LCA Case Studies

Life Cycle Inventory for the Production of Zeolite A for Detergents

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Abstract

Zeolite A is a crystalline aluminosilicate which has been used as a builder component in laundry detergents for many years. An LCI for the production of Zeolite A ("cradle-to-factory-gate") was carried out on behalf of the European Zeolite producers. Data from five European production sites were collected to generate an average LCI for Zeolite A. The plants covered more than 77% of the total European production in 1993 an therefore represent an average situation. The original LCI tables show detailed figures about raw material, intermediates and auxiliary material consumption. The overall energy flow for the production of 1 t of anhydrous Zeolite is 22400 MJ with a minimal spread of +/- 5% over the individual companies. Furthermore 25 air emission parameters and 35 water emission parameters are listed and categorised with respect to their origins e.g. process dependent, transportation, thermal energy and electricity production.
Each company is able to compare their individual data with the average LCI to identify any opportunities to improve production processes. In addition, this LCI of Zeolite A provides the basis for any further LCA studies of a product containing Zeolite A, including comparisons and assessments.

Keywords: Cradle-to-factory-gate, zeolite A; detergent production, LCA; laundry detergents; LCA; LCI, European zeolite A producers; LCI; Life Cycle Assessment (LCA); Life cycle inventory (LCI); phosphate; software "EcoPro"; zeolite production.

1 Introduction

The heightened awareness of the importance of environmental protection together with the possible impacts associated with products manufactured and consumed, has increased the interest in the development of methods to better comprehend and reduce these impacts. One of the methods being developed for this purpose is Life Cycle Assessment (LCA). It notably includes a Life Cycle Inventory (LCI), the phase of LCA involving collection and quantification of inputs and outputs for a given product system.

Detergents, as one of those products used in everyday life activities, have received specific attention, mainly because of the annual consumption of about 5.5 million tons in the EC (situation in 1993). In 1992 the Association of the Swiss Soap and Detergents Industry (SW1) commissioned LCAs on detergents and cleaning agents by the former LCA-Group of EMPA St. Gallen. From this first exercise it became obvious that these LCAs are most reliable if they can be supported by manufacturers of the corresponding ingredients rather than by its users. The European Detergent Zeolite Producers (ZeoDet) volunteered to carry out a life cycle study on the environmental effects of Zeolite A. Therefore an LCI of the production of Zeolite A was commissioned by the ZEODET Sector group of the European Chemical Industry Council (CEFIC). The full LCI study has been published as EMPA report N° 234 (FAWER, 1996).

Zeolites are a well defined class of crystalline aluminosilicate mineral. They occur naturally but also more than 150 types have been synthesised. In the seventies Zeolite A was developed as a detergent builder. Builders are ingredients which perform a number of functions in laundry detergents. The most important one is to soften the wash water by complexing the calcium and magnesium ions. Furthermore, builders provide an environment in which surfactants can efficiently remove soil and stains from textiles (ZeoDet, 1993).

This material is now well established as a builder component in the US, Europe and Japan. In 1993, world-wide production capacity for Zeolite A

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exceeded 1.2 million t; divided regionally between Europe, 540000 t; North America, 390000 t and the Far East, 270000 t. In the same year the European consumption was 520000 t.

2 Goal and Scope

The purpose of the study was to generate and publish an authentic and accredited LCI for the production of Zeolite A using a "cradle-to-factory-gate " approach. This comprises the flow of energy and raw materials, emissions to air and water and solid waste generation.

The aim was to trace back all production processes to the extraction of raw materials from earth and to calculate average data for the production processes of Zeolite A employed in Europe. The average LCI has been evaluated for general use (clients, consumers and government bodies) and augments the Detergents Ingredients LCI database. A further objective was to achieve and promote positive collaborations between the individual companies and zeolite manufacturer.

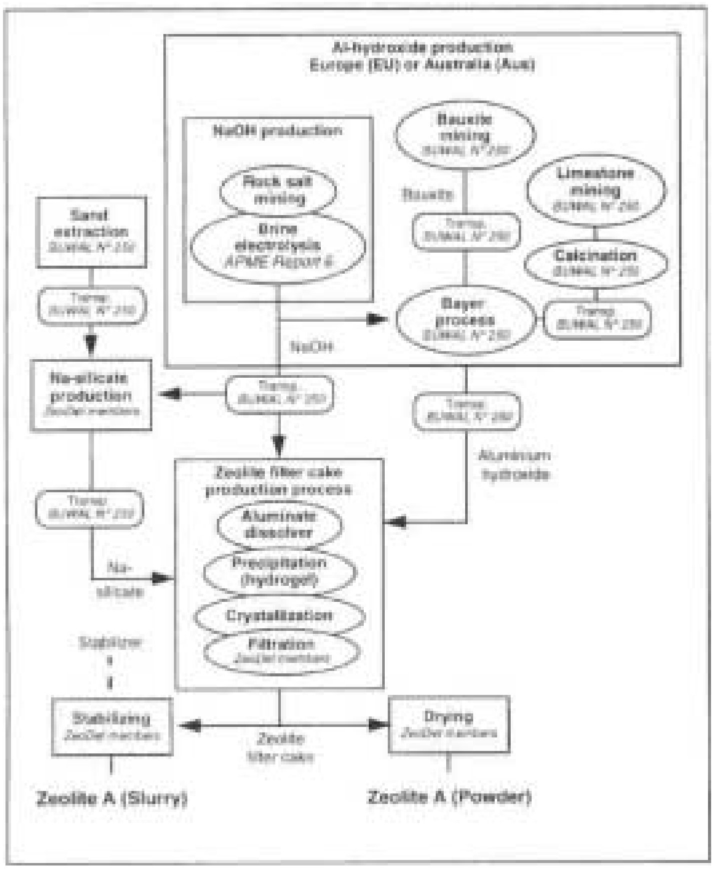

Fig. 1: Schematic flow chart for the production of Zeolite A.
Italic: Origin of data

Company specific information may be compared with the average LCI as an internal **bench marking process** which helps the individual producer to recognise the major potentials of **improving** their production processes environmentally.

The methodology applied was based on the principles of SETAC ['Code of Practice', 1993) and ISO (ISO/CD 14040, 1996). Figure 1 describes the system boundary of the Zeolite A life cycle study and the origin of data. The data collected referred to routine day-to-day operations of the processes, energy generation plants and transport.

The commercial production of detergent Zeolite A is worldwide mainly conducted using the aluminosilicate hydrogel route. Raw materials for this production route are sand, sodium chloride and bauxite. Sodium chloride is electrolysed to produce caustic soda (NaOH), which is used to convert bauxite to sodium aluminate and sand to water glass (sodium silicate). In the zeolite production process, sodium silicate and sodium aluminate solutions are mixed together, resulting in the formation of amorphous sodium aluminosilicate. This material is hydrothermally crystallised and filtered to yield Zeolite A filter cake, then further processed either to a slurry or a powder, which are the end-products of the described system.

For consistency the inventory data were calculated on the basis of the production of 1 t anhydrous Zeolite A (dried 1 h at 80WC). The functionality of the two different forms of Zeolite A is exactly the same concerning the performance of Zeolite A in the detergents. Subsequent use of Zeolite A in a detergent product and its final disposal were not included.

3 Inventory Results

In practice it is found that the gross energy requirement for the production of "Zeolite A filter cake", which is the common basic material for the slurry and the powder products, lies in the range of 21400 - 25200 MJ/t (anhydrous). The weighted average energy flow is 22400 MJ/t and is identical with the figure for Zeolite A slurry. A comparison chart of the aggregated data is presented in **Table 1** including figures for the commercial products slurry (50% active material) and powder (80% active material). Air and water emissions are only shown in a reduced parameter list.

The slurry form is economically preferable if delivery distances are short i.e. below the critical point where transport of water costs less than its removal at source. 150000 t, expressed in the anhydrous state, are distributed as Zeolite A slurry. The slurry is an

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aqueous suspension of Zeolite A (48-50%), stabilised with 1.5% surface-active substances (3.0% on anhydrous material), in order to prevent sedimentation. The surfactants function as the ones normally used in detergents and are therefore taken into account when formulating the final product. For this study the production of the surfactants is not included in the system yet. Only the amount of surfactants is given as information needed to elaborate an LCI for a certain detergent. At that stage the production of this surfactant must be included in the overall system.

From the total production of "Zeolite A filter cake", 250000 t, expressed in anhydrous state, are dried to powder. This process is mainly expressed in the use of electricity and gas. Air and water emissions for the final gas burning are average figures from an energy data base. 1 t of Zeolite A in powder form therefore uses slightly more energy (26450 MJ).

Table 1: LCI of Zeolite A - slurry and powder: Comparison chart

Weighted Average Functional unit	kg	LCI of Zeolite A Slurry 1000 kg anhydrous	LCI of Zeolite A Slurry 1000 kg 50% hydrated	LCI of Zeolite A Powder 1000 kg anhydrous	LCI of Zeolite A Powder 1000 kg 80% hydrated
Raw materials					
Bauxite	kg	762	381	762	609
Sand	kg	467	233	467	373
Rock salt	kg	222	111	222	177
Limestone	kg	40	20	40	32
Intermediates for zeolite filter cake + silicate prod.					
Washed sand	kg	467	233	467	373
NaOH 100 (50%-aq.)	kg	336	168	336	269
Na-silicate Na2O+2SiO2	kg	636	318	636	509
Al-hydroxide (Al(OH)3)	kg	606	303	606	485
Auxil. materials for zeolite filter cake + silicate prod.					
Water for steam prod.	m^3	1.5	0.8	1.5	1.2
Compressed air	Nm^3	64.7	32.4	64.7	51.8
*Cleaning agent	kg	1.7	0.9	1.7	1.4
*Filter cloths	kg	0.08	0.04	0.08	0.06
*Water conditioner	kg	0.07	0.03	0.07	0.05
*Stabilizers (tensides)	kg	30.6	15.3	30.6	24.4
Energy flow (Delivered energy)					
Electricity	MJ	7'780	3'890	8'537	6'830
Coal	MJ	826	413	508	407
Oil heavy	MJ	4'529	2'265	4'561	3'649
Oil average/light	MJ	766	383	749	599
Diesel oil	MJ	556	278	593	474
Gas	MJ	7'838	3'919	11'419	9'135
Others	MJ	94	47	94	75
Total	**MJ**	**22'388**	**11'194**	**26'461**	**21'169**
Recyclable materials					
Alu-residues	kg	3.1	1.6	3.1	2.5
NaOH (ca. 15%-aq.)	kg	87.4	43.7	87.4	69.9
Solid waste					
Mineral waste	kg	45.1	22.6	45.1	36.1
Red mud from bauxite mining	kg	206.8	103.4	206.8	165.5
Inert chemicals	kg	10.4	5.2	10.4	8.3
Slags and ash	kg	5.1	2.6	5.1	4.1
Regulated chemicals	kg	11.0	5.5	11.0	8.8
Water consuption					
Process water	m^3	2.2	1.1	2.2	1.78
Cooling water	m^3	14.1	7.1	14.1	11.3
Washing water	m^3	2.7	1.4	2.7	2.2

4 Conclusions

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The LCI for Zeolite A was carried out using the latest information about Zeolite production processes and the pre-combustion of required intermediates and energies. The data presented are therefore a good representation of average European practice during the year 1993. The methodology applied in this study is in compliance with the standard procedures of SETAC and ISO. A critical review, performed by three independent experts, supports the study. The critical review panel concludes that in general the methodology of the LCI is sound and that it has been carried out with commendable care and thoroughness using data which have been carefully collected and critically evaluated.

Each of the companies involved now knows their own LCI and is therefore able to compare these figures with the average LCI for Zeolite A and can determine any ecological weak points or identify any production process improvement opportunities (Hot spot analysis). This procedure is often an iterative one and, ideally, should be repeated periodically.

The LCI data generated in this Zeolite A study may subsequently be used to conduct full LCAs on detergent product systems, including comparisons and assessments. In particular, they can provide a basis for comparing the environmental characteristics of different builder systems. However, because the inherent builder properties of zeolite systems may be fundamentally different from those of other systems due to different hardness-ion properties and reaction rates any such comparison must be properly undertaken. Above all, this necessitates the correct specification of the functional unit, such that the performances delivered in practical washing systems are equivalent. Defining such functionality is a specialised undertaking in which all pertinent attributes of the systems and of the products themselves must be considered.

Remarks:

In the last few years several LCI or LCA studies have been conducted assessing the total environmental impact of builder systems, from cradle-to-factory-gate or final disposal (Phosphate report, 1994 and others). Since it is very difficult or misleading to compare inventory data from different studies without knowing and understanding fully the main issues under which an LCI has been performed, the process of comparing and critically reviewing two of the actual Zeolite LCI reports was carried out in a subsequent extension of the study. The purpose of the comparative study was to identify the main differences between the Landbank Phosphate Report, which also published LCI "data" for zeolite, and the present EMPA Zeolite A LCI study. It has focused on the inventory procedure of both exercises and therefore included neither the impact assessment step nor a critical review of the equivalent washing performances of the sodium tripolyphosphate (STPP) versus the Zeolite A - polycarboxylate (PCA) builder system.

The main differences between the two studies were found to be:

- Product form
  The two LCIs are based on different product forms. The EMPA-study specifies the output material as 1 t anhydrous Zeolite A dried at 800°C. The Zeolite A in the Landbank-Report is not clearly specified but from the input materials it is assumed that it must be hydrated and therefore contains 20% water.
- Pre-combustion energy
  Following SETAC and ISO recommendations it is necessary that the investigated system includes all operations involved in generating and converting energy (pre-combustion). This has not been included in the Landbank Report. This is rather surprising for an LCI carried out in 1994 especially because other studies have shown that pre-combustion can contribute up to 35% of the total energy flow of a process or a whole system. It must be recognised that pre-combustion energy has been excluded for all the systems reported by Landbank and must be stated anytime these data are compared with other LC1s.
- Data sources
  The data for Zeolite A in the studies are from different sources. Those for STPP were obtained directly from the manufacturing process but those for Zeolite and PCA were taken from the technical literature and patents. The sources are thus inconsistent in terms of quality, age and geography and are therefore disparate.

There is obviously a need for further clarification of the Landbank methodology and data sources. Therefore any quotation or comparison of the Landbank-data with any other LC1s needs a careful and transparent interpretation.

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