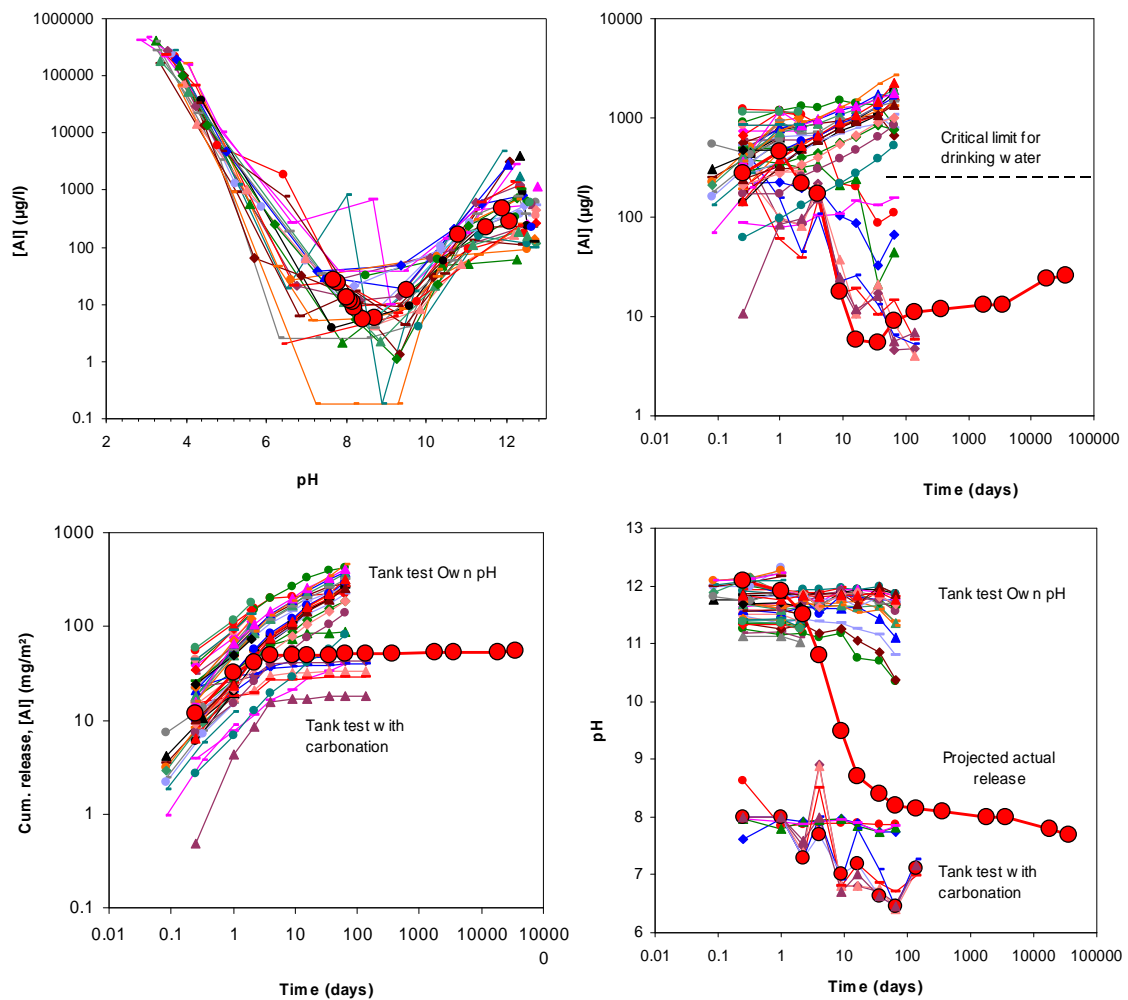


Figure 10. Projected release of Al under conditions where initially high pH dominates release and subsequently carbonation leads to a decrease in release (solid red dots). Other data in the graph show actual test data under own pH conditions (pH >11) or experiments with carbonation (pH 7 - 8).

4.1.2 Advanced models

More advanced modelling implies full mechanistic description of release taking full geochemical speciation into account. The physical constraints to release from monolithic specimen is covered by the release of relatively inert salts like K or Na. Apart from the release, which can be matched with the actual observations in the tank leaching test, information on the partitioning between porewater and the mortar matrix

within the product can be obtained, which is very enlightening as far as processes taking place in the reactive interface between mortar and surrounding is concerned. In figure 11 the concentration profiles of K, Al, Ca, Zn and Pb as a function of depth at a specified contact time (here 30 days) and the concentration profile of Ca as a function of time at a specified depth (here 0.003 mm) are given for a cement mortar exposed to carbonation. K is released as expected for a soluble salt. Al, Ca, Pb and Zn show re-precipitation peaks at the interface region with a prominent calcite precipitation. In case of Ca, this is illustrated also in the time series with mineral dissolution at the interface followed by calcite precipitation.

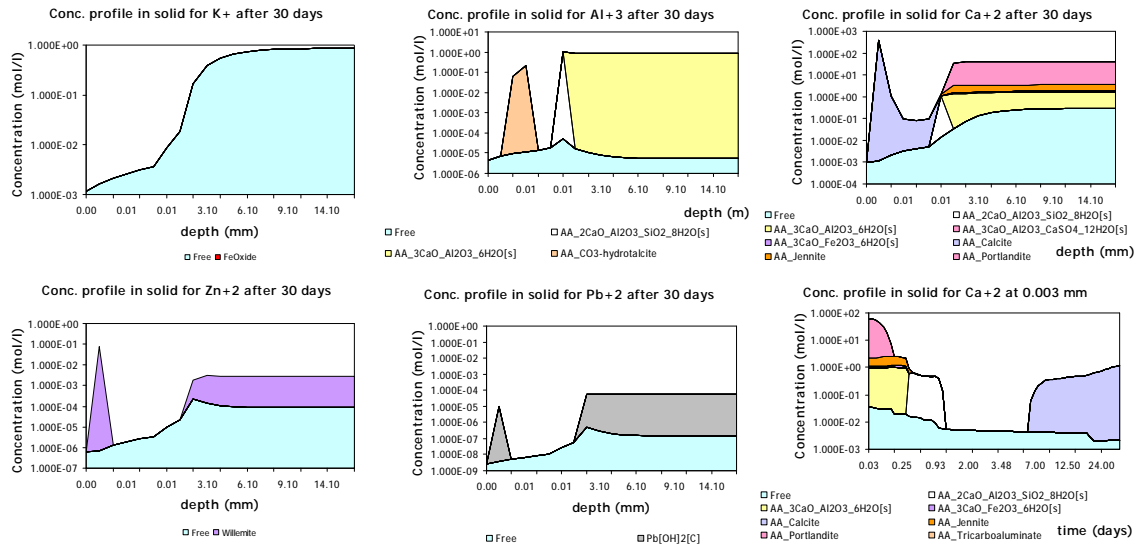


Figure 11. Interface reactions at the cement mortar - carbonated water interface for K, Al, Ca, Zn and Pb as a function of depth and for Ca as a function of time.

4.2 Recycling

Recycling of concrete construction debris in bound applications, such as the use as aggregate in concrete, will not lead to other conclusion as the ones made for the original mortar. However, application in unbound application as for instance in road base application, substantial carbonation may take place depending on the particle size distribution applied. In that situation, oxyanion leachability may increase to levels that come closer to acceptable levels for release to soil and groundwater. In figure 12 a scenario for evaluation of a road base application of unbound aggregate is given.

Approach proposed in CPD to assess impact and to derive criteria similar to scenario approach in EU LFD Annex II

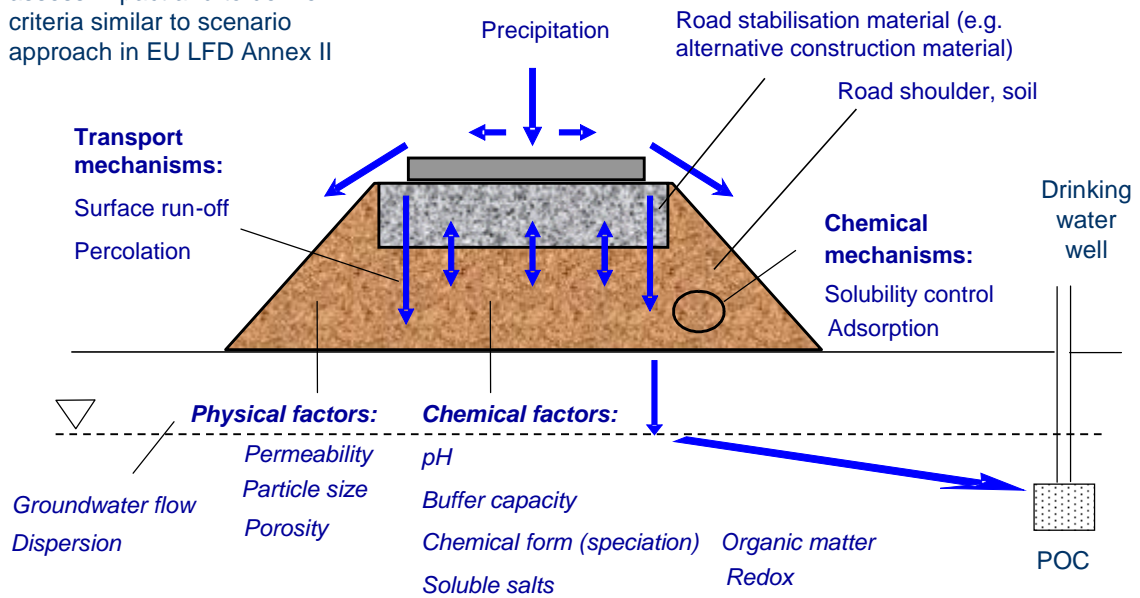


Figure 12. Aspects in evaluation road-base application of unbound material

4.2.1 Simple models

A simple model approach uses a straightforward decay function with fixed release parameters (kappa value) per element. Such an approach was applied in the development of the Dutch Building Materials Decree (1995) and in the development of criteria for the EU Landfill Directive (2002). The limitation is that release from specific materials may not be adequately described by the unified release parameters. For the transport to soil and groundwater a K_d type of approach was used. This has the limitation that mutual interactions between released components does not take place and in some cases an overly conservative approach results, while in other cases an under-prediction of release is noted. It appears that the former is the most prominent.

4.2.2 Advanced models

More advanced models take a full mechanistic approach with full chemical speciation of major, minor and trace elements, as well as preferential flow aspects. The development of such sophisticated models is so far advanced now that their use is becoming more practical. The advantage of such models is that all kinds of exposure conditions, which can not be mimicked in the lab can be modelled and verified against field observations. The latter has not been done sufficiently, but will be needed to provide credibility to the long term release predictions made with such more sophisticated models.

4.3 Criteria at point of compliance

The criteria to be applied at selected points of compliance (POC) are decisions to be taken by regulators.

5. EVALUATION OF ACCEPTABILITY AND LIMITATIONS

The evaluation of acceptability of release from specific materials will be based on scenarios of intended use to ensure a proper evaluation of impact. To decide on WT, WFT or FT, the distance between observed behaviour and possible critical levels can be used. For OPC and blended cement mortars some conclusions are given below.

5.1 Service life

In the initial stages of commissioning drinking water pipes of concrete lead to elevated levels of pH and possibly of Al. During service life this situation of elevated pH and increased Al levels can only occur after a certain time of stagnant water conditions. Management measures can prevent unacceptable pH and Al levels after such an event. For almost any other application with permanent contact with water or on land with intermittent wetting no exceeding of regulatory criteria as judged against the Dutch Building Materials Decree (BMD) is observed.

5.2 Recycling

For bound applications, the same observation applies as mentioned under 5.1. For unbound applications, potentially critical constituents are Ba, Cr, Mo, Ni, SO₄, Sb and V, when judged against the BMD for granular materials. However, this judgement is made for material size reduced to < 4 mm. Aggregate applications are often in a coarser size range, which implies that release may be expected to be smaller. A proper evaluation of these conditions is still needed, as the particle porosity plays a major role in the judgement of the long term behaviour in this type of material.

6. APPLICABILITY OF METHODOLOGY FOR OTHER CONSTRUCTION PRODUCT

In evaluating the above highlighted integrated approach for environmental impact assessment, it is clear that the applicability is much wider than construction materials. The approach covers wastes, stabilised waste, mining wastes, soils, soil amendments, contaminated soils, sediments and sludges. The main issue being a proper description of the source term for release to soil and groundwater. Points of compliance depend on choices made by regulators, but may be set at the material - soil interface for some very hazardous components, at the soil-groundwater interface or a varying distances from the application in groundwater. In figure 13 the various impacts to soil and groundwater that can be addressed by a common approach are indicated. The key aspect in all of these applications is a proper description of the source term. The impact to soil and groundwater will at the European level have to follow a fairly generic approach, as it will be impossible to deal with all the different soil qualities and types in the context of a generic regulatory framework.

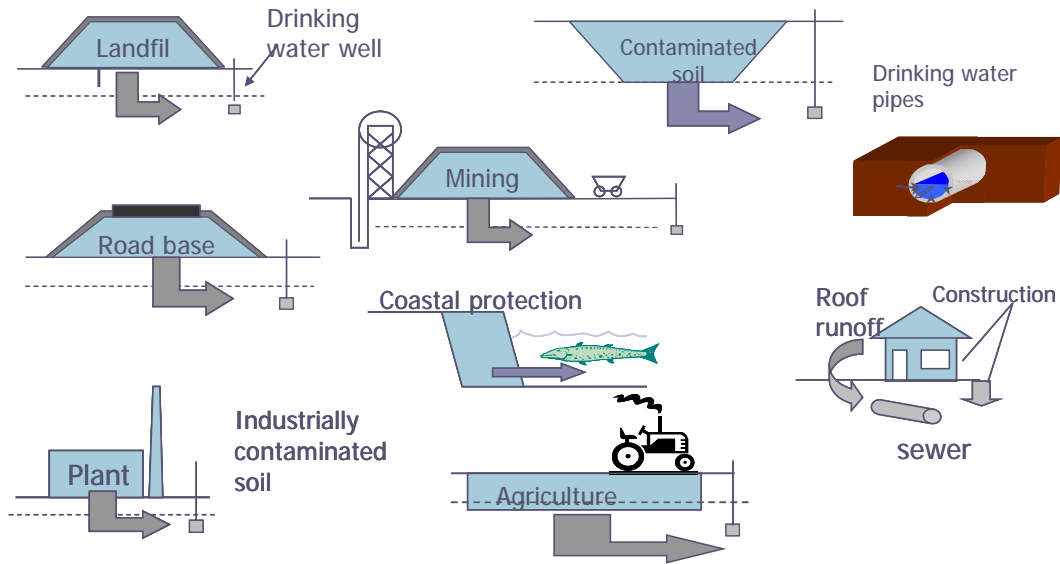


Figure 13. Different impact scenarios on soil and groundwater.

7. CONCLUSIONS IN RELATION TO CEMENT-BASED MATERIALS

A limited number of leaching tests (pH dependence, percolation test and tank leach test) can provide the crucial answers needed to assess long-term impact from both granular (unbound aggregate) and monolithic materials (service life).

To address the complex issue of environmental impact evaluation at the long term too simple approaches lead to poor management decisions.

For monolithic materials the combination of pH dependence test (chemical speciation aspects), the first fractions of a percolation test (pore water estimate) and a form of tank test (time dependent release) is suitable. For unbound recycled materials the combination of pH dependence test and a percolation test is adequate.

The proposed hierarchy in testing provides the necessary detail required by regulators and developers of treatment techniques. It also provides for cost effective verification and QC testing for daily practice.

The proposed limited set of test can cover the range of construction materials relevant for the CPD to the extent that testing will be needed (WFT and FT) or initial type testing is needed to decide on WT (without testing).

The approach presented for inorganic contaminants is equally relevant for organic contaminants and radionuclides.

Good progress has been made in understanding the release processes from monolithic materials (e.g. concrete) and from granular materials (e.g. unbound aggregate).

ECOserve - Cluster 1 Alternative fuels and raw materials for cement clinker production

Leaching of constituents from mortars produced with alternative fuels and alternative raw materials is marginal during service life. From an environmental point of view focus should be on the recycling, in particular, on use as unbound aggregate.

Blended cements based on slag feature low Cr VI leachability resulting from the inherent reducing properties of slag

Chemical speciation using mineral solubility, sorption and organic matter interactions provides identification of release controlling minerals and as such tools to improve product quality.

Modelling of materials mixtures is feasible now based on characterisation of constituting components and will be helpful in designing optimal blended cement mixes from an environmental perspective.

Creating a widely assessable database with environmental data will help to reduce the need for repeated testing.

8. FUTURE DEVELOPMENTS AND RECOMMENDATIONS

- Further development of an integrated expert system that couples test results of materials (characterisation, compliance, pilot studies, field data), intended use scenarios, and regulatory criteria (to the extent available) with chemical speciation and long term impact modelling. In figure 14 the outline of such a system in development is given.
- Development of a proper evaluation of the particle size effect in prediction of release from unbound recycled aggregates.
- Evaluate the possible use of the detailed speciation modelling capabilities for improvement of technical quality (durability) of concrete in different exposure environments (non - environmental aspects of chemical reaction transport modelling)
- Evaluate the effectiveness of CO₂ uptake in construction debris in view of the CO₂ balance in cement production. The present modelling capabilities developed for environmental impact after carbonation can provide relevant information for quantifying rate and magnitude of CO₂ uptake.
- Validation study of characterisation test through TC 351 with participation of European laboratories to obtain performance characteristics for the leaching test methods.-
- Verification of leaching behaviour of predicted blended cement mixtures by testing of such mix designs.

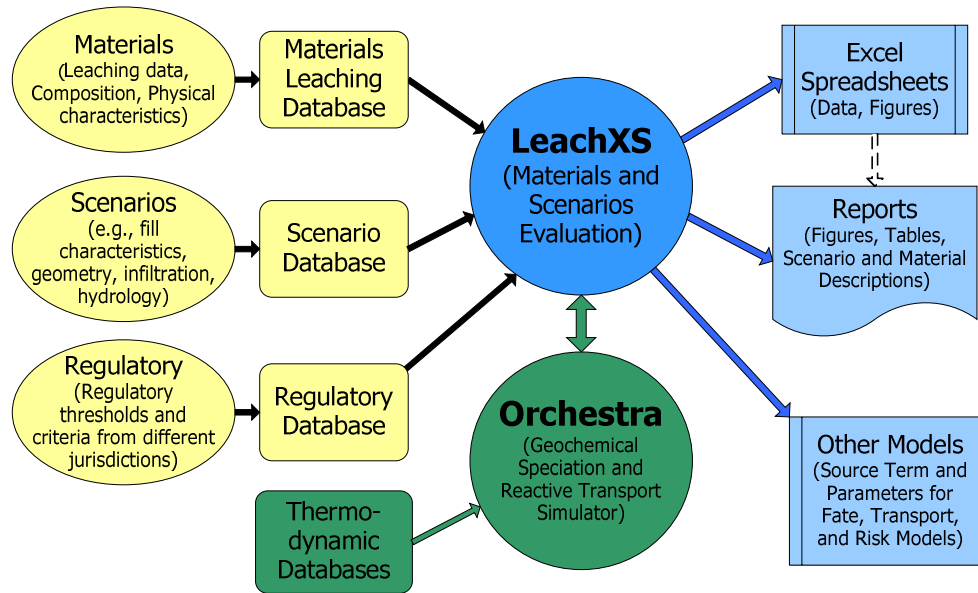


Figure 14. The structure of LeachXS-Orchestra.

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