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# SLUDGE MANAGEMENT IN WATER TREATMENT PLANTS

Building new water treatment plants (WTP) as well as rebuilding, enlargement and modernisation of the existing ones must also concern technology and sludge management objects, including the possibility of managing them outside the WTP.

The study identifies design and operating problems which have to be solved in the investment process. It also presents the technology of sludge processing designed for the WTP in the city of Rzeszów and the study results of the effects obtained during WTP starting.

It was proved that the assumed ecological effect of limiting the concentration of slurry discharged into the Lubcza River ($S_z$ < 35 mg/dm$^3$) and the effect of technological dewatering ranging from 24 to 47% d.m. were obtained. The dewatered sludge is a granulated product with a high proportion of mineral parts (above of 75%). It does not absorb water and does not putrefy while stored in the open air. After cementation it can be utilized for building purposes. Taking into account the sludge fertility values (river loess sludge), we should not dismiss the possibility of environmental or agricultural sludge utilisation after its storage or hygienization, which should eliminate sludge poisoning with *Salmonella* bacteria.

## 1. INTRODUCTION

Due to stricter and stricter requirements for treated water quality and the ecological conditions of surface water used for drinking, the majority of water treatment plants must face the implementing of new technological processes as well as rebuilding, the enlargement and modernisation of the existing objects, including operating changes. The changes must also concern technology and sludge management objects, with the possibility of managing them outside the WTP. The former methods of sludge retention and dewatering in sludge lagoons require occupying large areas. Dewatering results depend on the atmospheric conditions, and mechanic removal of dewatered sludge demands heavy equipment. Water filtration through sludge is very slow and the outflow of decanted water from the lagoons to a receiver does not guarantee meeting quality requirements for slurry concentration. Therefore, it is necessary

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to introduce new technologies for sludge management in the WTP that will ensure required ecological and technological results.

## 2. IDENTIFICATION OF DESIGN AND OPERATING PROBLEMS

The sources of sludge coming to the allocated sludge processing block (SPB), depending on the WTP technological plan based on the surface water intake, can be the following:

- sludge from periodical or constant cleaning of post-coagulation settling tanks,
- washing waters from rapid filters washing,
- washing waters from carbon filters washing,
- sludge from periodical cleaning of preliminary ozonization chambers,
- sludge from periodical cleaning of intermediate ozonization chambers.

The implementation of the sludge processing technology requires laboratory studies and tests on the composition and level of pollution of washing water, post-coagulation sludge and others. It is also necessary to estimate the volume of single discharges as well as their frequency and to take into account operating conditions for objects in water treatment line, both the existing ones which will be modernized and the completely new ones. The design should solve basic problems that have impact on the technological scheme, dimensioning and the following operation of objects and facilities in the sludge processing block. These problems include the following:

- Very high intensity of inflow of washing waters from the filters, occurring in a short time (several minutes), 10 times higher than technologically and economically justified hydraulic capacity of sludge pumping station, as well as line installations, and capacity of a flocculent feeder. It requires that the retention in tanks, either new or rebuilt from sludge lagoons, located in front of the SPB pumping station, is ensured.
- Relatively low slurry concentration in inflowing washing waters that requires their thickening, as well as collecting the thickened slurry before dewatering, so that the continuous work of dewatering plant is possible for at least several hours.
- Periodical discharges from structurally outdated post-coagulation settling tanks that have neither machines to scrape sludge nor the possibility of decanting over-sludge water, whose volumes can range from several hundred to a thousand cubic meters, and a number of settling tanks can be between ten and twenty. Leaving such settling tanks intact requires large retention volume in front of the SPB and longer sludge drain time for the settling tank. Operation of such settling tanks causes also substantial losses of water. Moreover, sludge collected in the settling tanks for several weeks or even several months can cause secondary pollution of treated water [1]. In many cases, the best solution is to use the line scrapers that work efficiently both in single and in storeyed settling tanks.

• Usage of a flocculant feeder that can work directly in the pipeline, easy to be controlled by setting the value of energy supplied to a static mixer [2]. Nowadays, the best solution seems to be the usage of an adjustable, settable flap valve.

## 3. SLUDGE MANAGEMENT IN WTP IN RZESZÓW

The WTP in Rzeszów is based on two water intakes from the Wisłok River and two technological treatment lines: WTP I and WTP II. In 2007, the sludge processing block (SPB) was put into use. Currently, the WTP has been equipped with carbon filters and facilities for intermediate water ozonization and disinfection with chlorine dioxide. Next year, the line scrapers in the post-coagulation settling tanks will be installed. The pre-design research and the subsequent design of the sludge processing block were performed in the years 1998–2000 [3]. The ecological and technological requirements were the following:

• suspended solids in the outflow of post-process water to the receiver $Z_{og.}$ ought to reach the concentration of 35 g/m$^3$;

• sludge thickening before dewatering must reach at least 0.5–0.8% of dry solids;

• such sludge dewatering as to obtain its hydration $U \leq 80\%$;

The SPB is fed with:

• Washing waters from the WTP I and II – 16 filters according to the design, no more than 8 filters are rinsed within 24 hours, water consumption is not higher than 309 m$^3$/d per one filter.

• Post-coagulation sludge from the settling tanks in WTP I and II – 9 settling tanks in WTP I with volume $V1$ = 868 m$^3$ each, and 6 settling tanks in WTP II with volume $V2$ = 600 m$^3$ each; according to the design only one tank in each WTP can be cleaned within 24 hours.

• Sludge obtained after cleaning the chambers of preliminary ozonization – 2 chambers with volume $V$ = 426 m$^3$ each. The whole chamber content will be directed to the sludge management station. The average cleaning frequency: once in every 2 months.

• Washing waters from carbon filters, common for both WTP I and WTP II stations – 6 carbon filters rinsed every 3 days, which means 2 filters per 24 hrs, and the volume of washing waters: 598 m$^3$/d per one filter.

Washing waters and sludge flow into 2 retention tanks rebuilt from the parts of the existing sludge lagoons, from which they are pumped by 2 pumping stations to one of 4 decanters. There are mixing apparatuses (by Bellmer) installed in the pumping pipelines, equipped with the heads dosing coagulum. Every decanter of 309 m$^3$ volume and useful height of 8.55 m is equipped with a mixer, a turbidity sensor and a device for sludge level measurement. The whole decanter, composed of rigid, articulately joined elements, is individually designed by a contractor because no company has agreed to provide a decanter to such a high tank. Decanted water is piped away to the Lubcza

River. The double system of turbidity measurement is used to protect the receiver against the discharge of water whose content of slurry is exceeded. Every day or every 2–3 days, sludge collected at the bottom of every decanter is dewatered on the Bellmer filter presses, equipped with lengthened belt thickeners. The filtrate from the thickener is utilised as technological water for tapes rinsing. The filtrate pumped to the receiver fulfils the conditions imposed on suspended solids concentration. During the system starting, some additional protection was provided, in case the slurry concentration in the filtrate is exceeded. In such a case, the filtrate is turned back to the pumping station or to the retention tank and introduced into a decanter, from where it is drained together with decanted waters. Dewatered sludge is a granulated product that can be cemented or limed, and then stored for further utilisation.

## 4. EVALUATION OF OPERATING RESULTS AND ECOLOGICAL EFFECT

The results obtained for sludge thickening up to 0.78–0.87% of dry solids without flocculant and 3.40–5.78% of dry solids with flocculant show that the thickening up to 0.50–0.80% of dry solids assumed in the design was obtained in the whole period of starting, performance test and operating. In this period, the results required could be obtained even without using boosting flocculant. However, it is not recommended to give up flocculant because of the purity of decanted waters. In other seasons, it might be necessary to use flocculant. Depending on the dose of flocculant, the results of the thickening expressed in % of dry solids can be considerably higher than the results assumed in the design. Gravitational thickening boosted by flocculant ensures both high technological effect and an ecological effect determined by the quality of the decant discharged into the Lubcza River.

Table 1

Results of studies of water quality after decantation from decanters

| Indicator | Unit | Date | |
|---|---|---|---|
| | | 9.11.2007 | 4.12.2007 |
| pH | – | 8.1 | 8.05 |
| Suspended solids | $mg/dm^3$ | 20.0 | 25.33 |
| Dry residue | $mg/dm^3$ | 357 | 376 |
| $BOD_5$ | $mg\ O_2/dm^3$ | 4.6 | 3.8 |
| COD | $mg\ O_2/dm^3$ | 23.5 | 21 |
| $N_{NH_4}$ | $mg/dm^3$ | 0.28 | 0.23 |
| $N_{tot.}$ | $mg/dm^3$ | 4.05 | 7.5 |
| $P_{tot.}$ | $mg/dm^3$ | 0.31 | 0.183 |
| Sulfates | $mg/dm^3$ | 49.8 | 42.8 |
| Chlorides | $mg/dm^3$ | 16.3 | 18.4 |

Table 1 presents the effects of gravitational thickening obtained in decanters. Technological effect of sludge gravitational thickening was presented in table 2. The results of sludge dewatering on the presses were presented in table 3.

Table 2

Technological effect of gravitational sludge thickening

| Sludge characteristics | Flocculant | Thickened sludge concentration (%) | Date | Assumed sludge concentration (%) |
|---|---|---|---|---|
| Washing waters from filters, no flocculant | – | 0.78–0.87 | 10.10.2007 | 0.50–0.80 |
| Mixture of washing waters and sludge from post-coagulation settling tanks | – | 0.78–0.87 | 10.10.2007 | 0.50–0.80 |
| Sludge from post-coagulation settling tanks, with flocculant | Praestol 2540 | 3.40–5.78 | 19,20.09.2007 | 0.50–0.80 |

Table 3

Results of sludge dewatering on presses

| Date | Dry solids concentration (%) |
|---|---|
| 19.09.07 | 36.8; 34.18; 44.48; 37.73 |
| 20.09.07 | 39.93; 34.91 |
| 27.09.07 | 40.25 |
| 28.09.07 | 39.38; 27.78 |
| 10.10.07 | 34.78; 28.30; 30.08; 30.58 |
| 11.10.07 | 35.00; 31.50 |
| 11.10.07 | 35.00; 31.50 |

In terms of the filtrate quality, the most advantageous operating parameters were as follows:

- hydraulic load: 15–30 $m^3$/h;
- mass load: 110–240 kg dry solids/h;
- slurry concentration in fed material: 0.80–1.20%.

## 5. CHARACTERISTICS OF DEWATERED SLUDGE

Our observations show that dewatered sludge left in the storage yard does not absorb water again, even without using cement or lime.

During starting and operating periods, 4 studies on the proportion of mineral and organic parts in sludge were conducted. The proportion of mineral parts is very high. Sludge does not show any tendency to putrescine. Possible usage of sludge cementation will additionally decrease the proportion of organic parts by 3–4%.

The proportion of mineral and organic parts in dewatered sludge was presented in table 4.

Table 4

Proportion of mineral and organic parts in dewatered sludge

| Date | Mineral parts (%) | Organic parts (%) |
|---|---|---|
| 27.09.07 | 84.62 | 15.28 |
| 11.10.07 | 74.8 | 25.20 |
| 11.10.07 | 79.40 | 20.60 |
| 11,12,07 | 81.1 | 18.90 |

The studies performed by the sanitary inspection in Rzeszów revealed that in the samples of fresh unstoraged sludge collected on the 7th December 2007 the following bacteria can be found:

- *Salmonella* sp., in 100 g of sludge, – bacteria were isolated,
- *Clostridium perfringens*, – the perfingers titre, $3 \times 10^{-5}$ g/bacterium,
- *Escherichia coli*, – the coli titre, $3.3 \times 10^{-5}$ g/bacterium,
- *Escherichia coli* of faecal type, – the coli of faecal type titre, $3.3 \times 10^{-5}$ g/bacterium.

These studies should be repeated for the sludge storaged at specific time intervals, in winter and summer, which should eliminate *Salmonella*. Bacteriologic pollution of sludge after its cementation and after its hygienic treatment with lime should be checked independently. In the pre-design research *Salmonella* bacteria were not detected.

## 6. CONCLUSIONS

- The starting of WTP and the effects of its operation have shown that in the existing installation the processing of sludge from washing waters and post-coagulation settling tanks can be conducted separately and in mixtures, and the technological effects obtained are very good or even better than the assumed ones.
- The ecological effect of the reduction in the concentration of suspended solids ($S_z < 35$ mg/dm$^3$) discharged into the Lubcza River persists.
- Sludge is considerably dewatered, it has a high proportion of mineral parts (above 75%), it does not absorb water and does not putrescine.

• The implementation of the sludge processing technology based on two-stage flocculation causes bacteriological pollutants from the Wisłok River waters to remain in sludge and not to be reemitted to the water in the Lubcza and Wisłok Rivers.

• Sludge can be utilized after cementation for building purposes. Taking into account the sludge fertility values (river loess sludge), we should not resign from the possibility of utilising sludge in nature or in agriculture after storage, which should eliminate its pollution with *Salmonella* bacteria. Sludge hygienisation by means of lime can also be considered. Sludge examination should be continued.

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## GOSPODARKA OSADOWA W ZAKŁADACH UZDATNIANIA WODY

Budowa nowych, przebudowa oraz rozbudowa, a także modernizacja istniejących obiektów zakładów uzdatniania wody (ZUW) musi obejmować również technologię i obiekty gospodarki osadowej oraz stworzenie możliwości zagospodarowania osadów poza terenem ZUW.

Przedstawiono identyfikację problemów projektowych i eksploatacyjnych, które muszą być rozwiązane w procesie inwestycyjnym, a także technologię przeróbki osadów zaprojektowaną dla ZUW w Rzeszowie oraz wyniki uzyskane w okresie rozruchu.

Potwierdzono uzyskanie założonego efektu ekologicznego, tj. ograniczenie stężenia zawiesiny ($S_z$ < 35 mg/dm$^3$) odprowadzanej do rzeki Lubczy, a także technologicznego efektu odwodnienia (od 24 do 47% s.m.). Odwodniony osad ma postać granulatu o dużym udziale części mineralnych (powyżej 75%), nie chłonie wody i nie zagniwa podczas składowania na wolnym powietrzu. Może być wykorzystywany po cementowaniu do celów budowlanych. Nie należy też rezygnować z przyrodniczego czy rolniczego wykorzystania osadu z uwagi na jego wartości nawozowe (rzeczne osady lessowe) po leżakowaniu lub higienizacji, które powinno zlikwidować zanieczyszczenie bakterią *Salmonella*.