Operational Paper

Modern plant technology for sludge treatment and volume reduction at Grane dam waterworks

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ABSTRACT

The introduction of a dosing unit for sulphuric acid at the Grane waterworks of the Harzwasserwerke GmbH in Germany has reduced the quantity of aluminium sulphate required for the treatment of the barrage water. The operating times of the filters were increased while the quantity of residue was reduced. Also, the availability of the treatment plant and its capacity were increased. The treatment residues are now separated in the newly installed solid treatment plant. The sludge with a residual water content currently 20% (containing contaminants originating from the barrage water and applied flocculants) is used in a brick factory.

Key words | backwash water treatment, barrage water treatment, sulphuric acid dosing, treatment of solids

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INTRODUCTION

Water from barrages requires specific treatment, based on its actual properties, to be suitable as drinking water. Such a treatment must be economically viable. Standard solutions for treatment might become uneconomical, as they might not, or only partly, fulfil the requirements. Continuous monitoring and inspection of the treated water and the applied method are of crucial importance to ensure and further improve the desired quality and safety of the water. On the one hand, this requires that the actual and desired data of the plant are known in detail. On the other hand, it is of equal importance to know exactly how improvements in relation to cost-effectiveness combined with optimum availability can be made. The monitoring and the regulation of the treatment process are thereby the main tasks of the plant. The plant management and plant designers must work closely together, as this ensures that all experiences gained in the operation of the plant are considered in the design of new, improved plants, units and components.

HARZWASSERWERKE GMBH

Harzwasserwerke GmbH, Hildesheim, Germany, supplies drinking water to cities, communities and industrial estates in the North-German plain. The company owns a water supply network of 518 km with a drinking water output of 86.5 million m^3 (1999). The water is partly collected in the large barrages in the western part of the Harz mountains, and partly taken directly from the ground in the North German lowlands. Figure 1 shows the supply network of Harzwasserwerke.

Harzwasserwerke GmbH employs 260 people, of which 110 are based at its administrative centre in Hildesheim. Another 150 staff work in 13 branch offices. The company's turnover in 1999 was approximately euro 35 million, including the draw-off charge of 5 cents m^{-3} of drinking water payable to the state of Lower Saxony.

The Grane dam waterworks

At the Grane dam near Langelsheim, Harzwasserwerke operates a drinking water treatment plant, which supplies drinking water (1999: 35.7 million m^3) via two main supply lines to the region north of the Harz mountains up to Braunschweig (Grane East) and to the area stretching to Hildesheim/Hannover up to the Mittellandkanal (Grane West).

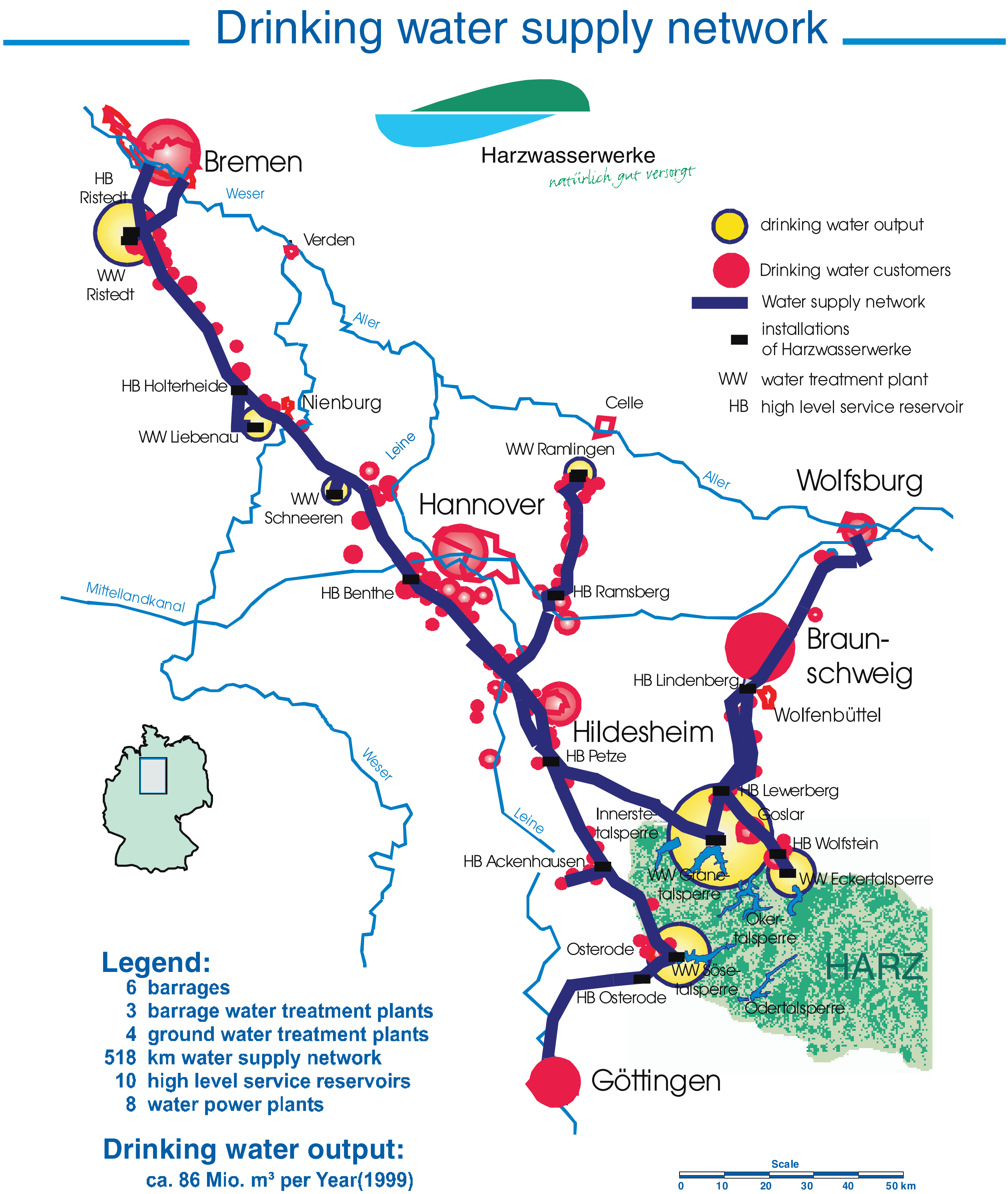

Figure 1 | Drinking water supply network of HARZWASSERWERKE GMBH.

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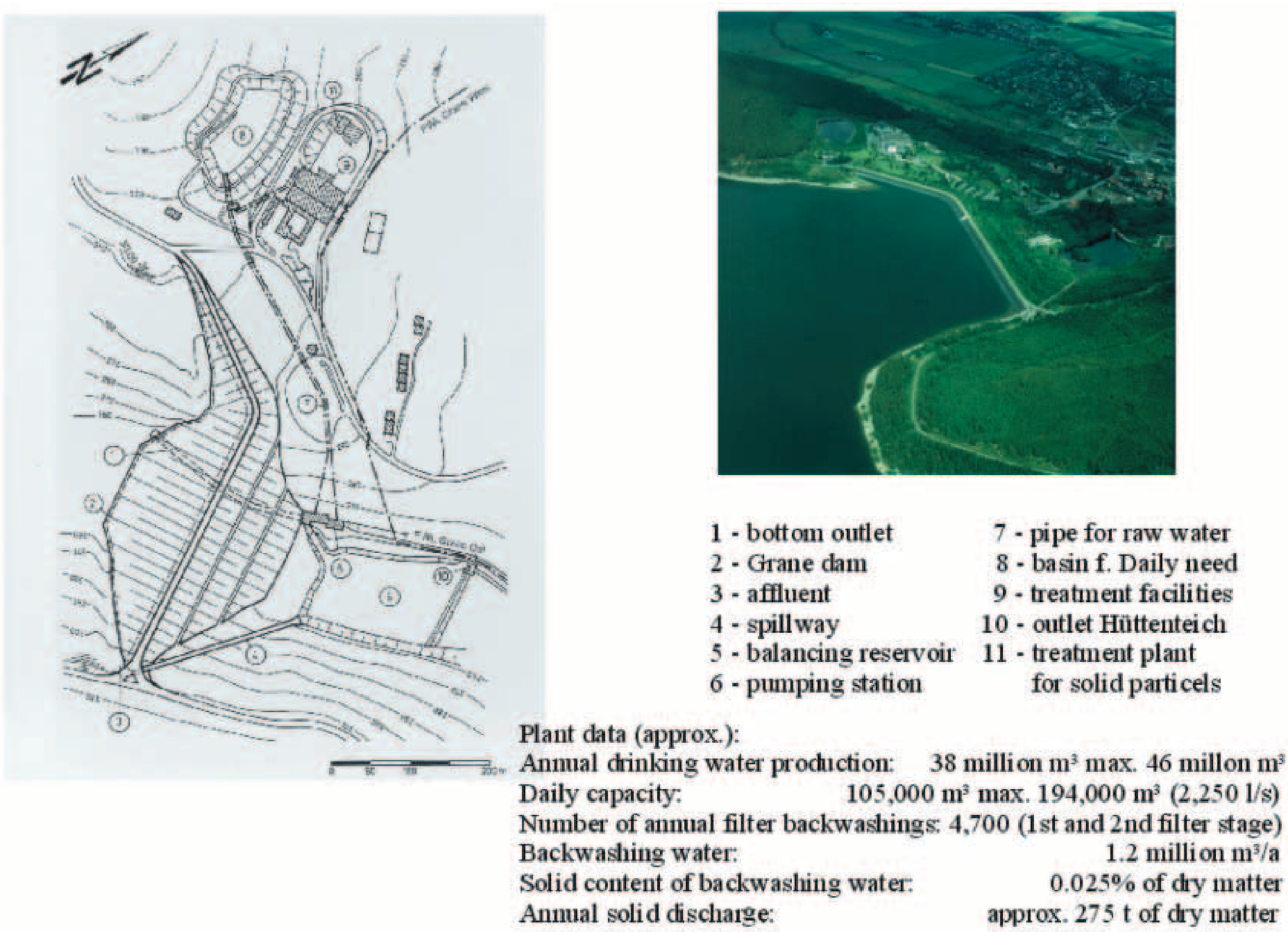

Figure 2 | Grane dam and connected plants.

Water treatment

The water collected in the Grane reservoir contains a number of substances that prevent the water from being suitable for use in households and industry. Furthermore, this water cannot be transported over long distances. Therefore, the water of the lake is treated and purified. The required treatment plant consists of a raw water station with pumps, a raw water storage basin, a filter plant, general premises and a treatment plant for solids.

For treatment, the water is taken via the bottom outlet of the Grane dam and pumped to an open basin located above the waterworks. From there, it flows into the waterworks. Figure 2 shows the Grane dam and connected plants.

The water is treated as follows: pH adjustment with sulphuric acid (since 1997), flocculation with aluminium sulphate and flocculant, filtration through a sand filter (first filter stage), pH adjustment by addition of lime water and contact-catalytic demanganisation via sand filters (second filter stage). The water treatment plant contains 40 accelerated filters (each of 54 m^2, with 1.8 m of quartz sand, grain size between 1.2 and 1.8 mm). The purified water is disinfected with chlorine gas.

Depending on the actual load (raw water quality, quantity of aluminium sulphate, pumping rate), the filters of the first filtration stage are cleaned after 28 to 48 hours, while those of the second stage are backwashed after 168 to 300 hours. Backwashing is carried out with water (filtrate of the respective filter stage) and air.

During a filter backwashing process, approximately 300 m^2 of backwashing water is produced in 15 min. This water is collected in the sedimentation basins (eight basins of approximately 360 m^3 volume).

When a sedimentation basin is filled with backwashing water and the solid parts have sedimented after a while, the cleared water on the surface is separated from the sludge liquor at the base according to the programme settings. The clear water is brought via a pipe to the drainage ditch of the Grane. The sludge liquor collected in the cones of the sedimentation basin is transferred to a storage basin.

Since 1998, the sludge liquor in the storage basin has been further processed and dehydrated in a solid treatment plant, where it is compacted, dehydrated and dried. The water is returned to the sedimentation unit, where it is mixed with the water used in the backwashing of the filters.

TASKS

Between 1987 and 1996, the volume of backwashing water required in the Grane treatment plant increased from approximately 2% to nearly 4% of the produced drinking water volume. This increase was caused by the improved quality standard of the water, the need to maintain this high quality at all times and to have the plant's capacity available. To optimise the operation, a number of extension and renovation works were carried out from the mid-1990s.

Until 1997, the pH adjustment necessary for flocculation was carried out with acidic aluminium sulphate solution. In order to achieve acceptable pH values for flocculation, up to 4 g of aluminium sulphate per cubic metre raw water was added on top of the quantity actually necessary for flocculation in the first filter stage (equivalent of 40% of necessary quantity). The resulting superfluous flocculant had a negative impact on the first filter stage and led to an increased sludge quantity.

The following objectives should be reached with an extension of the plant:

- Separation of pH adjustment and flocculation/destabilisation
- Optimisation of flocculation by exact adjustment of flocculation pH
- Reduction of flocculant quantity to the quantity actually required for the process
- Extension of filter cycle from 40 to approximately 52 h maximum, depending on the health and safety aspects
- Improvement of availability of plant also in special circumstances (high water) and sufficient drinking water supply during periods of peak demand, irrespective of raw water situation.

The increased quantity of sludge resulting from the higher dosing rates of aluminium sulphate led to a situation in which the sedimentation basins for the separation of the sludge liquor and the solid particles were filled faster than envisaged. The capacity of the collection ponds for sludge liquor and solid particles would have been exhausted within a few years. An extension of these ponds is currently not possible, due to the restrictive statutory regulations. Therefore, the only measures that could be taken were the reduction of the quantity and the processing of sludge towards subsequent recycling.

These overall objectives provided additional tasks:

- Reduction of the quantity of solid particles brought into the sedimentation basins
- Processing of the sludge liquor to obtain a transportable, possibly recyclable form.

PLANT EXTENSIONS

The above objectives resulted in plants that are considerably closer to the general scope of drinking water production with minimum waste, thanks to the application of state-of-the-art technology. The plants were mainly designed, tested, implemented and commissioned by the staff of Harzwasserwerke GmbH.

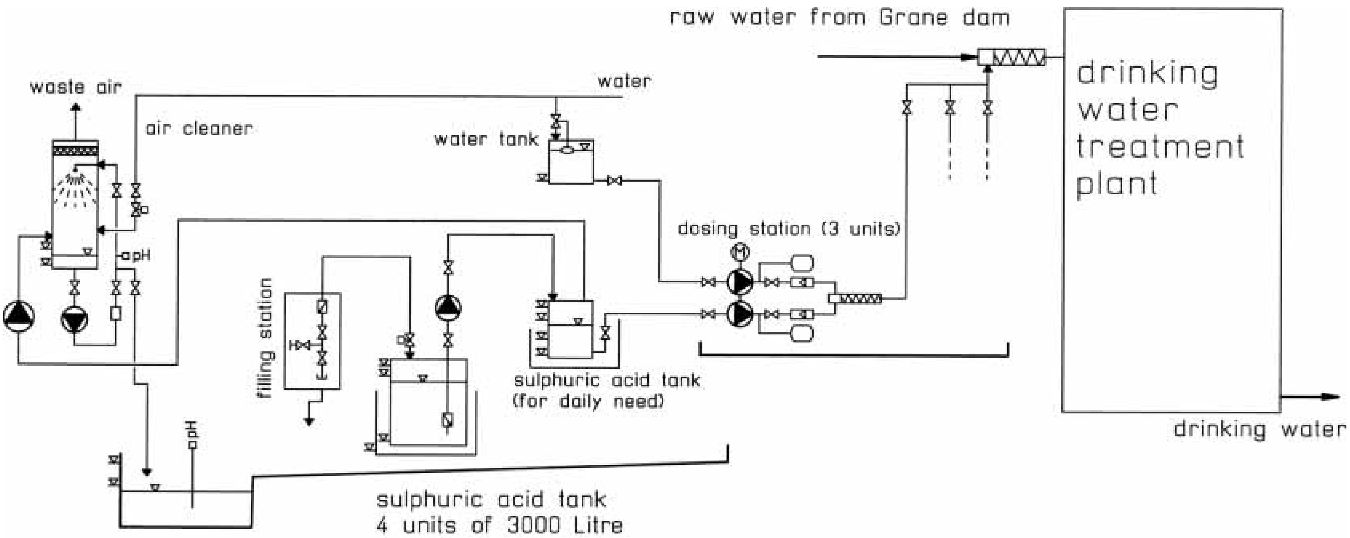

Figure 3 | Diagram of the sulphuric acid plant.

Sulphuric acid plant

By means of an additional dosing of acid, the pH of the supply water to the reaction basin of the first filter stage is adjusted in such a manner that a reduction to approx. pH 6.5, which is the ideal value for flocculation, can be achieved by the addition of aluminium sulphate.

The sulphuric acid is administered by means of double membrane piston pumps. They ensure a regular supply of sulphuric acid and the required water for dissolving at a fixed ratio from the preparation tanks to the inoculation inlet of the raw water line. The solution is mixed with the raw water by means of a static mixer. The dosing quantities are based on the quantity of drawn raw water. The volumes are measured with magneto-inductive volumetric flow meters and adjusted by means of a regulator with respective quantity settings. The dosing quantity can be adjusted by means of modification of strokes per minute or stroke length. One dosing unit with pump is assigned to one of the two waterworks sub-plants. An additional pumping station is available on stand-by. Figure 3 shows the sulphuric acid tank and dosing station.

After a gradual increase in the quantity of sulphuric acid added and the resulting reduction in dosed aluminium sulphate, the following quantities were achieved: 5 g sulphuric acid m^{-3} raw water (in reference to 100% acid); aluminium sulphate reduced by 4 g m^{-3}.

Treatment plant for solid particles

The collected and settled sludge liquor is no longer transferred to the collection ponds but processed in a dehydration and drying unit. The sludge volume is considerably reduced by this treatment. Solid particles are processed to granular, dry, bulk material, which can be disposed of with normal household waste, should a situation arise where further processing of the bulk material would not be possible due to its composition.

In the planning phase of the project, various solutions were evaluated. Of special importance were the following objectives:

- Use of a simple, multi-stage plant technology and redundant construction
- Minimal energy input
- No or only minimal quantities of additives (e.g. flocculants)
- Full control of dehydration and drying process as well as processing rates, thanks to multi-stage design

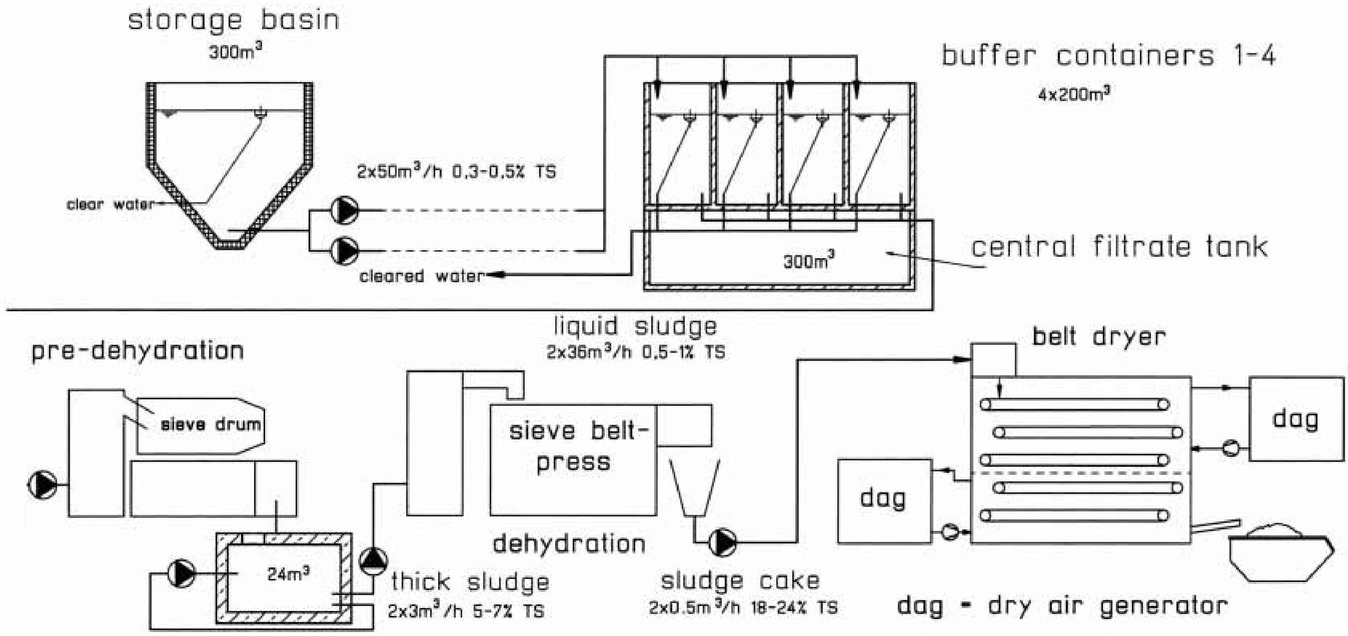

Figure 4 | Diagram of the solid treatment plant.

- Avoiding of hazardous or difficult to manage by-products such as flue gases, dust, etc.

Nearly all recycling methods require the pre-treatment of the liquid sludge, where water is eliminated and the solid particles are collected in a transportable form and as dust-free as possible. These were the objectives of the extension plant (treatment of solids).

The treatment plant for dehydration and drying of solids has been implemented by means of the construction of the following sub-plants: buffer containers, pre-dehydration, dehydration and drying station. Figure 4 shows a diagram of the plant.

Buffer containers

The buffer containers serve as intermediate storage tanks for the liquid sludge from the sedimentation unit of the waterworks, which operates 24 hours a day, 7 days a week. The containers make it possible that the treatment plant for solids can be operated during normal working hours, i.e. 8 hours a day for 5 days a week. In the containers, the sludge is also dehydrated to approximately 1% dry matter content.

The sludge liquor stored in the storage basin of the sedimentation unit is pumped by two pumps into the four buffer containers, which are filled and emptied in sequence. The clear water on the surface is drained off to the former collection ponds by floating strainers: the floating strainers are equipped with a sludge level monitoring device, which ensures that the outflow slide for clear water is opened and closed automatically. The clear water drain is metered by a magneto-inductive flow meter.

Pre-dehydration

Dehydration of the liquid sludge by separation of filtrate and thick sludge with a dry matter content of approximately 5% by means of a sieve drum.

The liquid sludge is transferred from the buffer container via a reaction mixer to the sieve drum unit. Immediately before it reaches the reaction mixer, a flocculation additive is applied to the sludge in a specially designed volume mixer (cone mixer). The sludge is

Figure 5 | Exterior of building 'solid treatment plant' and dry pellets.

pumped upwards through the reaction mixer, where a slow moving agitator supports the complete flocculation of the solid particles and the separation of water. Via an overflow, the flocculated liquid sludge is brought into the horizontal, slowly rotating sieve drum, where the flocculant sludge is separated from the water (filtrate). The filtrate is drained into the backwashing trays and from there to the central filtrate tank. The dehydrated thick sludge is brought via a device at the sieve drum to the thick sludge tank.

Dehydration

Pressing of thick sludge and further dehydration to sludge cake with a solid particle content of between 18 and 24% by means of sieve belt press.

Similar to the pre-dehydration, the thick sludge is transferred via cone mixers adding flocculant and via reaction mixer to the sieve belt press. From there, the flocculated sludge is brought to a strainer unit where the clear water is separated from the sludge. Subsequently, the sludge is transferred to the press zone. The sludge is brought between two sieve belts with rollers where it is milled and the residual water (filtrate) is pressed out of the cake. The filtrate is collected in the central filtrate tank. The dehydrated sludge (sludge cake) is transferred via a funnel to a pump from where it is brought to the belt drier unit. Figure 5 shows the exterior of the dehydration hall.

Drying process

Drying on belt drier by means of recirculated air and air dehumidifier. Dehydrated sludge is dried until a dry matter content of between 80 and 90% is achieved.

The drying unit consists of a belt drier with five sieve belts that are placed on top of each other and that move in opposite directions. There is a pelletizer and two dry air generators (dehumidifier with recirculated air blower). The belt drier is divided into a pre-drying unit (consisting of three belts) and the actual drying unit (two belts). Each section has its own dry air generator. Figure 4 shows the operating principles.

The dehydrated sludge cake is transferred by an eccentric screw pump from the sieve belt press via the pelletizer to the first (top) drier belt.

The nozzles mounted on the movable slide of the pelletizer ensure that the pellets on the first drier belt are layered in serpent-like lines and properly aired.

The feed rate of the screw pump and the velocity of the belt are adjusted in such a manner that an optimum amount of sludge pellets is placed on the belt. By transfer of the pellets from the top belt to the next one below, which moves in the opposite direction, the sludge matter is gradually transferred through the drying unit. Each belt is equipped with a separate drive, which is clocked in order to achieve optimum load heights (the bulk volume is considerably decreased during the drying process). The dry air flows upwards through the belt dryer. At each drying stage, the damp air is dehumidified by a dehumidifier (dry air generator), which operates according to the principle of condensation. There, the air is dehumidified by means of cooling at the evaporator. Subsequently, the air is heated to approximately 50°C at the condenser of the cooling cycle. At this stage, the air has a humidity of approximately 10–15% and is blown again through the belt dryers. As this procedure makes use of all the energy-saving properties of a heat pump, the drying process is particularly efficient. The air guide system of the unit is designed in such a manner that, during favourable weather conditions, the unit can be run with air drawn from outside and dehumidifying is thus not required. In such cases, the air is drawn from a central duct located below the belts and subsequently blown through the unit by means of a blower. The air adsorbs the moisture in the pellets and thus dehydrates the sludge cake. The humid air subsequently escapes through air ducts via the roof.

To ensure constant availability and safe operation, the solid treatment plant is equipped with two separate processing lines. Each line can be operated independently.

RESULTS

With the construction and commissioning of the sulphuric acid unit, the following objectives were achieved:

- Reduction of applied quantity of flocculant (aluminium sulphate) by 25%
- Prolonged filter cycles (20% increase)
- Plant capacity capable of handling all known raw water situations
- Reduction of backwashing water volume by more than 20%
- Reduction of solid particles in backwashing water by approximately 15%.

The applied method of sludge treatment has many significant advantages over conventional methods:

- Reduction of the residue to less than 6% of the previous wet sludge volume, which was dumped in collection ponds
- Comparatively low processing temperatures ($t<60°C$)
- Low energy consumption thanks to in-process energy recovery (total energy required for drying: approximately 350 Wh per kg of extracted water)
- Dust-free drying process and transport
- Simple operation (simple starting and shutting down of unit, simple adjusting of unit capacity to suit different loads)
- No additives required (apart from the small amount of 4–5 g of flocculant kg^{-1} dry matter)
- High dry matter content of end product (>80%)
- End product in the form of granular bulk material (grain size approx. 4–6 mm).

RECYCLING OF DRY MATTER

Due to the fact that the end product contains no hazardous substances and has a solid dry consistency (granular bulk with high strength), the dry mater can be disposed of together with normal household waste.

As the laws regarding waste management require that methods for recycling are found, a comprehensive study regarding possible recycling options was completed and a suitable solution was found. The dried sludge is currently recycled in a brick factory for the production of backing bricks. The dried matter is used as an additive for the improvement of the consistency for further machine processing of clay that shows fluctuating water content. The organic compound contained in the dried matter also improves the porosity of the baked bricks, which results in a better insulation coefficient of the material. The bulk material is transported in conventional containers.

As the solid treatment plant is equipped with two separate processing lines, sludge from other plants is from time to time processed, provided that it has the same consistency and quality as the internal sludge.

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