Refurbishment of Water Treatment Plant Borna-West – From Lab Over Pilot Scale to Operation Plant Modification

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Abstract

In this paper the refurbishment of the water treatment plant Borna-West in Germany is presented.

Experimental resulting from lab tests and onsite pilot testing over a period of several months combined with the consideration for other necessary changes in plant operation. While ongoing plant operation the integration of an additional process step and a refurbishment of the plant was achieved.

Keywords: Iron Removal, Removal of Hydrogen Carbonate, Active Water Treatment, Refurbishment, Lab Test, Pilot Test, Full Scale Plant

Introduction

In the lignite mining areas of Central Germany and Lusatia the regional water balance is heavily changed by the past and present mining industry. Through the groundwater rerise significant amounts of iron and sulfate enter the receiving water bodies. For the protection of the environment several water treatment plants are in operation to remove the iron.

Initial position

The water treatment plant Borna-West, which is in operation since 2007, is a replacement of a simple pumping station. The operation of the pumping station was necessary to prevent a national road from being flooded. As the iron contamination in the receiving water bodies was and is rising a water treatment plant had to be installed to protect the river Pleiße.

Borna West has a capacity of 65 m^3/h and is processing a classical Low-Density-Sludge (LDS)-treatment-scheme; by pH-adjustment with lime, parallel aeration, flocculation, and sedimentation. The water to be treated is a mix of rebounding groundwater, dump seepage water and surface water with an iron concentration between 100 and 300 mg/L (mainly iron(II)) and a total inorganic carbon concentration (TIC) between 80 and 90 mg/L.

This high level of TIC, which derives from hydrogen carbonate, leads to an unnecessary consumption of lime and to an increased production of sludge, which has to be disposed.

Lab tests

Analysis of the original sludge composition of the treatment plant led to the conclusion, that the large volume as well as the low iron content of the sludge is caused by high amounts of total inorganic carbon (mainly free carbonic acid) in the raw water.

As shown in Table 1, most iron is present as iron(II) and requires an oxidation step to be removed as iron hydroxide.

Therefore, several laboratory tests with and without aeration step were carried out before adjusting the pH-value with lime and aeration for iron oxidation.

The introduction of the aeration stage resulted in a significant change in the lime content of the precipitated sludge, as shown in Table 2.

***Table 1** exemplary raw water composition (excerpts).*

Parameter	Dimension	Value
pH		5.7
conductivity	µS/cm	3250
sulfate	mg/L	2200
iron (total)	mg/L	250
ferrous iron	mg/L	246
ferric iron (calculated)	mg/L	4
total inorganic carbon (TIC)	mg/L	69

***Table 2** sludge composition (lab tests/excerpts).*

Parameter		Sludge from water without additional pre-aeration step	Sludge from water with additional pre-aeration step
iron	%	20.1	36.1
calcite	%	32.2	7.2
dolomite	%	9.7	1.6
lime total	%	**41.9**	**8.8**

Based on the results of sludge composition, sludge volume and dewatering behaviour, calculations were made that predicted a 20% reduction of the annual sludge mass (for disposal) and a 40% reduction in annual lime consumption.

The joint conclusion from laboratory scale experiments and calculations were the basis for an on-site pilot test and the integration into ongoing plant operation.

Pilot test

For the pilot test several variants were reviewed and one preferred option was elaborated. It consisted of a separate concrete tank (volume 45 m^3) with an installed surface aerator. This additional treatment step was installed between the water collecting basin and the pH-adjustment/aeration step of the original treatment scheme. The integration was achieved through a bypass pipe in the treatment scheme and could handle the full flow of the treatment plant (60 – 70 m^3/h).

Figure 1 shows the tank for the additional pre-treatment step and the surface aerator in operation.

The pre-treatment step was running over a period of several months and was carefully monitored by periodic sampling routines and measuring campaigns.

In figure 2 a typical drop in the TIC-concentration after starting the surface aerator is presented.

***Figure 1** View on the pre-aeration tank (left side) and the surface aerator in operation (right side).*

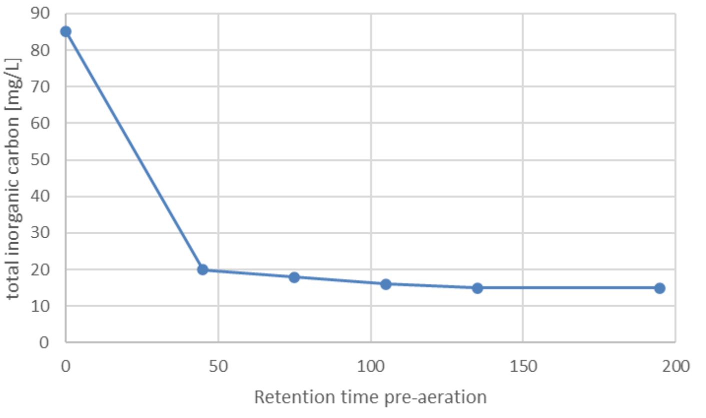

Figure 2 *TIC-concentration depending on retention time pre-aeration.*

The graph showed that a retention time of 40 minutes in the pre-aeration step is sufficient to reduce the TIC-concentration by 75%.

Before and after the pilot period the sludge composition in the sludge storage tank was analysed and showed substantial differences (Table 3).

Again, the pre-aeration led to a substantial composition change of the sludge (higher iron concentration, substantial lower lime concentration). Sulfate removal is not a target parameter of the water treatment plant. Depending on the fluctuating composition of the raw water, the sulfate concentration is at the limit of the gypsum equilibrium, therefore sulfate is sometimes precipitated as gypsum.

Compared to table 2 the lime concentration of both pilot test sludges was higher than in the lab tests. This is due to the fact that the adjustment of the pH-value in the water treatment plant is not working in an optimised way.

The lime dosing prior to the currently ongoing refurbishment of the plant is regulated by measuring the pH in the pH adjustment stage and in the discharge pumping station. These two values are combined and regulate the speed of the solid lime dosing.

If the operating parameters (flow rate of 65 m^3/h) are put in relation to the residence time in the sedimentation tank (10 h in continuous operation), there is an enormous time delay, reinforced by the fact that the plant does not run in continuous operation for lack of water. Therefore, the lime dosing mainly works in overdosing mode.

The predictions of the laboratory tests - a 20% reduction in the annual sludge mass to be disposed as well as a 40% reduction in the annual lime consumption - could be confirmed.

As the concrete tank of the pilot test was not winter proof, the to-be-treated water amount is increasingly reduced, the problems

Table 3 *sludge composition (pilot test/excerpts).*

Parameter		Produced sludge without additional pre-aeration step	Produced Sludge with additional pre-aeration step
iron	%	21.0	34.8
sulfate	%	2.0	1.53
calcite	%	58.93	20.78
dolomite	%	4.13	4.85
lime total	%	**63.06**	**25.63**

of the pH adjustment and several other needed modifications led to the decision, that a refurbishment of the water treatment plant is necessary.

Necessary changes in plant operation mode

During the planning process a variant consideration was done, taking into account the following specifications:

- flexibilization of plant flow rate → adapted to incidental water volume
- avoidance of discontinuous operation
- permanent integration of the pre-aeration step
- optimisation of pH-adjustment/lime dosing
- optimisation of flocculation
- modernisation of the process control system
- possibility of dealing with heavy rain fall events
- continued use of components where possible

Refurbishment

The results of the variant consideration and the planning process of the preferred option are summarized in table 4.

The heart of the refurbished water treatment plant is the new 3-chamber-concrete basin, in which the pre-aeration, the pH-adjustment/lime dosing with parallel aeration for iron oxidation and the flocculation are combined in three sub-basins in sequence (figure 3).

The challenge of the refurbishment is that all construction work has to be carried out in a very limited space while the plant is in operation.

The new 3-chamber basin is constructed between lime silo, old pH-adjustment and pumping station 2. All new piping is constructed until the final meter and all new control circuits will be prepared.

Finally, on day x, all new piping is connected, the new process control system is installed, and the new process has to start up. All this work has to be carried out within a very tight time frame, as it depends on weather conditions and there is only a limited time window of one to a maximum of five days of plant shutdown due to the limited water storage capacity in the retention basin.

Conclusions

The water treatment plant Borna-West is a very good example of how a theoretical data evaluation followed by intensive laboratory tests and verification in a pilot test on site can lead to a planning process that is very well validated with real process data.

The refurbished water treatment plant will provide significant cost savings due to reduced lime consumption and sludge

Table 4 *Results of planning process.*

Original status water treatment plant Borna-West	Refurbished water treatment plant Borna-West
fixed flow rate (65 m^3/h)	adjustable flow rate (10-65 m^3/h)
no TIC removal	TIC removal
lime dosing regulated by two pH probes (one with > 10h delay)	lime dosing regulated by two pH probes in two subsequent reaction tanks
dosing of flocculant directly in pipe to sedimentation tank	separate flocculation tank with slow stirrer
only 5-6 h operation time per day (start-stop, start-stop)	adjustable flow rate for a quasi-continuous operation
process control system with limited fault/alarm messages	modern process control system
one raw water pipe for normal operation/heavy rain fall event	separated raw water pipes for normal operation/heavy rain fall event (different pipe diameters)

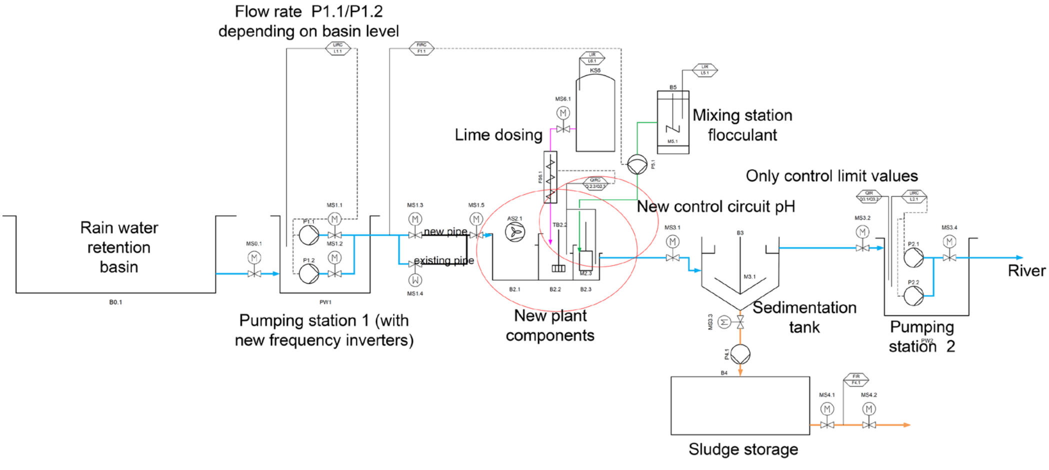

Figure 3 *New flow sheet of water treatment plant Borna-West.*

volume, will discharge better water quality into the river, and will be much more flexible to handle different volumes of water generated.

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