Mass Flow Analysis and Risk Analysis of Two Modern Superplasticizers

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Introduction

The general trend towards "green" buildings and sustainability leads to a demand for environmental friendly construction chemicals. In addition the environmental behaviour of a newly developed chemical is usually unknown and bears public awareness and legal risks to the producer, distributor and/or buyer of the product. Therefore understanding the movement and fate of new construction chemicals is a crucial step in state of the art risk management procedures (product stewardship). Moreover, analysing the mass flows and the risks of a chemical product enables the producer to understand the risk profile over the entire life cycle of buildings and addressing the risks by appropriate measures.

The presentation will show the potential emissions of modern superplasticizers into the environment as well as the risks to humans and the environment thereof through the entire life-cycle of the product.

Summary of the contents of the paper

Ecological demands on concrete and also the continuous adaptation and development of construction and working techniques represent a constant challenge to researchers and developers of concrete admixtures. An "ecological concrete" is a concrete which according to ecological criteria has an optimized composition of the individual components (sand/gravel, cement, water, concrete admixture, additives) as well as a high durability meeting high technical specifications. The latter is positively influenced by the proper use of modern concrete admixtures [1]. According to FSHBZ statistics approx 14,000 t of concrete admixtures were sold in Switzerland in 1994, thereof approx. 75 % are superplasticizers. Today about one third of all concrete manufactured has been modified with concrete admixtures [2].

Former studies focussed on the environmental behaviour of superplasticizers such as melamine sulphonate polymers and naphthalene sulphonate polymers that were chosen because of their wide range of uses, the total quantity used in construction and their material properties. For these types of concrete admixtures mass flow analyses indicated that with correct use and disposal of these superplasticizers no adverse effects are to be expected for the health of man and environment [1, 3].

In the presented study the fate and risk of two modern superplasticizers (polycarboxylates) throughout their life-cycle are modelled by applying a mass flow analysis. Two different types of polycarboxylates were chosen out of six products, representing a product with stable bonds (best case) and a product with labile bonds (worst case). The two polycarboxylate products are each represented by four different fractions of chemicals, such as active ingredient (polymer), and smaller fractions of not reacted monomers, free polyethylenoxide and biocides. It was defined that each fraction represents a substance group with comparable physico-chemical behaviour and similar degradation characteristics.

To assess the environmental behaviour of the two superplasticizers concrete test cubes were prepared in the laboratory using standardized composition of sand/gravel, cement, water and concrete admixture. After a hardening time of 28 days the concrete cubes were broken with a hammer crusher. The crushed materials were sieved to gain fractions with particle size distributions of 0.063-1, 1-4 and 4-8 mm, respectively. Sequential leaching tests were performed with bi-distilled water and the emissions were quantified by the analysis of the dissolved organic carbon (DOC) concentrations. The results showed that a significant fraction of the total organic carbon in the concrete sample is leaching out of the crushed concrete mostly in the case of the polycarboxylates with labile bonds (worst case). These emissions are dependent on the particle size distribution (Table 1). However, the leachable fraction only comprises monomers or oligomers, but no polymers. In the case of the polycarboxylate with the labile bonds the leachable fraction is readily biodegradable.

Table 1. Cumulative emissions of dissolved organic carbon (DOC) from different particle size fractions in leaching tests with concrete cubes prepared with two different superplasticizers (polycarboxylates)

Test sample	**polycarboxylate with stable bonds**			**polycarboxylate with labile bonds**		
Fraction (mm)	**0.063-1 mm**	**1-4 mm**	**4-8 mm**	**0.063-1 mm**	**1-4 mm**	**4-8 mm**
DOC						
Leaching for 24 h (mg C/kg of concrete)	42.0	33.1	17.4	193	53.8	31.7
Leaching for 48 h (mg C/kg of concrete)	56.0	42.6	24.7	224	74.5	47.7
Leaching for 72 h (mg C/kg of concrete)	68.1	51.6	31.6	242	88.6	58.2
Leaching for 96 h (mg C/kg of concrete)	84.4	60.2	39.7	259	97.5	62.9

The movement and fate of the two selected superplasticizers were modelled based on mass flow analysis by considering different stages in the life cycle of concrete admixtures that could lead to emissions into the environment such as production, transport, storage/handling, use of the concrete admixtures, service life of the building, recycling of concrete after demolition of the building and disposal of building waste and residues. Calculation of the expected concentrations in different environmental compartments were performed on a regional (Switzerland) and on a local basis (e.g. groundwater affected by a recycling plant for concrete) in accordance with the EU technical guidelines [4]. The calculations were also based on results from leaching and biodegradation tests (Fig. 1).

Fig.1. Mass flow analysis of the polycarboxylate with stable bonds in Switzerland (worst-case assumptions, schematic)

Based on the estimated concentrations in the environment as presented in Fig. 1 and the corresponding toxicological data, a risk assessment was developed and will be presented. The largest emissions are expected due to the reuse of old concrete (concrete rubble) in non-bound form such as the application in road foundations. However, due to the low toxicity of the products no significant risks for humans and the environment can be expected.

Conclusions

Large amounts of concrete is manufactured by the use of concrete admixtures today. However, buildings last for 50 up to >100 years. This implies that depending on the reuse of old concrete large emissions could be possible after the demolition of the buildings. New legislation will be in force in the future and it might be possible that up to 100 % of the concrete will be recycled. Since the future cannot be predicted it is advised to eliminate potential problems already during the development phase of products. Mass flow analysis, risk assessment and life-cycle analysis are valuable tools to support future developments in the construction industry.

References.

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