LIFE CYCLE ASSESSMENT OF SODIUM CLORIDE PRODUCTION AND TRANSPORT

FRANZ GOETZFRIED[1], BRITTA STRATMANN[2], DIETLINDE QUACK[2]
[1]SUDSALZ Gmbh, Heilbron, Germany
[2]ÖKO-INSTITUT e.V., Freiburg Germany
e-mail: franz.goetzfried@suedsalz.de

ABSTRACT

Aspects of a sustainable production are increasingly discussed. As contribution for this discussion on the methodical basis of a life cycle assessment (LCA) relevant salts (rock salt, vacuum salt, sea salt) were compared. For the study of Südsalz together with the German Öko-Institute e.V., Institute for Applied Ecology, the life cycle of the salts was considered from the raw material extraction to the salt storage at the salt production site ("cradle-to-gate"). Transport to the customer was considered in the context of an analysis of sensitivity. The balances showed that the sea salt extraction has the smallest impact on the environment compared with the two other kinds of salt.

KEYWORDS: Life Cycle Assessment, sea salt, rock salt, vacuum salt

INTRODUCTION

The study was accomplished in accordance with the life cycle assessment methodology, which is standardised by the ISO 14040:2006 „Environmental management – Life cycle assessment -Principles and Framework "as well as ISO 14044:2006 - 10„ Environmental management – Life cycle assessment - Requirements and Guidelines". In a life cycle assessment as comprehensively as possible the entire product life way and the associated ecological effects are seized and the consumptions of energy and materials arising during the product life and the potential environmental impacts resulting from it are quantified.

For the set up of the life cycle assessment the software tool Umberto 5.5 was used, software which is based on the concept of the material flow nets. In the study the three types of salt, different after their manufacturing process were examined: rock salt (extracted by mechanical mining) vacuum salt (manufactured from brine with the multiple effect and mechanical vapour recompression procedure) and sea salt (evaporation of sea water and crystallization of NaCl).

In agreement with the goal and scope with this study the following impact categories were considered:

- Primary energy consumption (cumulated energy expenditure) in megajoule equivalents,
- Greenhouse gases (global warming potential) in kg carbon dioxide equivalents (CO_2eq),

- Formation of photo chemicals (summer smog potential) in kg C_2H_2 equivalents (C_2H_2eq),
- Eutrophication potential in kg PO_4 equivalents (PO_4eq),
- Acidification potential in kg SO_2 equivalents (SO_2eq),
- Land use of the production plants, and
- Salty waste water (bitterns etc.)

Data for rock salt

The specific data of the year 2008 for the German rock salt mine Heilbronn (capacity 4,500 kt NaCl/year), whose extraction depth amounts to approx. 200 m, were used. Heilbronn extracted the salt in the year 2008 about 70% by the blasting method and about 30% by continuous mining. In the comparison with the other relevant European mines and their annual productions the data from Heilbronn illustrate the average situation quite well and can being regarded as representative. The dry finished salt has a purity of 98 to 99 % NaCl with a residual moisture content of 0.2 %. The study used the German electricity mix.

Data for vacuum salt (multiple effect procedure)

The specific data for the production of vacuum salt with the multiple effect procedure come of the engineering company Evatherm AG. They represent average values for a typical five-step evaporation plant with a capacity of 500 kt NaCl/year. This corresponds approximately with the average vacuum saltworks size in Europe. For the calculations a centrifuge-wet salt with 2-3% water content and the electricity mix of the Netherlands were used. The production of the raw brine takes place with solution mining. For the brine production data were used from the company DEEP, which orients itself at the brine production for large vacuum saltworks with yearly capacities from 1,200 to 2,400 kilotons.

Data for vacuum salt (mechanical vapour recompression, MVR)

Specific consumption data for the production of vacuum salt by means of MVR are based on effective values of the German saltworks Bad Reichenhall (capacity 300 kt NaCl/year) for the year 2007. They correspond to the today's state of the art and are world-wide valid for modern MVR plants. They vary only within the range of the brine purification process, their chemicals consumption depends of the composition of the raw brine, and within the range of the salt drying process (grade of drying). For the salt drying process the situation of the saltworks Bad Reichenhall was represented here, where by a 1:1 - mixture of centrifuge-wet and dried vacuum salt the desired road salt moisture of approx. 1-1.5% is received. This procedure illustrates both the situation of the vacuum salt production with MVR in Germany as well as in Austria and Switzerland. The calculations took place with the German electricity mix. Within the scope of the study was a brine production with combined mechanical and solution mining and pump out of natural underground brine.

Data for sea salt

The specific data for the electricity consumption of the different pumps, the conveyors and different machines as well as for the diesel consumption of the harvesting machines come from Salt Partners, and refer to a sea salt plant in West Australia with a capacity of 3,000 kt NaCl/year. These data are comparable with the data for large sea salt plants in the Mediterranean area, e.g. in Southern France, Tunesia and Egypt. Salt washing as well as a thermal salt drying process were not considered. It proceeded from residual moisture of the finished salt of 4% and the French electricity mix, which is dominated by nuclear power.

RESULTS

The results show that for the life cycle assessment of salt productions only the cumulated primary energy consumption and the greenhouse potential of importance are. The other impact categories can be neglected (Table 1).

Table 1. Overview of the total results per functional unit (1 ton salt) for the production of the three salt types

Impact category	**Unit**	**Sea salt**	**Rock salt**	**Vacuum salt**	
				Multiple effect	**MVR**
Cumulated energy consumption	MJ	68	195	2,247	2,486
Greenhouse potential	kg CO_2eq	1	13	139	155
Acidification potential	kg SO_2eq	0.01	0.03	0.12	0.23
Eutrophication potential	kg PO_4eq	0.00	0.00	0.01	0.02
Smog potential	kg C_2H_2eq	0.00	0.00	0.02	0.01

It becomes clear that sea salt and rock salt production have the smallest impact on the environment compared with the vacuum salts. In particular the sea salt extraction has the lowest primary energy consumption and therefore also the lowest greenhouse potential. The production of vacuum salt uses 10 to 30 times more energy than the extraction of sea salt and rock salt. The vacuum salt production is dominated by the high electrical (MVR) and steam consumption (multiple effect procedure). The rock salt production consumes electricity and diesel fuel, and the large sea salt plants are consumer of fuel mainly. The greenhouse gases emissions connected with the production of salt are strongly dependent from the salt plants energy supply: own production of electricity and steam in a cogeneration plant or purchasing electricity and steam; the biggest influence has the respective regional or local electricity mix (coal, oil, gas, nuclear power, hydropower, etc.).

For a comprehensive view it is necessary also to consider the transport of the salt to the customers. Selected means of transport (truck, train, ship) and the distance of the salt producers location to the salt destination are of big relevance (Figure 1 and 2).

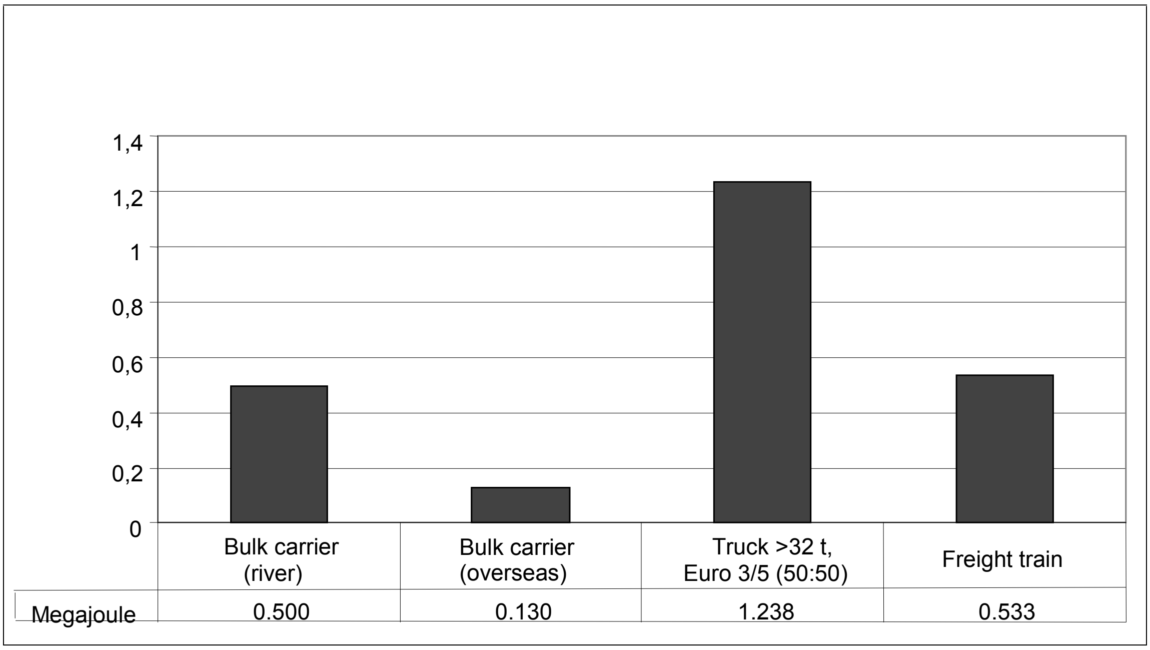

Figure 1. Cumulated energy consumption (Megajoule) for selected means of transport per tonne-kilometre (tkm) (averaged freight train driven with 37.5% diesel and 62.5% electricity).

Despite the ecological superiority of sea salt and rock salt also vacuum salt has its right of existence. In areas where only brine from a solution mining operation is available and not sufficient sun and wind or large suitable land surfaces for a solar salt production is present, there is the production of vacuum salt the only possibility to get crystallized salt. Also the quality requirements to the salt, requested by different applications, can be fulfilled often only by vacuum salt, which is manufactured from brine or by recrystallization of sea salt or rock salt. This is valid for example for the salt for water treatment (ion exchanger regeneration, disinfection through on-site electrolysis) and for the salt for pharmaceutical applications (dialysis, infusions). Vacuum salt can be also an alternative to sea salt and rock salt as feedstock for the chlor-alkali electrolysis; the relative costly manufactured vacuum salt puts, due to its high purity, aside a full brine treatment in the electrolysis plant for the separation of calcium, magnesium, sulfate and insoluble matters, how it is necessary with rock salt and sea salt. Also the production of vacuum salt for the use as food salt can make sense, if the available rock salt quality is too low, as it is for example in South Germany the case, or if sea salt qualities are very bad, as in Bangladesh.

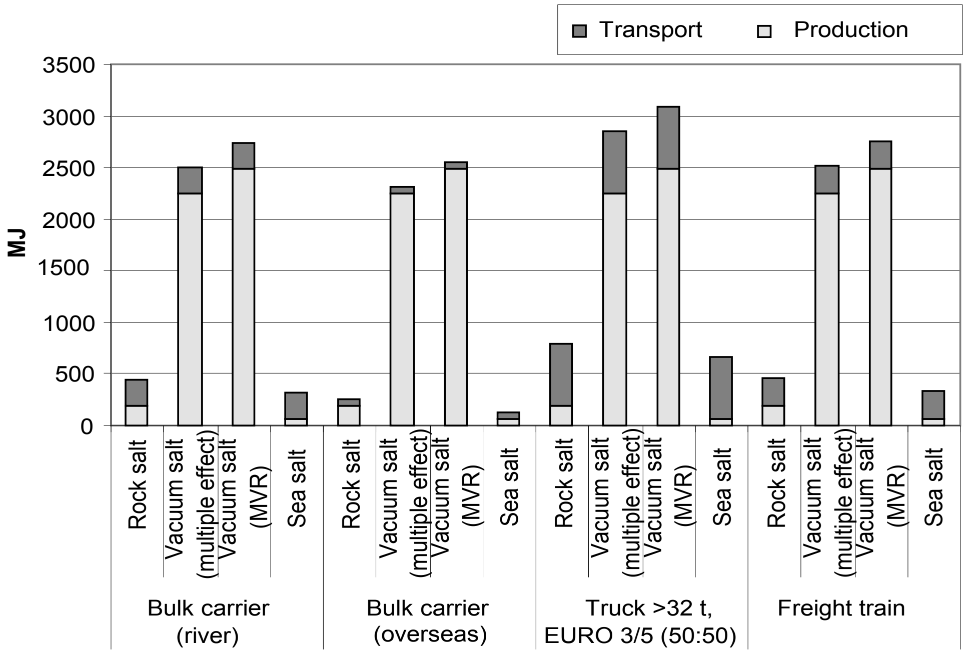

Figure 2. Energy consumption in Megajoule (MJ) for the production and transport (500 km) of 1 ton of salt.

REFERENCES

1. A. Marques et al., *Sustainability Assessment of Traditional Solar Salt*, Proceedings of the 2nd International Conference on the Ecological Importance of Solar Saltworks (CEISSA 2009) Merida, Yucatan, Mexico, 26 – 29 March 2009, p. 88 – 97.
2. Climatop, *Klimabilanz: Speisesalz im Kanton Waadt*, Factsheet 26.08.2009.
3. G. Specklin and M. Matrat, *Sustainable Development and Winter Viability: The case of public markets for road salts in France*, Proceedings of the XIIIth PIARC International Winter Road Congress, Québec 2010.
4. D. Quack, B. Stratmann and F. Goetzfried, *Comparative Life Cycle Assessment of different De-icing Salts: Rock Salt, Vacuum Salt and Sea Salt*, Straße und Autobahn 2/2010, p. 80 – 88.