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Environmental Risk Assessment (ERA) and Life Cycle Assessment (LCA) studies of the same product

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1. Introduction

Three studies on the same product have previously been performed within Akzo Nobel Surface Chemistry and the experiences and conclusions from these three studies are compiled in this report. Short presentations of these studies are presented below.

Environmental risk assessment of an adhesion promoter used in asphalt [1]

The aim of this study was to carry out an Environmental Risk Assessment (ERA) of a product, AA017, used as an adhesion promoter in hot mix asphalt. AA017 is a development product from the product called Wetfix I. An Environmental Risk Assessment is a way of evaluating the possible detrimental effects that a substance can have in the environment.

Life cycle assessment of an adhesion promoter used in hot mix for asphalt pavement [2]

The second study presents the results of a Life Cycle Assessment (LCA) of Akzo Nobel's asphalt additive "Wetfix I". This chemical, among other benefits, extends the life of the asphalt pavement in which it is added. The aim of this study was to determine how much the asphalt additive needs to extend the life of the asphalt pavement for the whole system to have a reduced environmental load. The study was therefore connected with an LCA of the asphalt pavement, namely a hot mix.

Comparison between Lime, Cement & Wetfix I from a life cycle perspective [3]

In the third study "Comparison between Lime, Cement & Wetfix I from a life cycle perspective" a comparison was made between the environmental load from the use of Wetfix I, lime and cement in hot mix for asphalt pavement. An alternative to using Wetfix I as an adhesion promoter is to add lime or cement to the hot mix. This study was therefore based on a comparison between these products. All comparisons were made between the used amounts of each product in the hot mix.

2. Environmental Risk Assessment of an adhesion promoter used in asphalt [1]

2.1 Environmental Risk Assessment (ERA)

An Environmental Risk Assessment (ERA) is a procedure for identifying and evaluating the possible adverse effects on the environment, caused by the use of a chemical substance. This is done by estimating the concentration of the substance in the three compartments water, soil and sediment caused by emissions of the substance in different phases of the life cycle and comparing these concentrations with the sensitivity of the species living in these compartments. This means that the Predicted Environmental Concentrations (PECs) in different compartments are compared with the Predicted No Effect Concentrations (PNECs)(see Figure 1). Risk Characterisation Ratios (RCRs) are then obtained by dividing the PECs with PNECs. If this ratio is higher than 1, the substance can constitute a risk to the environment in this compartment. The risks are evaluated for different compartments and for different stages of the lifecycle of the substance. ERA can also show if measures are needed to limit the consequences that a substance can cause and it can point out if further testing or other information about a substance is needed.

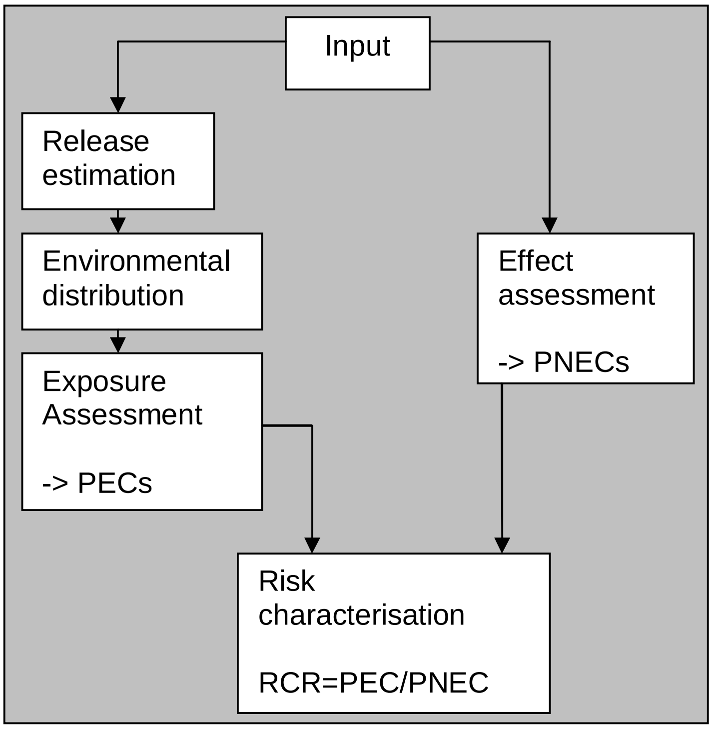

Figure 1. System structure in Environmental Risk Assessment

The assessment performed in this study was done according to the Technical Guidance Document for new and existing substances (TGD) provided by the European Commission. A software called EUSES (European Union System for the Evaluation of Substances) has been used for some of the model calculations.

2.2 Background to the study

The aim of this study was to collect information about the product, AA017, and carry out an assessment of the environmental risks posed by the product, based on the TGD. The substance assessed is the active substance in an asphalt product called AA017. This substance is used to improve the binding between the bitumen and stone material in asphalt. AA017 is a further developed product from a product called Wetfix I.

An environmental risk assessment is a complex way of evaluating the environmental load and impact of a substance. Characteristics of the environment and the substance interact with each other to determine the distribution of a substance in the environment in order to finally estimate a PEC. The model calculations in the program EUSES are very general. A general, average European environment is defined and used in the distribution calculations and general release tables are used in the cases where no other information is available. Therefore, the results from this kind of modeling should be seen only as a hint of a possible environmental risk posed by the substance in the defined applications. Further studies may then be conducted in order to further specify emissions, substance information or circumstances surrounding the applications. Emission sources that may not have been noticed before can also come into the light during the study.

2.3 Results from the study

The RCRs for the production show no risk in any of the environmental compartments. The highest RCR is for the water and consequently the sediment compartment. The production site is located near a large river and the water is treated in a water treatment plant, which result in effective water treatment and a large dilution factor. These circumstances have large influence on the results. The assessment on the regional scale shows that there are no risks on that scale and this is very likely since this substance is not so widely used and the amount produced is relatively small.

During the formulation, i.e. the mixing of AA017, bitumen and aggregate, some AA017 may evaporate, especially if the mixing is done under high temperatures, but the RCRs do not indicate any risks to the environment.

It could not be excluded that AA017 may constitute a risk to the environment during the construction and use of a road. More information about the releases and distribution of adhesion promoters near by roads and pavement areas is needed.

2.4 Discussion

An important aspect when discussing the result of this study is the fact that almost all of the used data on the inherent properties of AA017 are either from similar products, calculated or estimated. The distribution calculations largely depend on the value of K_{OW} (octanol-water partition coefficient) and since no data for this parameter could be found it was calculated. However, since the substance is highly surface active, i.e. it concentrates on or between surfaces, these calculations are very unreliable. This results in very uncertain distribution and exposure modeling i.e. the PEC. The PNEC is based on only one eco-toxicological value for a substance similar to AA017 and thus there are large uncertainties in the PNEC. The very restrictive assessment factor of 10 000 will however most likely assure that the risks are not underestimated.

A conclusion from this study is that the only stages in the lifecycle that seems to be of concern are the construction and use stages at the local scale since no emission data at all are available for these stages. There is thus a need for further testing and information in order to be certain that there are no risks associated with the construction and use of AA017.

3. Life Cycle Assessment of an adhesion promoter used in hot mix for asphalt pavement [2]

3.1 Life Cycle Assessment (LCA)

Life Cycle Assessment (LCA) is a method for assessing the potential environmental impacts associated with a product by identifying and quantifying energy and materials used as well as emissions and wastes released into the environment. The assessment covers the entire life cycle of the product, including extraction and processing of raw materials, manufacturing, transportation and distribution, use, re-use, maintenance, recycling and final disposal.

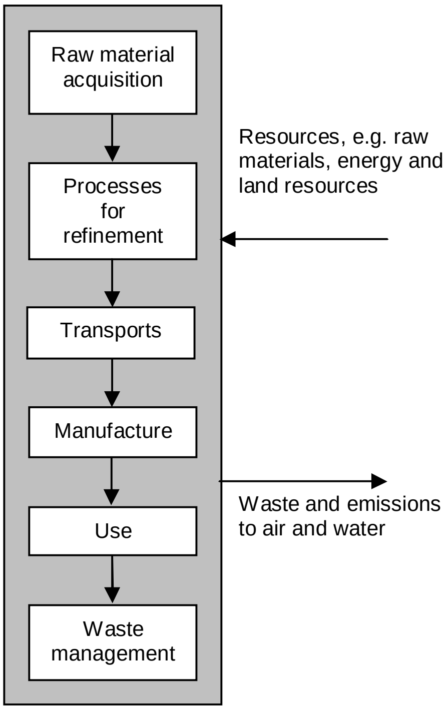

Figure 1.1 A model of a product's life cycle. The boxes represent physical activites

3.2 Background to the study

The aim of this study was to determine how much the asphalt additive needs to extend the life of the asphalt pavement in order for the whole life cycle to have a reduced environmental load. The main contributors to the total environmental impact were identified and improvement possibilities could be revealed. The goal of the study was achieved by comparing Wetfix I with the necessary additional maintenance of the asphalt pavement, namely a hot mix.

Wetfix I represents the adhesion promoters used in hot mix. It is a surface-active substance that concentrates at the interface between bitumen and the the aggregate. It is required at low use levels ranging from 0,2 to 0,4% by weight of bitumen. Wetfix I is an alternative to lime or cement use. Its raw materials are a polyamine (VEA = Various Ethylene Polyamine), Tall oil Fatty Acid (TOFA) and a solvent. The production also requires the use of water, isopropyl alcohol (IPA), nitrogen and of course electricity and steam. The asphalt is a hot mix of aggregate (94% by weight), bitumen (6%) and Wetfix I (0,024%). The functional unit is the asphalt pavement of a 1km x 13m average Swedish countryside road over 40 years (including the maintenance).

With the help from suppliers, manufacturers and users, the constituents of the asphalt pavement are tracked back to their cradle, thus including the extraction and production of raw material and energy resource (for heat or electricity) and the transportation of the raw materials. The production, and transportation of the Wetfix I as well as the pavement aggregate and the paving and maintenance of the road are also included.

3.3 Results from the study

The results from the environmental inventories of the asphalt pavement life cycle and of the Wetfix I show that the environmental impact of the adhesion promoter is equivalent to 2% of the total impact from the asphalt pavement life cycle. This result is based on the CO_2, NOx, SO_2 and HC emissions to air and on the use of natural energy resources (crude oil and natural gas). This result implies that there is an environmental benefit from the use of the adhesion promoter provided that it reduces the maintenance need, and consequently the lifetime, of the asphalt by more than 2%.

The main contributor to the total environmental impact of Wetfix I is VEA. It is the source of more than 90% of the air emissions and requires 92% of the total crude oil resource used although it only represents 40% of the final product by mass. It is worth noting that more than 70% of the air emissions from VEA are due to earlier phases in the life cycle of VEA and the raw materials dichloroethane, ammonia and sodium hydroxide are responsible for most of the air emissions and energy requirements.

The main contributors to the air emissions and depletion of fossil fuel resources of the total life cycle of pavement are the bitumen and the heat for the hot mix production. The impact from bitumen is due to the transport of crude oil / bitumen by tanker from Venezuela to Sweden and, by far less, due to the extraction of bitumen in Venezuela. Both activities have relatively high air emissions and crude oil requirements.

4. Comparison between Lime, Cement & Wetfix I from a life cycle perspective [3]

4.1 Background to the study

In this study a comparison was made between the environmental impact from the use of Wetfix I, lime and cement in hot mix for asphalt pavement. All comparisons are based on the used amounts of each product in the hot mix in order to achieve the same durability of the pavement. In contrast to the use of lime or cement, adhesion promoters are in general required much lower levels in the pavement.

All life cycle phases prior to production have been included in the assessment, like natural resource extraction, raw material production and transports. The main energy resources and amount of air emissions for hot mix and the three different additives are based on the amount of hot mix and additive used in the pavement.

The basis for the calculations is one asphalt layer of a 1km x 13m road. Usually 1,5-2,0% of the aggregate is added as cement or lime. 1,5% was chosen in this example. The amount of added Wetfix I is normally 0,2-0,4%. In this study 0,3% is used. An asphalt layer of a 1km long road therefore consists of 1235 ton hot mix and additionally 17 ton cement or lime or 0,2 ton Wetfix I.

Note that even though increases of environmental load due to the additives are discussed here, the additives increase the lifetime of the road and the total environmental load will therefore decrease when additives are used.

4.2 Results from the study

It can be noted that the emissions to air (CO_2, NO_x, SO_2) and use of natural resources (crude oil, natural gas) are larger from the hot mix than from the additives compared in this study. About 95% of the energy resources used for hot mix are crude oil (40%) and natural gas (55%).

Table 1. Increases of environmental impacts by adding Wetfix I, lime or cement to hot mix used in asphalt pavement.

	Energy resources	CO_2	NO_X	SO_2
Wetfix I	1%	1%	1%	1%
Lime	10%	65%	10%	10%
Cement	5%	20%	10%	10%

It can be concluded from these results that adding lime or cement have a much larger impact on the environment than using Wetfix I

5. Comparison between the ERA and the LCA of adhesion promoter

The ERA study indicates that the use of an adhesion promoter in the asphalt pavement may signify a risk to the environment during construction and use and that further information about these phases is needed. There are however no risks to the environment during the production and formulation of the product according to the results of the study.

The LCA study shows that the main contributor to the total environmental impact from the asphalt additive is the production of one of the raw materials, VEA. The LCA also shows how much an adhesion promoter needs to extend the life of an asphalt pavement in order to yield a reduced environmental impact of the pavement.

The ERA and LCA studies point out different hot spots in the life cycle for the same product. In an ERA the focus is on the emissions of the active substance in the product and the possible effects that the substance can have in different environmental compartments, while in an LCA the focus is on all of the potential environmental impacts the use of a product gives rise to.

The comparative study between lime, cement and Wetfix I from a life cycle perspective add further aspects to the environmental impact assessment of the use of an adhesion promoter in asphalt. The use of Wetfix I is compared with the alternatives, lime and cement, and the LCA study shows that the environmental impacts from Wetfix I are much smaller than from the alternatives.

An LCA does usually not take eco-toxicological or toxicological aspect into consideration and it would therefore be beneficial to weigh the environmental impacts that the LCA points out against the results of an ERA. In combination, Life Cycle Assessment (LCA) and Environmental Risk Assessment (ERA) form a very good overall view of the possible environmental impacts from a product, in this case an adhesion promoter.

6. Discussion

It is difficult and maybe not useful to join the two different tools Life Cycle Assessment (LCA) and Environmental Risk Assessment (ERA) into one integrated tool. Both assessments are time consuming and costly, especially if the required data are difficult to retrieve. The two tools also have different perspectives on the product/function.

LCA is considering the consumed resources, emitted emissions and produced wastes a particular function (be it a product or service) gives rise to and tries to predict the potential environmental impacts of these. ERA is considering the possible releases of a single substance from the different uses of that substance and tries to predict the risks of eco-toxicological impacts from that particular substance. LCA summarizes all of the releases of different substances, e.g. CO_2 for the whole life cycle, while ERA considers each release of the substance separately.

ERA can be included in an LCA by making some kind of generic ERA of the toxic releases included in the LCI (Life Cycle Inventory), but this requires so much work that it becomes undoable.
LCA gives a more overall picture of the environmental impact from the use of a substance than an ERA and can be a good complement to an environmental risk assessment, maybe in a socio-economic analysis in the risk management of a substance.

7. References

1. Christina Berggren - Environmental risk assessment of an adhesion promoter used in asphalt; 2002
2. Ries Adeline – Life Cycle Assessment of an adhesion promoter used in hot mix for asphalt pavement; 2001
3. Karin Löfnertz - Comparison between Lime, Cement & Wetfix I from a life cycle perspective; 2001