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ENVIRONMENTALLY EFFICIENT MANAGEMENT OF WATER RESOURCES IN THE GERMAN POTASH INDUSTRY (a)

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1. Abstract

Water is essential for nearly all separation processes in the potash industry. While cooling water leaves the plant almost unchanged, water used in wet separation processes becomes a saline solution, almost saturated with one or more salts such as sodium chloride and magnesium chloride.

Dry electrostatic separation, multiple use of water and strict separation of weak and highly salinated solutions reduces water use to the unavoidable minimum.

Intermediate storage in retention basins and controlled and monitored disposal of waste water into natural flowing waters ensures acceptable environmental conditions and compliance with existing legal limits.

2. Water Supply

The processing of crude salts that contain potassium and magnesium salts, and in particular the production of potassium sulphate and highly purified products, is heavily dependent on the use of water. Additionally, the German potash plants have their own power stations, in which water is needed to produce boiler feed water.

Fig. 1: Werra river at Widdershausen

Although surface water in the form of river water or bank-filtered water can be used for cooling processes and the production of standard products, water of at least drinking quality is needed to produce highly purified products for the chemical and pharmaceutical industries. The raw water used as boiler feed water also needs to be of drinking quality, in order to minimise the use of treatment chemicals and thus to minimise the amount of waste generated by such treatment.

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In view of these quality requirements, the German potash industry uses river water, bank-filtered water, groundwater and spring water. In addition, sites without water extraction facilities of their own draw their water from the public water supply

The extraction of water from surface waters or groundwater is a form of surface water utilisation. Under the terms of the German Water Management Act, the abstracter must obtain a permit or licence. In the context of the approval procedure, it must be regularly demonstrated that the quantity of water abstracted is necessary for the given purpose and is to be kept as low as possible in line with good engineering practice.

In Germany, the choice of the quality of the raw water to be used is subject to certain constraints. The necessity for using water of a higher quality must be demonstrated from case to case. The qualitative order of priority is as follows:

- Surface water (e.g. river water, bank-filtered water)
- Spring water
- Ground water

Whenever possible, surface water should be used. Only if surface water is not suitable for the intended purpose water of a higher quality can be used.

3. Extraction of River Water

An intake system usually has to be constructed in or on the river to enable river water to be abstracted. The intake should not impair the natural flow of the river, especially at times of high water or flooding. The intake is therefore designed to take account of the visual impact and recreational value of the river landscape. Any additional river maintenance costs caused by the intake is generally borne by the abstracter.

When water is abstracted from small watercourses, it may first be necessary to dam the watercourse. Furthermore the passage of fish, in particular, to the upper and lower reaches of the watercourse must not be impaired or blocked. If necessary, fish ladders must be constructed.

The extraction of river water is restricted in the licensing process to the extent that a minimum flow must always be guaranteed, including the low-water periods.

Fig. 2: Fish pass at Salzdetfurth, Lamme river

4. Extraction of Bank-Filtered Water

The quality of bank-filtered water is similar to that of river water, but the soil acts as a filter and thus removes the organic and inorganic suspended matter that is inevitably present in directly abstracted river water. This eliminates the need for filtering to be carried out at the point of use, thus avoiding the generation of solid wastes when the filters are back-flushed. The quantitative constraints are the same as those that apply to the extraction of river water.

Fig. 3: Extraction of bank-filtered water

5. Extraction of Spring Water

The quality of spring water is often equivalent to that of drinking water. If it is used in the chemical or pharmaceutical industries to produce highly purified products for human consumption, its chemical and hygienic properties should be regularly analysed.

Compared with the extraction of water from wells, the extraction of spring water has the advantage that it does not affect the quantitative status of the groundwater.

Fig. 4: Visible part of tapping water (Nauses spring at Ronshausen)

However, constraints may also be placed on the extraction of spring water if such extraction can be expected to have a negative impact of the natural environment or the landscape, especially along the course of the spring water flow. An environmental impact assessment will serve as a basis for deciding whether the spring water can be used without restriction or whether a minimum flow must be maintained.

Fig. 5: Groundwater well Ziegelei at Wölfers-hausen

6. Extraction of Groundwater

The extraction of groundwater from wells always affects the quantity of available groundwater. For this reason the amount of water that can be abstracted from a well is always limited.

Pumping trials are carried out to determine the yield of a well. The fall in the groundwater level caused by pumping at a constant rate of flow is determined over a measured period of time. When pumping is stopped, the rise in the groundwater level is plotted over time until the original level is reached.

The yield of the well is calculated from the curves of the falling and rising groundwater level. Furthermore, the extent of the fall in the groundwater level can be calculated for a given quantity of abstracted water. The maximum amounts of water that can be abstracted over different periods of time are then defined in the licensing procedure on the basis of these experimental results.

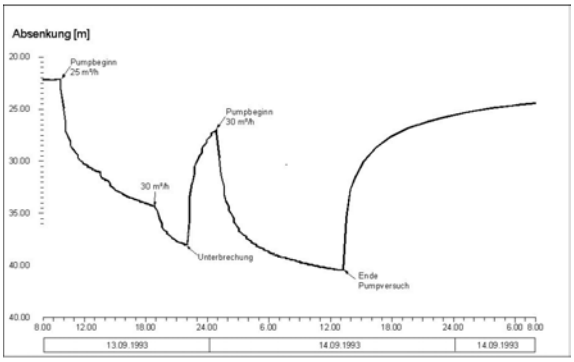

Fig. 6: Lowering of groundwater level in a pumping test

This process ensures that the rate of groundwater extraction never exceeds the rate of groundwater replenishment.

7. Wastewater Disposal

The amount and composition of the wastewater from a potash plant depends largely on the composition of the crude salt and the processing method used. The production of highly purified products is also usually associated with very high levels of water consumption and large volumes of waste water. A sylvinitic crude salt, which contains no other salt of oceanic origin other than sodium chloride and potassium chloride, can be processed to obtain standard potassium chloride with 60% K_2O (95% purity), generates hardly any waste water, because the amount of water that has to be added during the flotation process does not significantly exceed the amount of water that evaporates from the product during the drying phase. Nevertheless, the production of industrial quality potassium chloride with 62% K_2O (99% purity) unavoidably results in the generation of waste water. The amount of waste water generated increases considerably if hartsalz or carnallite is used instead of sylvinite, and if magnesium salts or potassium sulphate or extremely pure products for the pharmaceutical industry are produced.

Depending on the use of the supplied water, therefore, a potash plant generates different types of waste water:

- Cooling water
- Rinsing and cleaning water
- Waste brine

The discharge of waste water into surface waters is a form of surface water utilisation that requires a permit or licence. The approval process requires demonstrable proof that the quantity and harmfulness of the wastewater are kept to a minimum in line with good engineering practice.

Such a licence to discharge waste water into surface waters generally imposes controls and reporting obligations on the discharger.

8. Disposal of Cooling Water

In the potash industry, cooling water is almost exclusively taken from rivers. Most of the cooling water is used in the loss stages of the vacuum cooling plants in the hot leaching process. The cooling water is not chemically changed but is simply subjected to a temperature increase, i.e. a physical change.

After the river water has been used as cooling water it is discharged into a watercourse. Care must be taken that the receiving water is not subjected to an excessive thermal load. In the licensing procedure, therefore, the maximum allowable temperature of the receiving water is defined. In most cases it is between 28 and 30 degrees Celsius, depending on the sensitivity of the watercourse. For the purpose of satisfying the limits set by the respective government agency and to avoid the escape of waste brine from the site, the salt content of the cooling water is monitored by continuously measuring its conductivity prior to discharge.

The temperature of the water in a small watercourse cannot be maintained below the limit value when large amounts of water are abstracted and simply discharged back into the watercourse after use. In such cases, plants install their own internal re-cooling systems, through which most of the cooling water is cycled; only a fraction of the total cooling water cycle is abstracted from the watercourse and discharged back into it. The internal re-cooling ensures that the temperature of the water in the watercourse remains within ecologically acceptable limits.

9. Disposal of Rinsing and Cleaning Water

When saturated salt solutions are used, encrustation occurs in building, containers and plant components. The encrusted salt has to be regularly removed with water. This generates rinsing and cleaning water with a low salt content relative to the saturated salt solutions. This water is therefore suitable for use in other parts of the production process (water reuse). To facilitate this, potash plants have constructed separate systems for diluted and near-saturated salt solutions. This allows cleaning water to be reused several times, thus minimising total water consumption.

Rinsing and cleaning water is reutilised in the production process, provided this does not impair the quality of the products. However, the special quality demands of extremely pure products for the chemical and pharmaceutical industries make these types of water unsuitable for their production.

Where an unusable excess of rinsing and cleaning water is generated it is generally discharged into a watercourse.

10. Disposal of Waste Brine

Waste brine is waste water that is almost fully saturated with salts. It is unavoidably generated by the production processes in potash plants. The composition of the waste brine depends on the composition of the processed crude salt, the production processes employed and the products of these processes.

At K+S KALI there are two different types of waste brine:

- Waste brine with a low magnesium content from the processing of sylvinite in the Sigmundshall (Lower Saxony) and Zielitz (Saxony-Anhalt) potash plants;
- Waste brine with a high magnesium content from the processing of hartsalz in the Neuhof (Hesse) potash plant and the Werra potash plant sites in Hesse and Thuringia.

The unavoidably generated waste brine is disposed of in two ways:

- Underground storage in a geologically suitable horizon (sheet dolomite);
- Discharge into a suitable watercourse.

11. Storage of Waste Brine in Geologically Suitable Horizons

Waste brine from the potash plants on the Werra and Fulda has been disposed of in a porous rock layer (sheet dolomite) at a depth of approximately 400 m since 1925. This sheet dolomite layer is located above the potash deposits. Above and below it are water-impermeable clay layers, which separate the brines from other groundwater. The sheet dolomite rock formation contains saline formation water, which is unsuitable for human consumption. The introduction of waste brine into this porous aquifer diplaces formation water, some of which creeps through cracks and fissures into surface water. The waste brine, which is denser than the formation water, is confined into a lower layer.

Trough structures in the sheet dolomite can therefore be used for the long-term storage of waste brine without significantly impacting the quality of groundwater and surface water.

Fig. 7: Deep well disposal of saline water (Herda 10 at Gerstungen)

A large number of groundwater monitoring wells have been specifically sunk for the purpose of measuring the effects of this form of waste brine disposal. Groundwater samples are regularly taken from these wells and analysed. This monitoring is based on a measurement and observation plan, which is regularly updated in consultation with the respective government agency. Numerous springs and wells in the vicinity are also included in this programme. The government agency in charge prepares an annual report of the monitoring results.

12. Discharge of Waste Brine into a Watercourse

K+S KALI potash plants are licensed to discharge waste brine into a watercourse, provided defined limits are not exceeded in the receiving water. In general, a limiting value is set for the chloride content of the receiving water, as a sum parameter for the salt content. Moreover, at sites with very hard waste brine (waste brine with a high magnesium content) a limiting value is also set for the water hardness.

Additionally, sudden large fluctuations in the salt content of the receiving water system must be avoided. For this purpose the potash industry has constructed systems consisting of retention basins and discharge controls, which ensure that the discharge of waste brine is directly related to the condition of the receiving water (flow, prior pollution level, compliance with the set limits). The salt content of the watercourse is continuously monitored with conductivity probes. The chloride content is determined from the conductivity with the help of a regularly updated and re-assessed correlation function.

Fig. 8: Waste water disposal at Dorndorf (Werra river) with self-acting sampling equipment

The discharges are continuously monitored by the dischargers and the government agency. As a result of the above-mentioned reporting obligations, the competent authority is always aware of the quality of the receiving water.

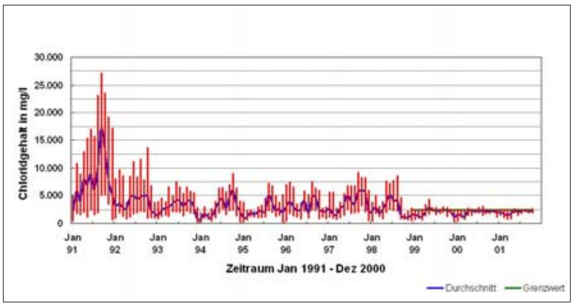

Fig. 9: Chloride content of Werra water at Gerstungen

Fulda, Ulster, Werra and Weser were studied in detail from 1993 to 1997 in the context of comprehensive investment measures aimed at reducing salt pollution. Alongside the physico-chemical parameters, special attention was paid to the biological factors in particular. The studies showed, that the increased salt content had caused changes in the flora and fauna, and in particular in the species profile of benthic diatoms, the macrozoobenthos and fish, relative to natural bodies of water with a low salt content. Instead of the expected freshwater species profile, there had been a shift towards salt-tolerant species in Ulster, Werra and Weser.

On the basis of these results it can be assumed that at least Werra must be regarded as having been heavily modified by human activity. In this case, the river must have a good ecological potential and no further deterioration of the quality of the river can be allowed.

The German potash industry has applied these principles for many years and has continuously reduced the water pollution by implementing suitable measures to avoid and reduce waste water.

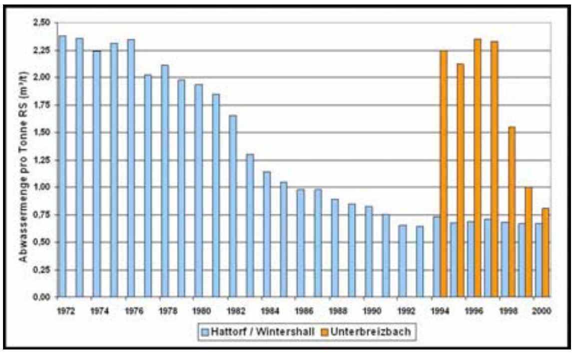

Fig. 10: Abatement of specific amount of waste water

The chloride content of Werra has fallen considerably between 1990 and the present day. The very high concentrations of the early 1990s have been steadily reduced and concentrations since 1999 have remained at a relatively constant low level. The salt content fluctuations, which were in excess of 20,000 mg/l in 1991, have been cut dramatically and now amount to only a few hundred mg/l.

The Hattorf and Wintershall sites in Hesse have continuously reduced their wastewater volumes since the 1970s. In line with good engineering practice, they have maintained a specific wastewater volume of approx. 0.7 m³ per metric ton of processed crude salt since 1992. After the potash industries of Eastern and Western Germany merged, wastewater-reducing measures were also introduced at the Unterbreizbach site in Thuringia. It is clear that this site, too, has achieved a major reduction in its specific wastewater volume.

13. <u>Conclusions</u>

Water use and wastewater disposal in the German potash industry now generally complies with common accepted environmental standards, especially the German and European water directives. However the quality of the receiving water systems (e.g. the Werra and Weser river basins) has been affected by the saline waste water. Continuous measures have been taken by the German potash industry to minimize all detrimental affects on our environment and to ensure acceptable water qualities.