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John Nurminen Foundation

Technical Audit of the Brest Wastewater Treatment Plant

Establishment of the Most Feasible Way for Accelerated Phosphorus Removal

Competence. Service. Solutions.

Table of Contents

Annexes

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1 INTRODUCTION

1.1 Background

The John Nurminen Foundation, the Union of the Baltic Cities Commission on Environment and HELCOM (Baltic Marine Environment Protection Commission) have agreed to work together in order to improve the state of the Baltic Sea. In that purpose the Parties have applied and received financing from EU Baltic Sea Region Programme 2007-2013 for a three-year project called "PURE" (Project on Urban Reduction of Eutrophication), started in December of 2009. The objective of the project "PURE" is to reduce phosphorus discharges to the Baltic Sea by enhancing phosphorus removal at municipal wastewater treatment plants and also improve the knowledge on best available techniques on phosphorus removal in cities and water companies around the Baltic Sea. The "PURE" project was approved by the EU BSRP Monitoring Committee on 16th September 2009.

The 'PURE' project partners also include the following cities and/or water companies: Brest Vodokanal, city of Gdansk, Jurmala Water, Kohtla-Järve Water Company (Järve Biopuhastus OÜ) and Szczecin Water Company. The cities and/or water companies have agreed that a technical audit will be carried out at their wastewater treatment plants in order to assess the feasibility and cost efficiency of enhanced, chemical phosphorus removal and other low cost options to reduce phosphorus discharges to receiving waters. The Project Partners intend to achieve an average annual concentration of 0.5 mg phosphorus / litre in effluent waste water on continuous basis. Also investments to achieve this value are included in the project 'PURE' at the wastewater treatment plants of Brest and Jurmala, starting in 2011. The Project will be carried out in harmony with the national legislation, rules and environmental regulations of each participant and EU.

1.2 Objectives of the project

The overall objectives of the assignment are

- to review the current wastewater and sludge treatment processes especially in terms of phosphorus removal,
- to develop the most cost effective plan to enhance phosphorus removal to the level of 0.5 mg/l and
- to estimate additional O&M costs required by the enhanced treatment.

In addition, the specific objectives for the implementation of the recommended investments are

- to implement the works without stoppage the operation of the WWTP as a whole, creating as little disturbance to the operation as possible
- to implement the works without any wastewater overflows to the recipient and
- to implement civil, mechanical, electrical and automation works in accordance to EU norms and regulations

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The proposed technical solutions and investments for each WWTP shall be in line with the current status of each WWTP, agreed by the target WWTPs and based on low cost/high impact approach.

2 BREST WASTEWATER TREATMENT PLANT

2.1 General

The population of the Brest City was 314 300 persons according to 1.1.2008 statistics. There are a total of 450 km of sewers and 43 wastewater pumping stations (50 in the near future) in the city.

The treatment plant is situated on the western skirts of the city outside of residential areas. The plant has been built in three stages. The first stage (35 000 m^3/d) was taken into operation in 1969, the second stage (58 000 m^3/d) in 1981, and the third stage (42 000 m^3/d) in 1992. The plant has conventional mechanical treatment with screens, sand separation and primary clarification, conventional activated sludge process for removal of BOD, and lagoons as a polishing step for biologically treated wastewater. Sludge treatment consists of gravitational thickening and mechanical dewatering. Anaerobic digestion will be taken into operation in the autumn of 2010.

Treated wastewater is discharged into the river Western Bug, through which it finally ends up in the Vistula River and the Baltic Sea.

2.2 Wastewater flows and loads

2.2.1 Wastewater flow

The investments to be planned will be based on the existing wastewater loads and flows, namely the average influent values from the year 2009. Data from this year are presented and analysed below.

82 % of the wastewater comes from municipal and 18 % from industrial sources. In 2009, the wastewater flow varied from 82 000 m^3/d to 91 000 m^3/d. The yearly average was 86 076 m^3/d. The daily flow values were clearly below the dimensioning flow value of 135 000 m^3/d. The influent flow during 2009 is shown in Figure 2.1. Data of wastewater flow for 2008-2010 are presented in Annex 3.

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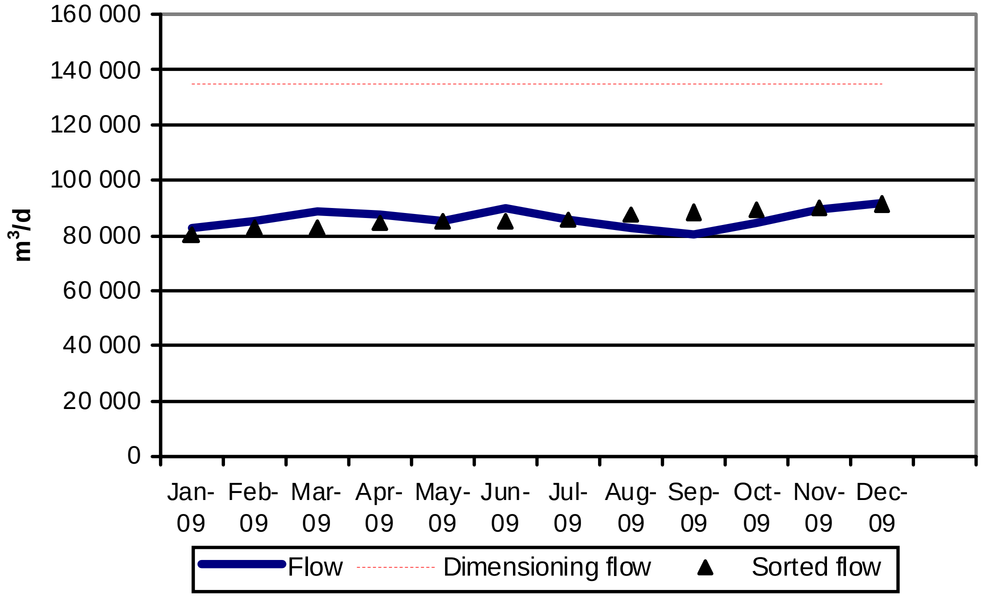

Figure 2.1. Influent wastewater flow, 2009.

2.2.2 Wastewater loads

The Brest WWTP has been designed only for the removal of BOD and suspended solids. Total nitrogen and total phosphorous concentrations are not analyzed at the plant. The values of total nitrogen and total phosphorus concentrations presented in this chapter have been estimated based on the data available and experience from similar WWTPs. In addition, samples and total phosphorus analyses taken specifically during this project have been used in the calculations presented in Chapter 3.

The plant was built in a three stages, and the dimensioning loads of each stage were specified separately during the construction, on the basis of existing wastewater characteristics at the time. Therefore, accurate dimensioning loads for the whole treatment plant are not available. Data of wastewater characteristics for the years 2005-2009 are presented in Annex 3.

Organic load

BOD_5- loads and concentrations varied as shown in Table 2.1. The influent BOD_5-loads during 2009 are shown in Figure 2.2.

Table 2.1 BOD_5 loads and concentrations, 2009

BOD_5	Average	Min	Max
Concentrations (mg/l)	220,5	205	244
Loads (kg/d)	18988	16328	20987

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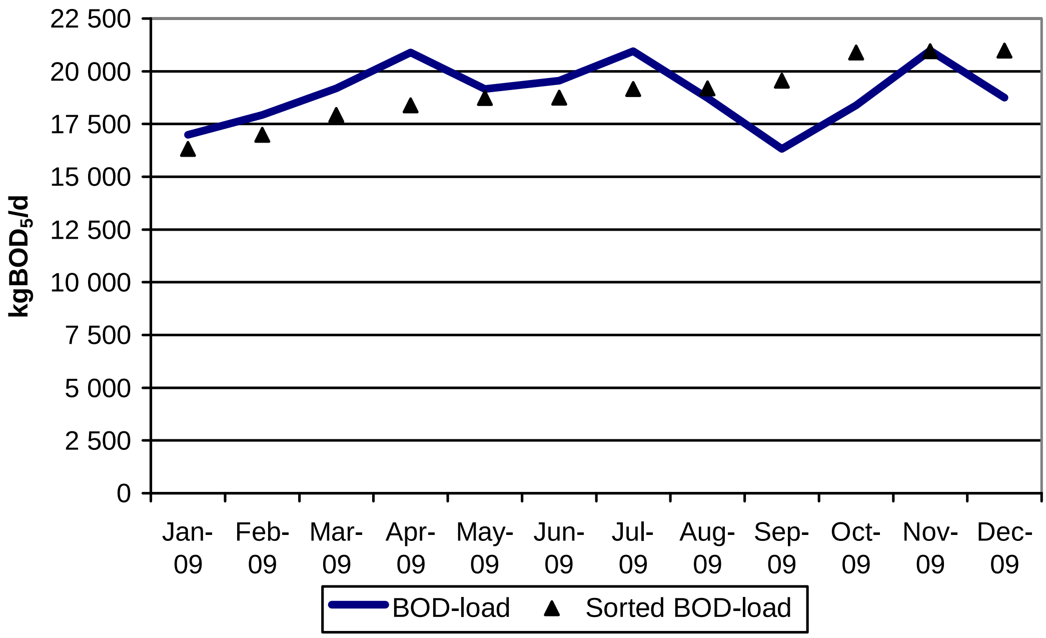

Figure 2.2. Influent BOD_5 loads, 2009.

COD_{Cr}- loads and concentrations varied as shown in Table 2.2. The influent COD_{Cr}-loads during 2009 is shown in Figure 2.3.

Table 2.2 COD_{Cr} loads and concentrations, 2009.

COD_{Cr}	Average	Min	Max
Concentrations (mg/l)	502	260	750
Loads (kg/d)	43281	21467	66340

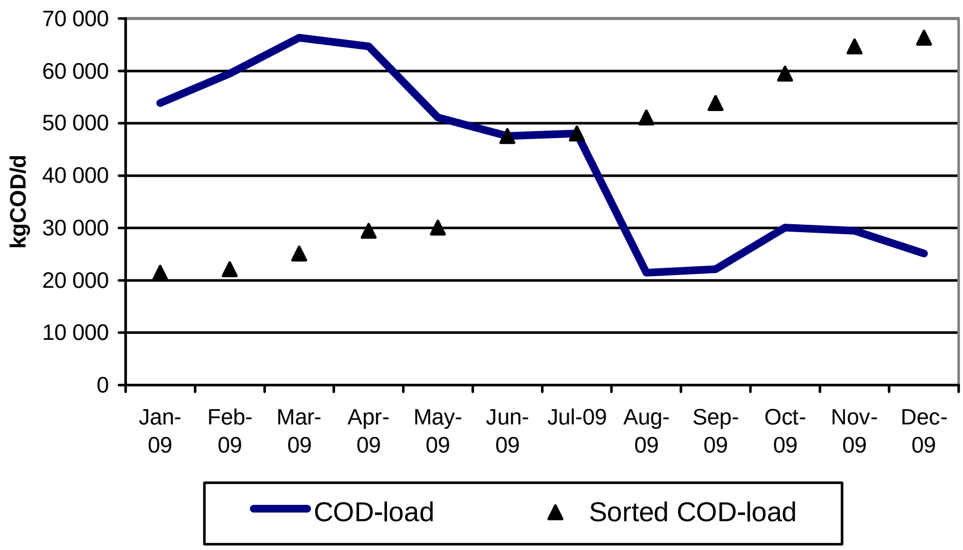

Figure 2.3. Influent COD_{Cr} loads, 2009.

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From Figure 2.2 and Figure 2.3 it can be seen that the COD load has fallen dramatically after April of 2009, while BOD_5 load has remained on the same level throughout the year. Either some major industrial source producing inert or very slowly biodegradable COD has closed down or a systematic error has occurred in the laboratory analyses of COD. This question can be further evaluated by looking at the COD/BOD ratios shown Figure 2.4.

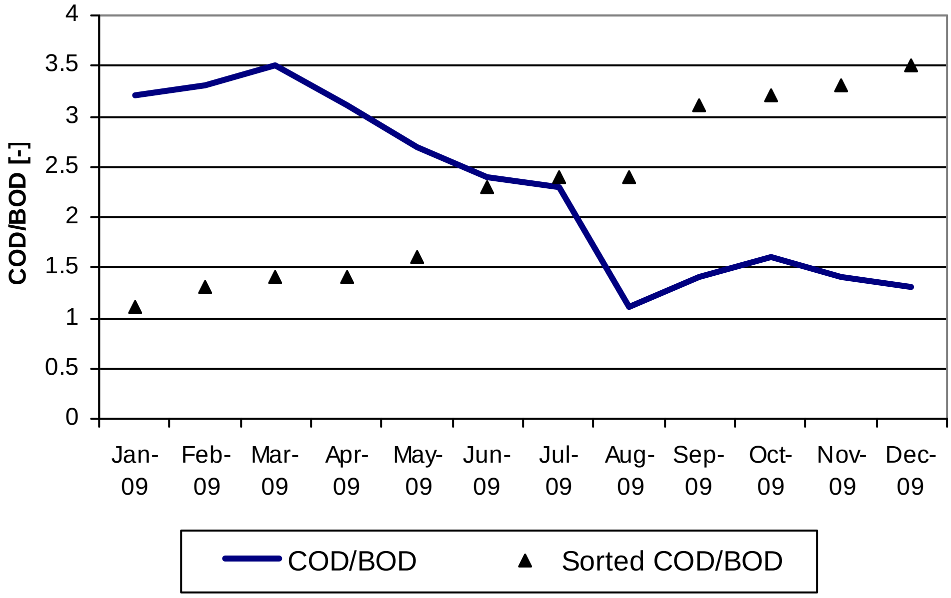

Figure 2.4. COD/BOD ratios, 2009.

The COD/BOD value has decreased from 3 – 3,5 in the beginning of 2009 to 1 – 1,5 at the end of the year. Normal values of COD/BOD for this type of wastewater, taking into account the amount and origin of industrial wastewater, would be approximately 2 – 2,5. Thus, the values of COD/BOD ratio at the beginning as well as the end of the year 2009 are on abnormal levels. We recommend that the procedure of COD analysis at the laboratory should be reviewed.

Nutrient loads

Influent phosphate phosphorus concentrations in Brest WWTP are shown in Table 2.3. The influent PO_4-P load during 2009 is shown in Figure 2.5.

Table 2.3. Influent phosphate phosphorus loads and concentrations, 2009

$P\text{-}PO_4^{3-}$	Average	Min	Max
Concentrations (mg/l)	7,6	6,2	8,7
Loads (kg/d)	655	543	739

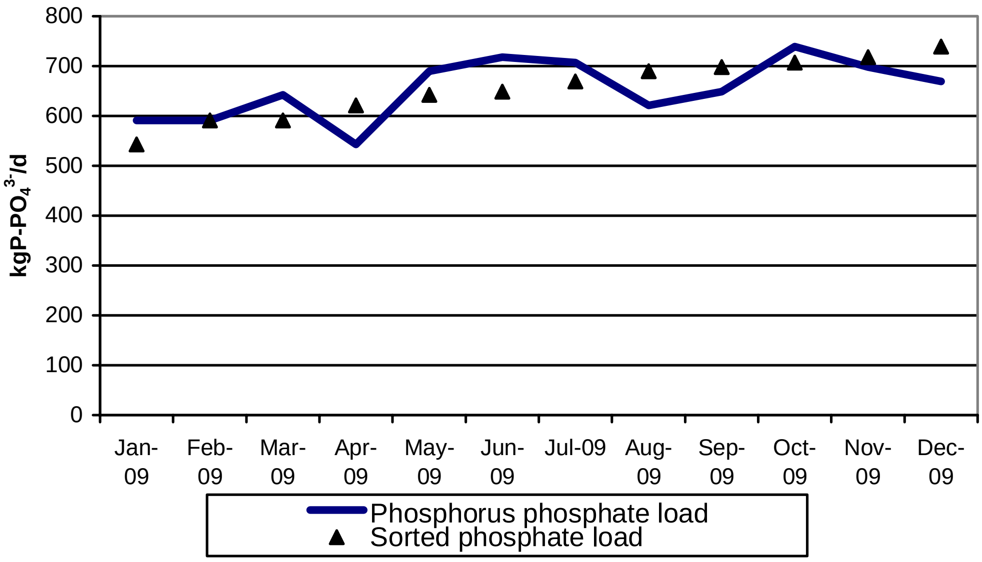

Figure 2.5. Influent phosphate phosphorus loads, 2009.

The phosphate phosphorus concentrations are higher than the usual values for municipal wastewater. On the basis of the phosphate concentrations, the total phosphorus concentration in influent can be as high as 14 g/m^3. This would result to a per capita load of 3,8 g P/ca/d, which is unusually high. The normal level for municipal wastewater treatment plants is approximately 2,0 g/ca/d. The exceptionally high phosphorus load can be caused by industrial wastewater, e.g. from food industries.

During the preparation of the Technical Audit, the WWTP carried out an analysis program of total phosphorus. The results are commented in Item 3.3.2.

Influent ammonium nitrogen concentrations in Brest WWTP varied as shown in Table 2.4. The influent ammonium nitrogen loads during 2009 are shown in Figure 2.6.

Table 2.4. Influent ammonium nitrogen loads and concentrations, 2009

$N\text{-}NH_4^+$	Average	Min	Max
Concentrations (mg/l)	40	30,5	49,1
Loads (kg/d)	3444	2787	4121

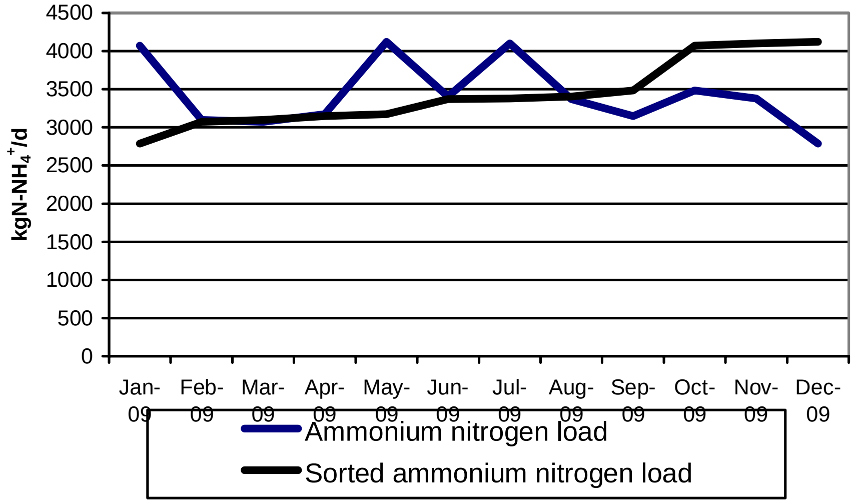

Figure 2.6. Influent ammonium nitrogen loads, 2009.

Suspended solids

The suspended solids loads and concentrations in Brest WWTP varied as shown in Table 2.5. The influent SS loads during 2009 are shown in Figure 2.7.

Table 2.5. Influent suspended solid loads and concentrations, 2009

Suspended solids	Average	Min	Max
Concentrations (mg/l)	198	179	233
Loads (kg/d)	17052	14944	20809

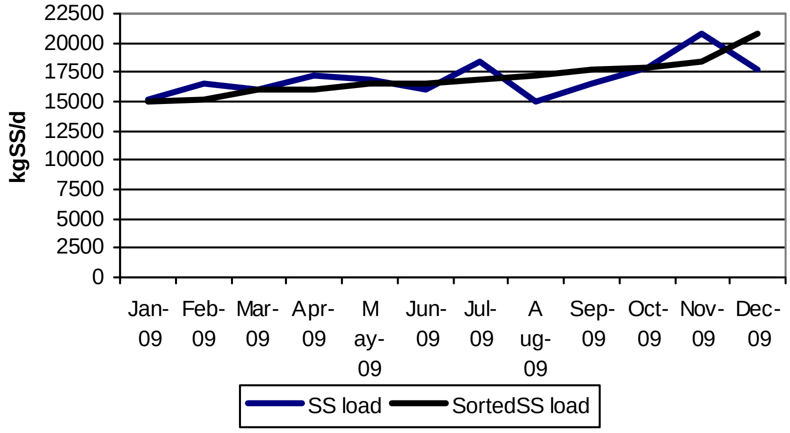

Figure 2.7. Influent suspended solids loads, 2009.

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2.2.3 Temperature

Influent wastewater temperature varied from 9.3 to 24.3 °C and was on average 14.5 °C. Of all temperatures 50 % were above the design temperature of 12 °C (Figure 2.8.)

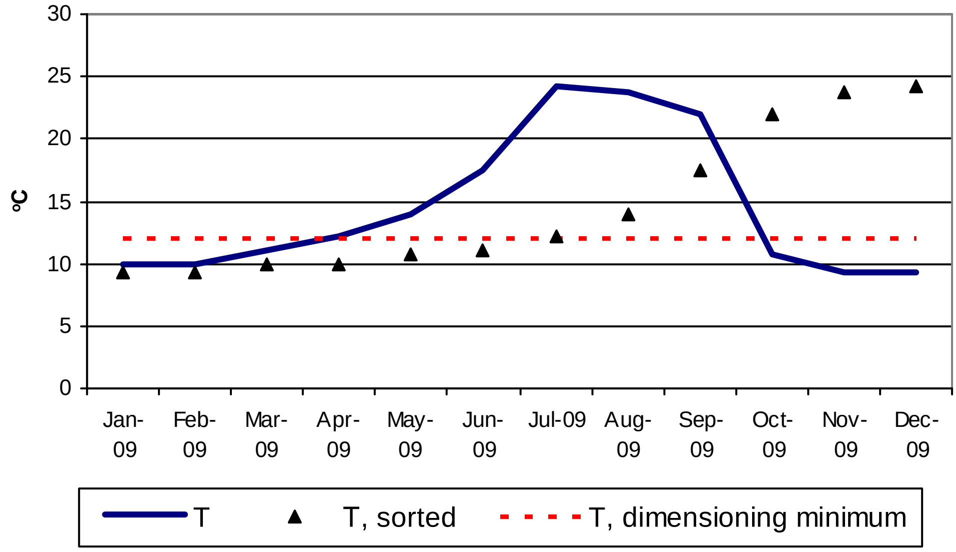

Figure 2.8. Influent wastewater temperatures, 2009.

2.3 Treatment requirements and state of nutrient removal

2.3.1 Effluent wastewater quality

The achieved treatment results in 2009 are compared to the current demands and to the recommendations of HELCOM in Table 2.6. The effluent concentrations for total nitrogen and total phosphorus, which are not analysed at the plant, were calculated on the basis of concentrations of ammonium nitrogen, phosphate phosphorus and suspended solids.

Table 2.6. Achieved effluent parameters compared to demands and HELCOM recommendations, 2009

Parameter	State demand	HELCOM recommendations		Achieved (average 2009)	
	mg/l	mg/l	%	mg/l	%
Suspended solids	-	-	-	46	79
BOD_5	6	15	80	25	89
Total nitrogen	-[1)]	15	70 - 80	34[2)]	32[2)]
Total phosphorous	0,2	0,5	90	7,9[2)]	44 %[2)]

[1)] Requirements are not established
[2)] Estimated value

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From Table 2.6 it can be seen that the achieved treatment results did not fulfil the HELCOM recommendations or state demands for any of the measured parameters.

The effluent nitrogen concentrations are shown in Figure 2.9. Total nitrogen in effluent wastewater varied between 28.5 – 38.0 mg/l, which is substantially above the HELCOM recommendation of 15 mg/l.

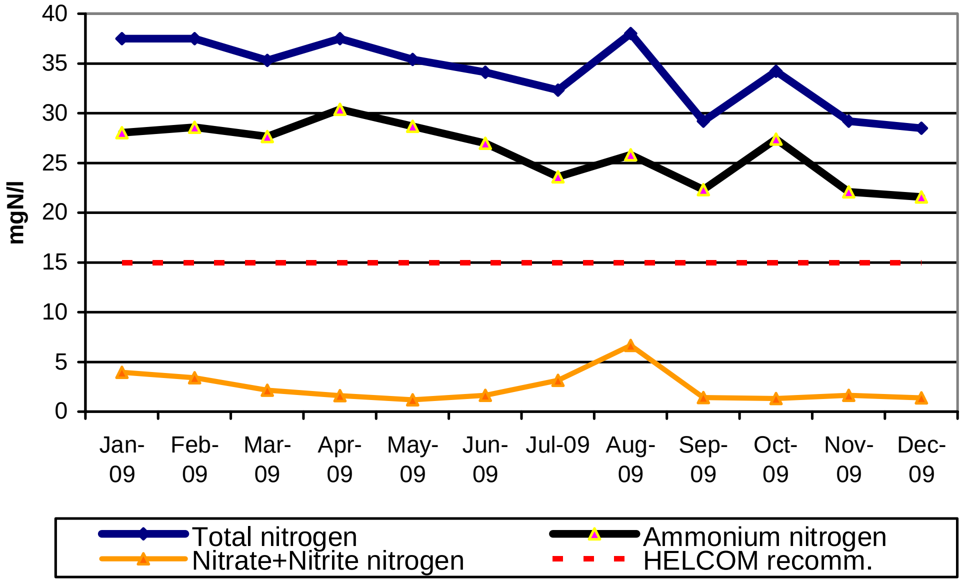

Figure 2.9. Effluent nitrogen concentrations, 2009.

Figure 2.9 shows that slight nitrification occurs only during July – August, when the wastewater is warm. For most of the year, there is no nitrification.

The effluent total phosphorus concentrations are shown in Figure 2.10.Total phosphorus in effluent wastewater varied between 7.5 – 8.2 mg/l, which is substantially above the HELCOM recommendation of 0.5 mg/l.

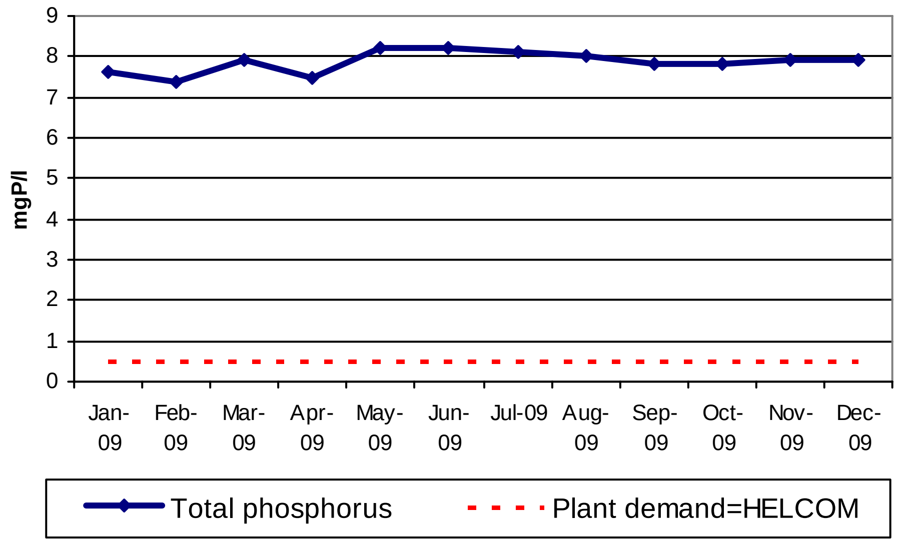

Figure 2.10. Effluent total phosphorus concentrations, 2009.

When evaluating the treatment results for nitrogen and phosphorus, it has to be kept in mind that the WWTP has not been designed nor operated for nitrogen and phosphorus removal.

The effluent values of suspended solids and organic matter analyzed as BOD_5 and COD_{Cr} also exceeded effluent requirements throughout the year. The average effluent suspended solids concentration, 46 mg/l, indicates a permanent overloading of the secondary clarifiers or low settleability of the activated sludge.

2.4 Process description

The schematic diagram of treatment plant is shown in Figure 2.11. The main dimensions and capacities of the unit processes are presented in Annex 1.

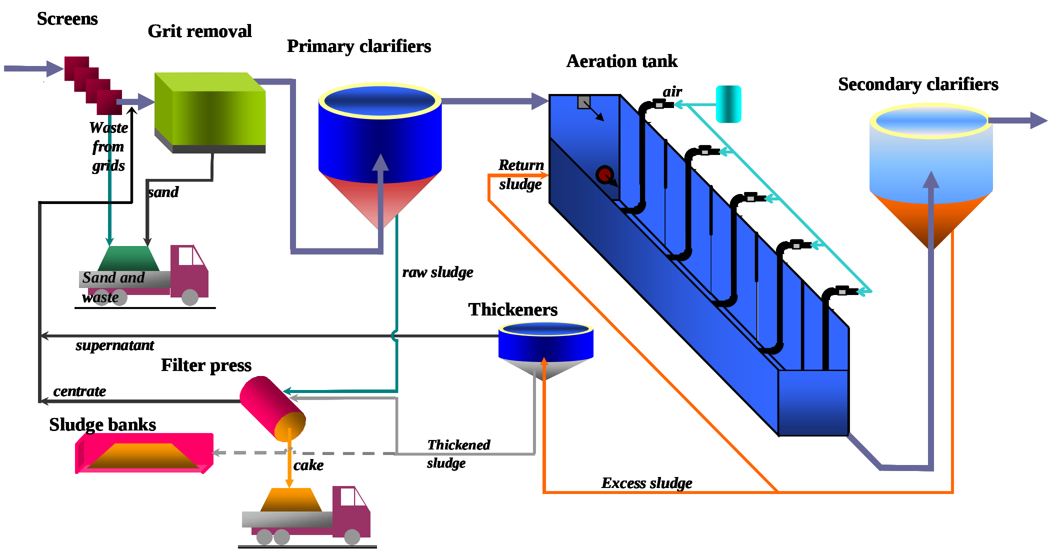

Figure 2.11. Schematic diagram of the Brest WWTP.

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2.4.1 Primary treatment

There are two individual preliminary treatment trains, built at different times, and hereafter referred to as Stage A and Stage B. Each train consists of inlet chambers, screens and grit removal basins.

The plant has no influent pumping station of its own. Wastewater enters the inlet chambers through pressure sewers.

Stage A has four automated “Hydropress” fine screens with openings of 6 mm. Stage B has three similar fine screens. The capacity of each screen is 2,190 m^3/h, adding up to a total of 15 330 m^3/h. Screenings are transported by screw conveyors to open containers.

Pumps for technical water supply to the screens and for removal of sand from grit removal units are located in the screening building of Stage 1.

Preliminary treatment stages A and B both have four rectangular, aerated grit removal lines. The total volume of grit removal units is 2 x 540 m^3 = 1080 m^3, indicating that the minimum hydraulic retention time with typical maximum flow rates is about 13 min. Air is supplied via perforated pipes situated along one wall of each treatment line. The dimensioned aeration capacity is 3 – 5 $m^3/m^2/h$, i.e. 1100 – 1800 m^3/h. Separated grit is removed from the bottom of the basins by hydraulic transfer to two sand bunkers and transported to landfill for final disposal.

From the outlet of grit removal basins, wastewater is directed by channels to the distribution chambers of primary sedimentation. There are two distribution chambers and six round sedimentation basins. One distribution chamber serves sedimentation tanks 1 and 2 and the other one serves tanks 3 – 6. Distribution is regulated manually by sluice gates. The diameter of tanks 1 – 2 is 28 m and that of tanks 3 – 6 is 30 m. The perimeter depth of the settlers is 3,0 – 3,1 m.

There are two raw sludge pumping stations: one serving primary clairfiers 1 – 2 and one serving primary clarifiers 3 – 6. In addition to raw sludge pumps, the pumps for emptying of the primary clarifiers and for flushing the sludge lines are located in the raw sludge pumping stations.

2.4.2 Secondary treatment

The secondary treatment stage consists of 6 aeration tanks and 6 secondary clarifiers.

Wastewater is directed from the outlet throughs of primary clarifiers 1 – 2 to the distribution chambers of aeration lines 1 and 2 by a channel, and from primary clarifiers 3 – 6 to the distribution chambers of aeration lines 3 – 6 by pipes.

Lines 1 – 4 are S-formed (three corridors) and lines 5 – 6 of U-type (two corridors). In all lines, return sludge is discharged to the beginning of the line. Wastewater can be introduced stepwise in the first and second corridors. Depth of aeration basins varies from 4,4 to 5,0 m. During the visit to the treatment plant, the wastewater supply in the

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1st aeration section was carried out in the beginning of the first and the beginning of the second corridors, in the 2nd aeration section – in the beginning of the first corridor and on the full length of the second corridor, in the of 3rd aeration section – on the full length of the first and second corridors (see Figure 2.12). The total volume of the aeration basins is 39 700 m^3.

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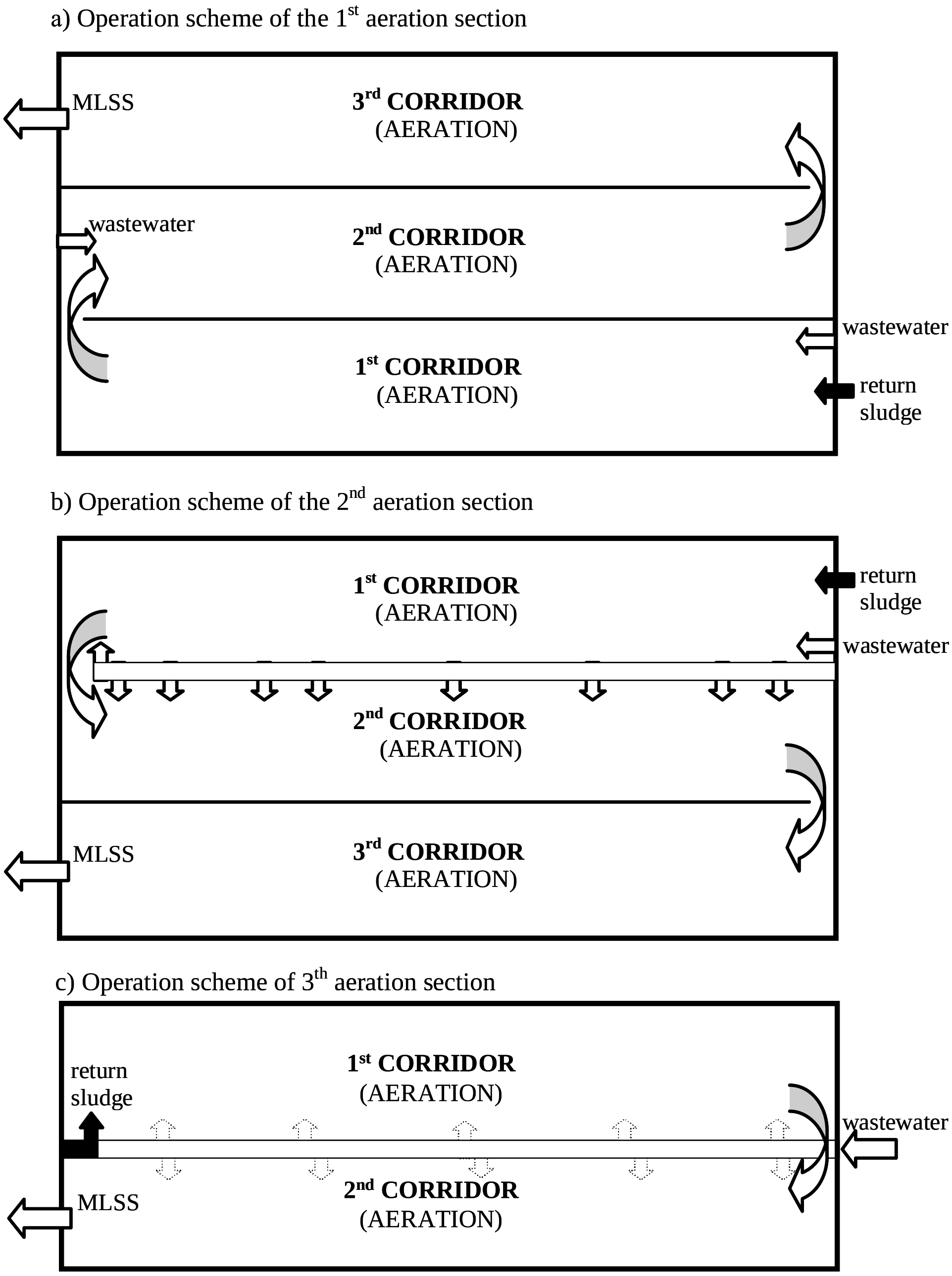

Figure 2.12. Operation schemes of aeration tanks at Brest WWTP

All aeration basins are equipped with tubular coarse-bubble bottom aerators of type “Radaka”, which cover half of the bottom of each corridor (see Figure 2.13). Aeration air is produced with four HV-Turbo KA22SV compressors, two of which are normally in use. All compressors are connected to the same air main, and all aeration lines are in the same pressure system. Distribution of air to the aeration basins is regulated with manually operated valves. There is one automatic oxygen meter in each basin.

a) coarse bubble aeration installation at Brest treatment plant

b) aeration tank in Brest wastewater treatment plant

Figure 2.13. Tube aeration system "Radaka" in the aeration tanks of Brest WWTP

All aeration basins discharge to a common outlet channel from which the activated sludge is directed to the distribution chambers of secondary clarifiers. Clarifiers 1 – 2 (d = 28 m) serve primarily aeration lines 1 – 2 and clarifiers 3 – 6 (d = 30 m) serve primarily aeration lines 3 – 6. The peripheral depth of all clarifiers is 3,1 m. Sludge is removed from the clarifier bottom by suction scrapers and transferred by pipes to the suction basin of return sludge pumping station.

The return sludge pumping station serves all six activated sludge lines. Return sludge is pumped with three Flygt 3300.181 pumps to distribution chambers, where it is divided by sluice gates to the aeration lines. Biological excess sludge is removed from the return sludge pressure line and directed to gravitational thickening.

From the outlets of the secondary clarifiers, the treated wastewater is directed to lagoons, where it is retained for additional solids separation. There are a total of 8 lagoons, with a total area of 40 hectares. From the outlet of the last lagoon the water is directed to the receiving river.

2.4.3 Sludge treatment

At the moment, raw and excess sludge are treated separately, because dewatering of both sludges simultaneously with the belt presses has been very problematic.

Raw sludge is directed from the raw sludge pumping stations to sludge pumping station and from there to a sludge tank and further to belt presses for dewatering. There are a total of three new belt filter presses (Vanex VX 15) at the newly reconstructed dewatering station. The installation of new presses has improved the dewatering performance but has not solved the problems of co-treatment of raw and biological sludges. The dewatered sludge is stored to seven separate sludge piling sites, which have total volume 180 000 m^3.

Biological excess sludge is thickened in two gravitational thickeners (d = 9,0) and pumped to sludge lagoons to be dewatered later.

The dewatering problems are expected to be solved after anaerobic digestion has been taken into use.

The amount of raw sludge formed in 2008 was 107 668 m^3/a and in 2009 89 221 m^3/a. The design sludge loading parameters from the WWTP to the digestion plant have been estimated as 250-350 m^3/d raw sludge (5 – 8 %TS) and 550-650 m^3/d excess sludge (1,8 – 2,0 % TS).

2.5 Operation

2.5.1 Operational indexes

Sludge retention time and MLSS concentration

The average MLSS concentration in 2009 was 2,0 g/l, varying between 2,0 and 3,7 g/l as shown in Figure 2.14 .

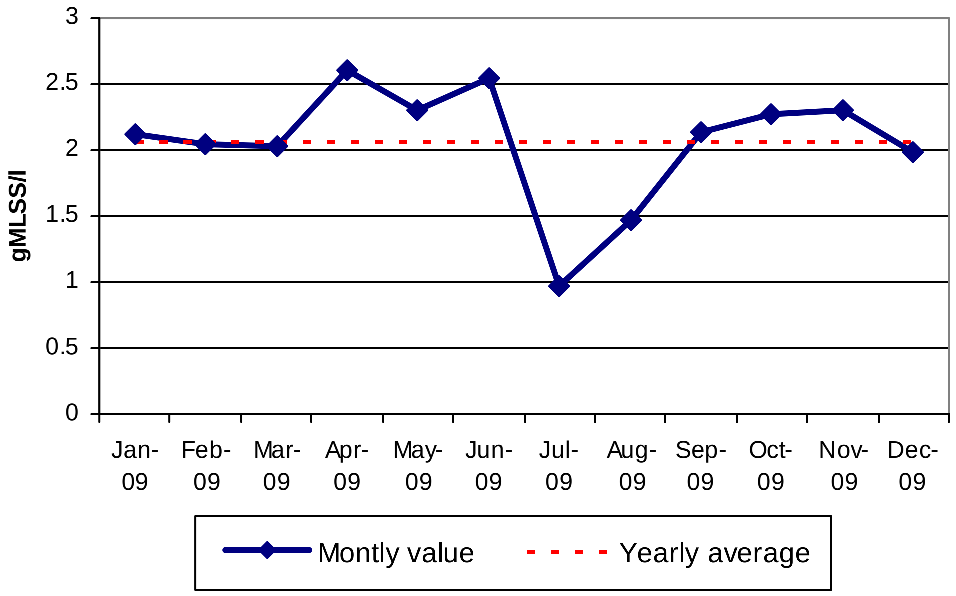

Figure 2.14. MLSS concentration, 2009.

The average total sludge retention time in 2009 was 6,2 d (2,2 – 8,5 d) as shown in Figure 2.15.

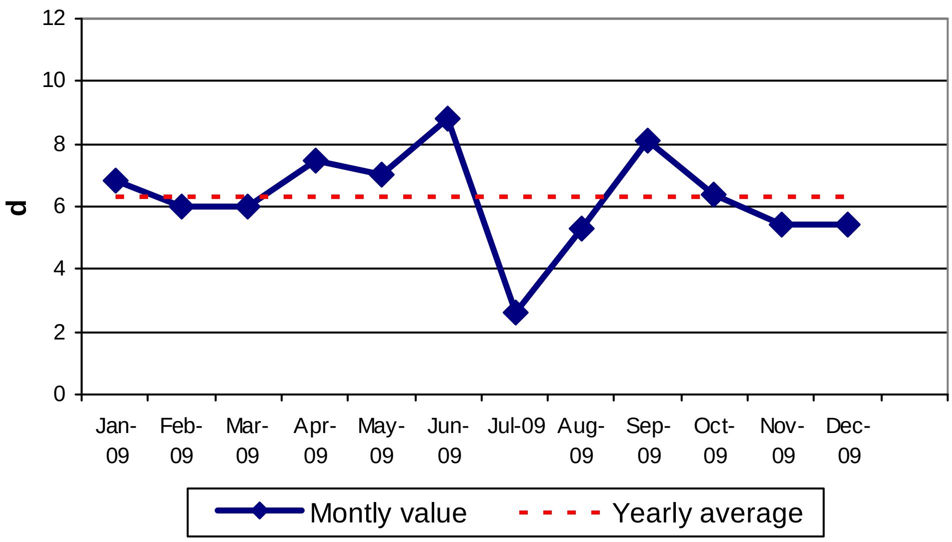

Figure 2.15. Sludge retention time, 2009.

Sludge volume index

The sludge volume index (SVI) was, on average, 342 ml/g (240 – 430 ml/g). The values from 2009 are presented below (see Figure 2.16). The SVI is highest during wintertime and approximately 30 % lower during warm period. The values are very high throughout the year, which is uncommon for a BOD-removal plant operated with a short sludge retention time. The high SVI values may indicate low sludge settleability properties, which may have a connection to the high effluent SS concentrations.

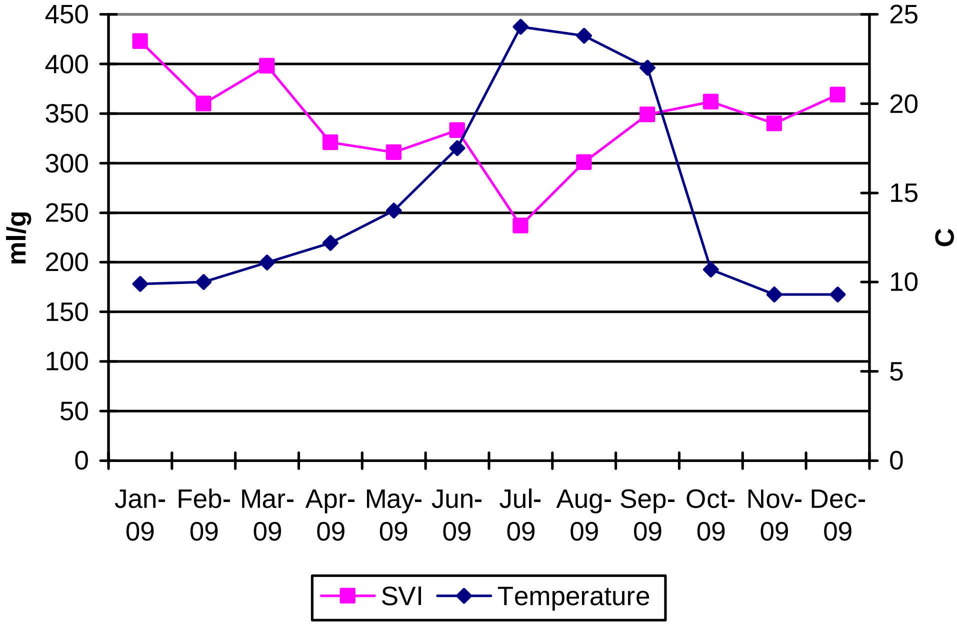

Figure 2.16. Sludge volume index and influent temperature, 2009.

2.5.2 Loading of the activated sludge process

BOD_5 loads

The F/M-ratio (organic load) and volumetric load to aeration for the year 2009 are presented below in Figure 2.17. The average values were 0,15 $kgBOD_5/kgMLSS/d$ (0,012…0,32) and 0,29 $kgBOD_5/m^3/d$ (0,24…0,32).

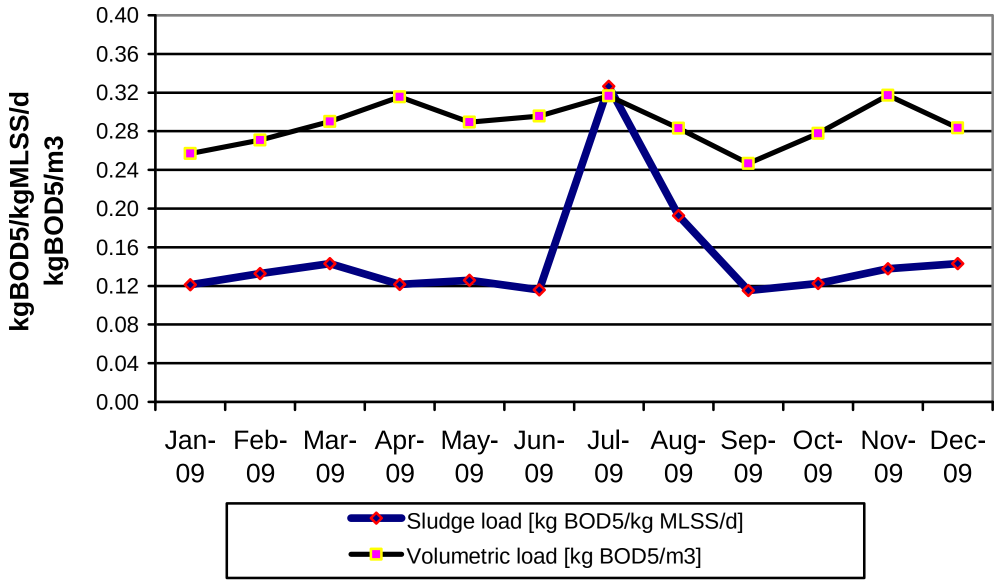

Figure 2.17. Organic load to aeration, 2009.

Nitrogen loads

The total nitrogen load to biological process was estimated based on the influent ammonium load, assuming that in pre-settled wastewater NH_4-N = 0,8 * N_{TOT} and that rejects from sludge treatment increase the total nitrogen load by 10 %. The nitrogen load per kgMLSS and per aeration basin volume is plotted in Figure 2.18. The average values for 2009 were 0,06 kgN/kgMLSS/d (0,04…0,14) and 0,12 kgN/m^3/d (0,10…0,14).

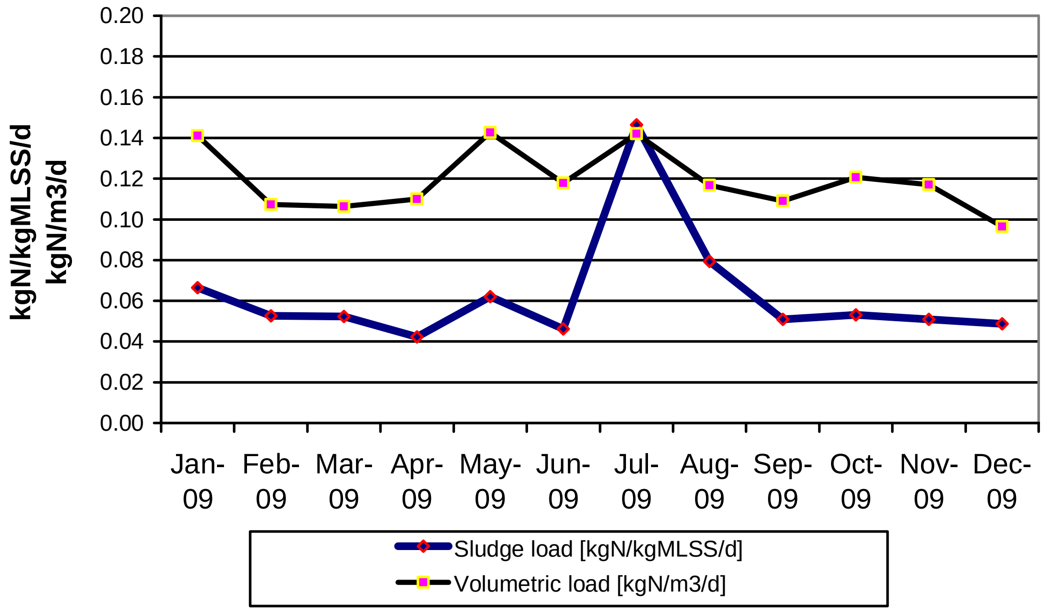

Figure 2.18. Nitrogen load to aeration, 2009.

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3 ANALYSIS AND PROPOSED IMPROVEMENTS

3.1 Analysis of plant conditions

Structurally and mechanically, the conditions at the plant can be described as fair to barely acceptable, which is often the case in Eastern-European plants of this age. Some of the machinery (e.g. compressors, return sludge pumps, belt filter presses) are modern, some old (e.g. aeration pipes, valves and aerators).

The influent of the plant is characterized by high nutrient loads, especially phosphorus. It is highly probable that at least 20 % of the phosphorus load comes from the local food industry facilities, which are among the biggest in the whole country.

The nutrient loads will increase further in the immediate future, when the anaerobic co-digestion plant will be commissioned and the reject waters from this plant are directed to the WWTP. The expected efficiency of biological nitrogen and phosphorus removal in Brest would be low because of the low BOD/N and BOD/P ratios of the influent wastewater. In terms of BOD and SS the influent wastewater quality corresponds to normal municipal wastewater.

The simplified phosphorus balance of the WWTP and digestion plant is presented in Figure 3.1. The phosphorus included in raw sludge and assimilated in the biological excess sludge of the WWTP will be, to a certain extent, released in the digester and returned to the WWTP in the reject waters from sludge dewatering.

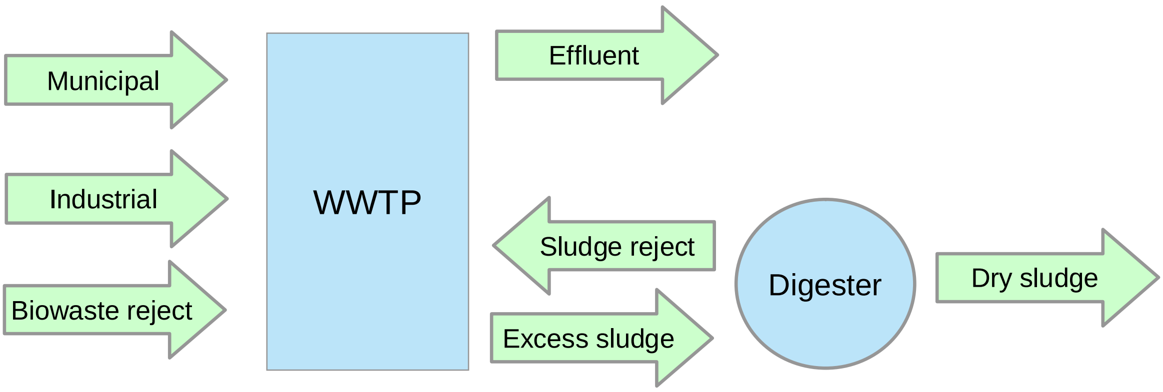

Figure 3.1. Simplified phosphorus balance of the WWTP and digestion plant

At present, the plant performs virtually no nitrogen or phosphorus removal. The volumetric capacity of the biological process and the achievable sludge retention time would be sufficient for nitrification. Even partial total nitrogen removal could, theoretically, be achieved at least in the summertime, to the extent allowed by nitrate recycling via return sludge and mixing of the first aeration corridors with low-intensity aeration. However, the aeration system as a whole is not capable of supplying enough air to all parts of the aeration basin and cannot be controlled adequately. Thus, stabile nitrification is difficult to maintain and total nitrogen removal is practically impossible.

Enhanced biological phosphorus removal (EBPR) cannot be performed due to lack of sufficient basin volumes, machinery and controllability.

3.2 Possible solutions

Below, we present some options for improvement of nutrient removal at the Brest WWTP. The effect of reject waters from the digestion plant is included in the preliminary calculations, which were made to produce the numerical values presented below.

3.2.1 Source control of industrial wastewater

The major industrial sources of nutrient loads should be recognized and the loading coming from them should be quantified. Pre-treatment of industrial wastewaters at source (e.g. precipitation of phosphorus), before discharge to municipal sewers, should be considered. If this is not possible, the plant operator should reach an agreement with the industries on sharing of capital and operational costs of phosphorus removal at the WWTP.

3.2.2 Phosphorus and nitrogen removal at Brest WWTP

To reach the HELCOM targets for phosphorus and nitrogen, two basic upgrading options can be formulated:

1. denitrification-nitrification process for nitrogen removal; phosphorus removed by assimilation and chemical precipitation
2. biological nitrogen removal and EBPR by e.g. JHB-process; complementary phosphorus removal by chemical precipitation

Schematic presentations of the present operation of the biological process and the upgrading options mentioned above are presented in Figure 3.2, Figure 3.3 and Figure 3.4.

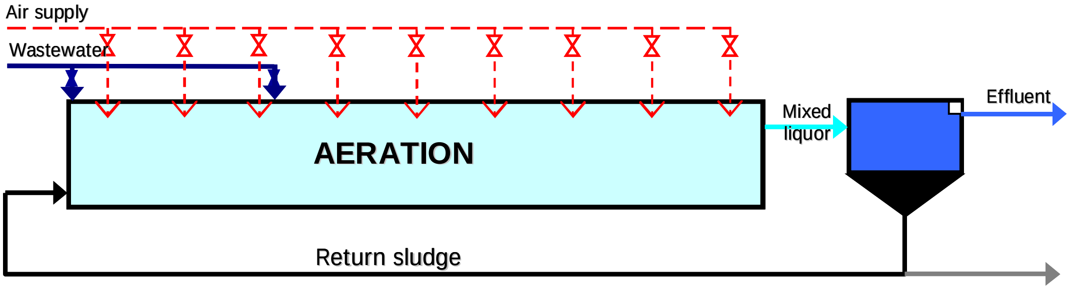

Figure 3.2. Present operation scheme.

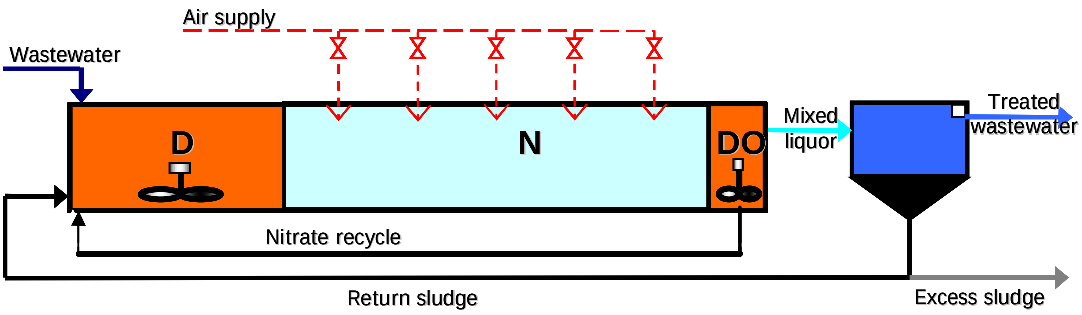

Figure 3.3. Denitrification-nitrification (DN) process for biological nitrogen removal.

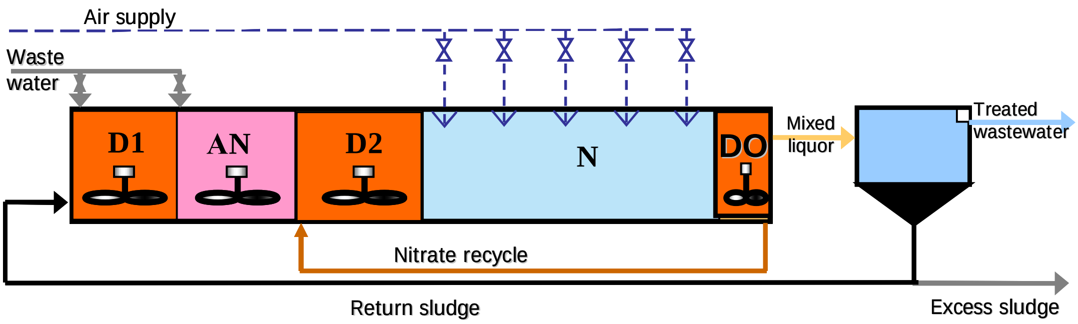

Figure 3.4. Johannesburg process (JHB) for biological nitrogen and phosphorus removal.

In the figures above, the following functional codes are used:

– AN = anaerobic zone; release of cell-internal phosphorus to liquid phase
– D = denitrification zone; reduction of nitrate to nitrogen gas
– N = nitrification zone; oxidation of BOD to CO_2 and cell mass; oxidation of ammonium nitrogen to nitrate; and excess uptake of phosphorus in the JHB process

Upgrading the biological process for nitrogen and phosphorus removal would require at least the following major investments:

– substantial increase in aeration volume, approximately:
  – 8 000 m^3 for DN-process
  – 15 000 m^3 for JHB process
– construction of two new secondary clarifiers
– dividing the aeration basins to separate zones for denitrification (anoxic, D) and phosphorus release (anaerobic, AN) with light-structured walls
– implementing propeller mixing in the D- and AN-zones
– nitrate recycle pumping and piping
– division of influent wastewater to two feeding points in the JHB process
– complete renovation of the aeration system
  – dividing the basins into pressure zones according to basin depth
  – automatization: control valves, instrumentation, automation
– instrumentation for control of nitrogen (and phosphorus) removal, e.g. measurements for redox potential, ammonium nitrogen, nitrate nitrogen and phosphate

Baltic Sea Region
Programme 2007-2013
Part-financed by the European Union (European Regional Development Fund and European Neighbourhood and Partnership Instrument)

– measures for better control of sludge retention time

In addition, efficient phosphorus removal requires chemical precipitation in both presented options.

3.2.3 Phosphorus removal only

Phosphorus removal can be increased also, and even better, without simultaneous improvement of nitrogen removal. Two basic options can be formulated:

1) biological removal of BOD and EBPR with AO process; complementary phosphorus removal by chemical precipitation
2) removal of BOD with the present operation scheme; phosphorus removed by assimilation and chemical precipitation

The AO process, which is the most simple solution for biological phosphorus removal, is presented schematically in Figure 3.5. In this solution, the beginning of the aeration line is mixed and the rest is aerated. Phosphorus is released from the phosphorus-accumulating organism (PAO) cells in the anaerobic zone and taken up in the aerobic zone. In addition, BOD is oxidized in the aerobic zone. Nitrification is suppressed by keeping the sludge retention time short. Nitrification is undesirable, because in the absence of a denitrification zone, any nitrate formed in the aerobic part is recycled to the anaerobic zone via return sludge, decreasing the effect of EBPR.

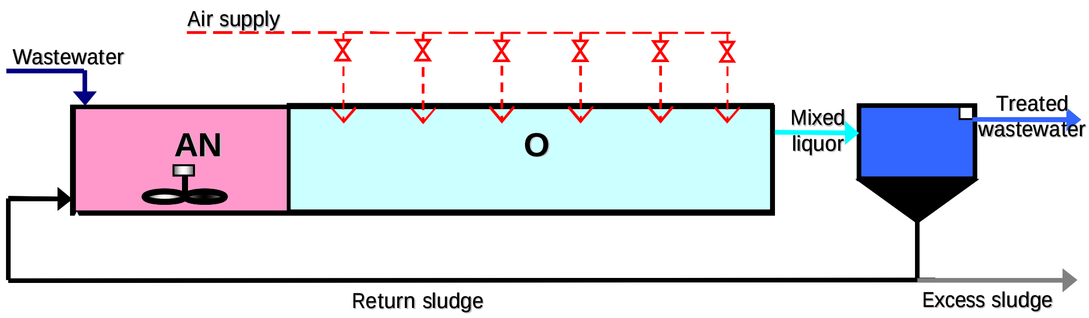

Figure 3.5. AO (anaerobic-oxic) process for biological phosphorus removal.

Implementing the AO process would require at least the following major investments:

– dividing the aeration basins to anaerobic and aerobic zones with light-structured walls
– implementing propeller mixing in the anaerobic zones
– at least partial renovation of the aeration system
– instrumentation for control of phosphorus removal, e.g. measurements for redox potential and phosphate
– measures for better control of sludge retention time

The AO process can be expected to perform better phosphorus removal than JHB process, if nitrification can be suppressed. Then, in the absence of nitrate, all available readily biodegradable COD (RBCOD) can be used by the PAOs, whereas in the JHB

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process nitrate is formed and denitrified, which consumes part of the RBCOD. However, chemical precipitation will still be needed.

3.3 Recommended actions

3.3.1 General

It is evident that efficient phosphorus removal at Brest WWTP absolutely requires chemical precipitation, regardless of what is done to the biological process now or in the future, and even if industrial load is pre-treated at source.

Implementing biological nutrient removal with JHB process or nitrogen removal with DN process is definitely out of scope of the budget available for this project. In addition, BNR will probably be implemented in the near future, in conjunction with a major renovation and expansion project financed by e.g. the Nordic Development Bank. Implementing the AO process as an intermediate option would be much cheaper and would reduce the required chemical dose by about 30 %. In addition, the equipment (mixers, aeration) procured for the AO process could probably be directly used in the future rehabilitation and expansion project.

However, reaching the HELCOM target of 0,5 gP/m^3 will require a lot of precipitant even with the AO process. We suggest that the investments financed by the PURE project be directed to chemical precipitation of phosphorus and monitoring of the phosphorus load and treatment performance of the plant. This is the best way to achieve tangible results as soon as possible.

3.3.2 Analysis of total phosphorus load of the Brest WWTP

At present, total phosphorus is not included in the monitoring of the WWTP. For accurate dimensioning of the treatment facilities, it is essential to know the true total phosphorus load of the plant. Therefore, the WWTP undertook a monitoring and analysis campaign in September – October of 2010 according to the following parameters:

- sampling points
  - sewer before inlet chambers
  - inlet chambers 1 and 2
  - wastewater after grit removal
  - overflow from gravitational thickening
  - reject water from belt filter presses
- analyses
  - total phosphorus
  - phosphate phosphorus
  - total suspended solids

On the basis of these analyses, the ratio PO_4/P_{TOT} in the inlet chamber was 0,86. This value is abnormally high taking into account the typical phosphorus content of suspended solids and their concentration in the wastewater. It is possible that all particulate phosphorus was not disintegrated, as the sample was heated on a stove instead of a heating reactor. The typical total phosphorus concentration in the inlet chamber was therefore calculated on the basis of PO_4-P concentrations and SS concentrations, assuming P/SS = 0,01. This way, PO_4/P_{TOT} = 0,66 which is closer to normal values, although still on the higher side, which reflects the soluble phosphate load of industrial wastewaters. The resulting concentration, 9,3 gP/m^3, was used in the dimensioning calculations as the present-day value.

On the basis of this new information, at least 20 – 25 % of the influent phosphorus originates from industries. It must be noted that although phosphate analyses from industrial wastewaters were collected, flow rates were not, so the industrial loads could not be calculated directly. Therefore, the concentration of total phosphorus at plant inlet and the proportion of industrial phosphorus load is more an educated guess supported by interpretation of on-site data than an established fact.

3.3.3 Chemical precipitation of phosphorus

The recommended dosing points of precipitation chemical are the receiving chambers of influent wastewater and the distribution chambers were activated sludge coming from the aeration basins is divided to the secondary clarifiers (see Annex 3). In addition, the reject waters originating in the dewatering of digested sludge and possible overflows from the digesters should be precipitated before they are directed to the plant in order to maximize the efficiency of chemical use. The dosing should be controlled by continuous measurement of plant inflow and reject inflow.

The phosphorus loads coming from different sources have been estimated based on the data received from the treatment plant, balance calculations of the digester process and reference data from other plants in Finland, Germany and Russia. In Table 3.1 below, the loads have been projected as phosphorus to be precipitated, i.e. the effect of primary treatment without chemicals has been taken into account. The effect of reject waters from the future biowaste treatment plant are not shown, because accurate data for them was not available. Their effect to the phosphorus load is, however, expected to be substantially lower than that of the other sources. The municipal and industrial loads include a 5 % increase as a reservation for population and production growth.

The amount of phosphorus to be precipitated and, consequently, the chemical consumption depends on the biological process of the WWTP. The calculated amounts in Table 3.1 are presented for two situations, namely the present situation (N and P removal by assimilation only) and the expected future situation (biological nutrient removal, BNR. If BNR is applied, more phosphorus is bound biologically than in the present situation, but more phosphorus will also be released in the anaerobic digestion process.

At the moment, renovation of the WWTP is being negotiated with possible financiers. The preliminary renovation plan is based on the JHB principle. Consequently, we have

Baltic Sea Region Programme 2007-2013

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assumed in the calculations that biological nutrient removal would be executed with JHB process.

Table 3.1. Preliminary dimensioning of phosphorus precipitation.

PRECIPITATION OF PHOSPHORUS		Present	BNR
Phosphorus to precipitate			
Municipalities	kg/d	331	130
Industry	kg/d	153	153
Rejects	kg/d	47	101
Total	kg/d	531	385
Chemical consumption			
Municipalities	m^3/d	5.6	3.3
Industry	m^3/d	1.7	1.0
Rejects	m^3/d	0.7	1.5
Total	m^3/d	8.0	5.8

As can be seen, approximately 30 - 60 % of the required chemical consumption is due to municipal load, 30 - 40 % due to industrial load and 10 – 30 % due to rejects.

To optimize the investment, we suggest that the precipitation facilities be dimensioned to treat the phosphorus load of municipal wastewater and sludge rejects (see Figure 3.6).

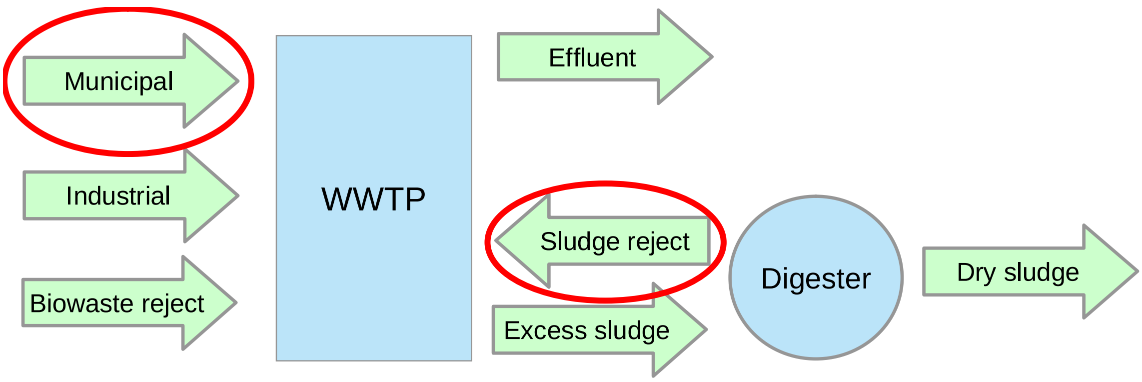

Figure 3.6. Suggested targets of chemical precipitation funded by the PURE project.

To illustrate the effect of different actions for improvement of phosphorus removal, the treatment results of biological removal and proposed precipitation are compared to the present process and to fulfillment of the HELCOM limits (Figure 3.7).

Baltic Sea Region
Programme 2007-2013

Part-financed by the European Union (European Regional Development Fund and European Neighbourhood and Partnership Instrument)

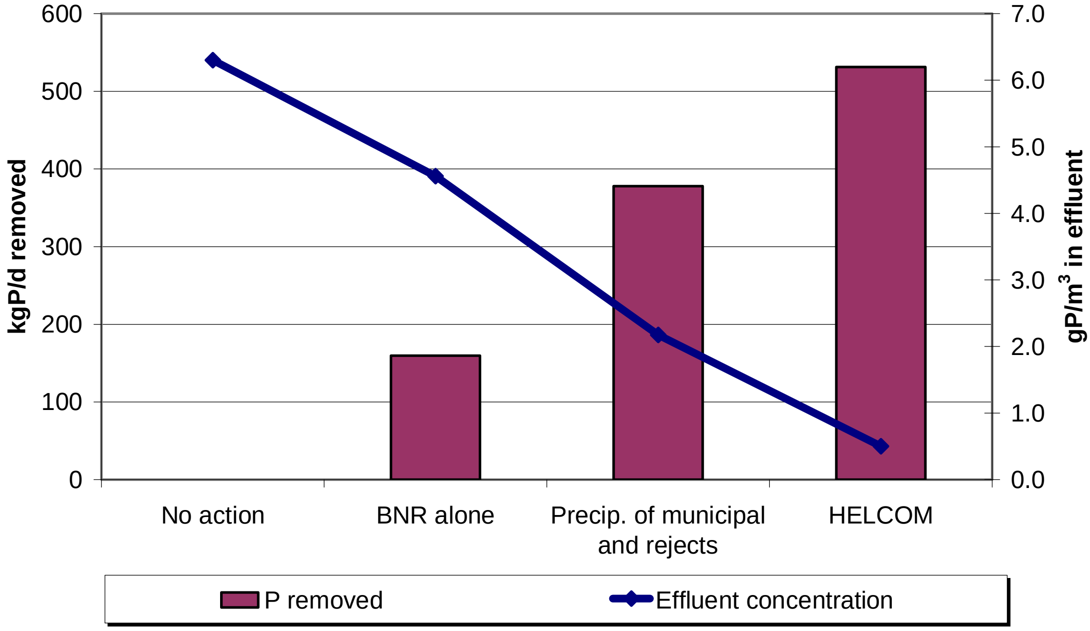

Figure 3.7. Effect of different actions on phosphorus removal.

3.3.4 Monitoring of phosphorus

To optimize the use of chemical precipitation and to support the operation of the biological phosphorus removal process in the future, on-line analysis of total phosphorus and phosphate phosphorus can be implemented in the pre-clarified and effluent wastewater. In addition, the laboratory of the WWTP should be equipped with facilities for analysing total phosphorus. These include a spectrophotometer, a heating reactor and a first supply of reagents. They are needed to analyse the phosphorus in plant influent and to monitor the reliability of the online analyses.

3.4 Dimensioning, operation and implementation of new units

3.4.1 Chemical precipitation of phosphorus

The chemical precipitation units financed by the PURE project are dimensioned to treat the estimated phosphorus load of municipal wastewater and digester rejects in the situation, when the digestion plant is in operation but no changes have been implemented in the biological process of the WWTP. The dimensioning chemical consumption, assuming PIX-105 ready-to-use solution (11,5 % Fe, 1,5 kg/l) is 5,6 + 0,7 = **6,3 m^3/d** (see Table 3.1).

The chemical storage and dosing station will be implemented in the old, unused pre-aeration basins. One half of the tank will be divided into storage tank (200 m^3), dosing tank (100 m^3) and pumping room (100 m^3). A room for electrical switchboards will be constructed on top of the chemical tanks. The implementation of the storing and dosing station is shown in the layout drawings (Annex 3). Dosing arrangements are shown in the flow diagram (Annex 2). The implementation shall permit both the use of a ready-made solution and a solution made locally from granular or powdered chemical and technical water.

The main items of the proposed plan are the following:
- civil works (excavation, concrete walls, dismantling of old walls, PE lining etc.)
- 8 dosing pumps with frequency transformers
- mixer in the dosing tank
- bag hopper, screw feeder and lifting crane for granular and powder products
- piping from pumping room to dosing points, trace heated
- ventilation and heating as required
- electrics, instrumentation and automation

3.4.2 Monitoring of phosphorus

The phosphate measurements are executed by two analysers, which are located indoors in the compressor building. The samples are pumped to the analysers continuously from the effluent channels of primary and secondary sedimentation. The sample to be analysed is filtrated and taken to the analyser via an automatically controlled valve system. The analyser operates continuously, controlled by a separate control system which is included in the analyser supply.

The suggested primary implementation plan for monitoring of phosphorus includes the following main items:
- 2 phosphate phosphorus analysators (1 after primary sedimentation, 1 after secondary sedimentation)
- 4 sampling pumps
- 4 sample pre-treatment units (filtration)
- sampling piping
- spectrophotometer, heating reactor and reagents for the laboratory
- electrics, instrumentation and automation

In addition to phosphorus, it is important to monitor several other parameters in order to operate nutrient removal successfully. The first supply of reagents included in the investment consists of analysis kits for ammonium nitrogen, nitrate nitrogen, nitrite nitrogen, total nitrogen, phosphate phosphorus, total phosphorus and organic acids (an important carbon source for EBPR). The amount of reagents included allows for 100 analyses of each parameter.

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Baltic Sea Region
Programme 2007-2013

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Annex 1

Historical data of wastewater flows and characteristics

1. Wastewater characteristics for 2005-2009

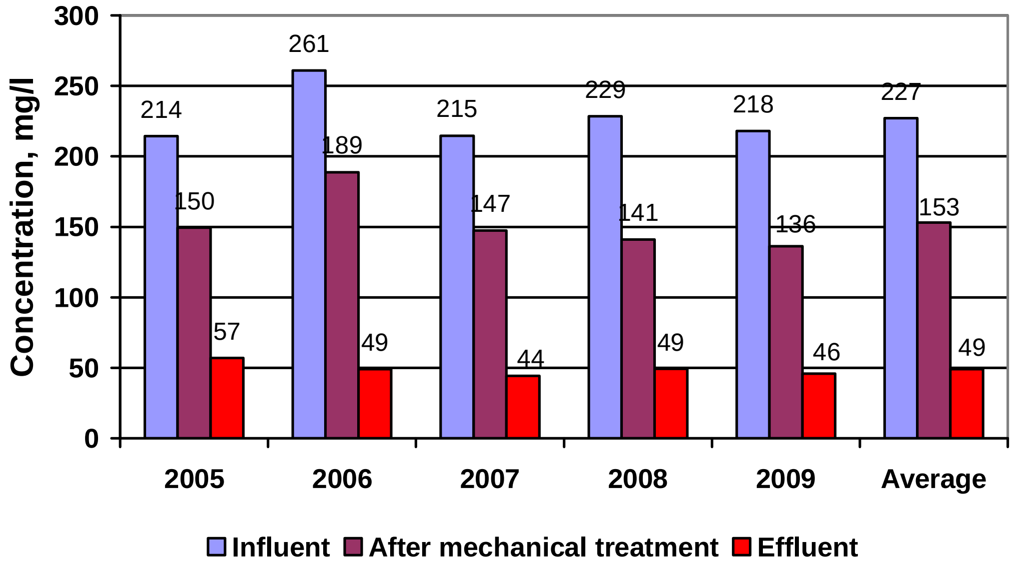

Fig.2.1. Suspended solids concentrations 2005-2009

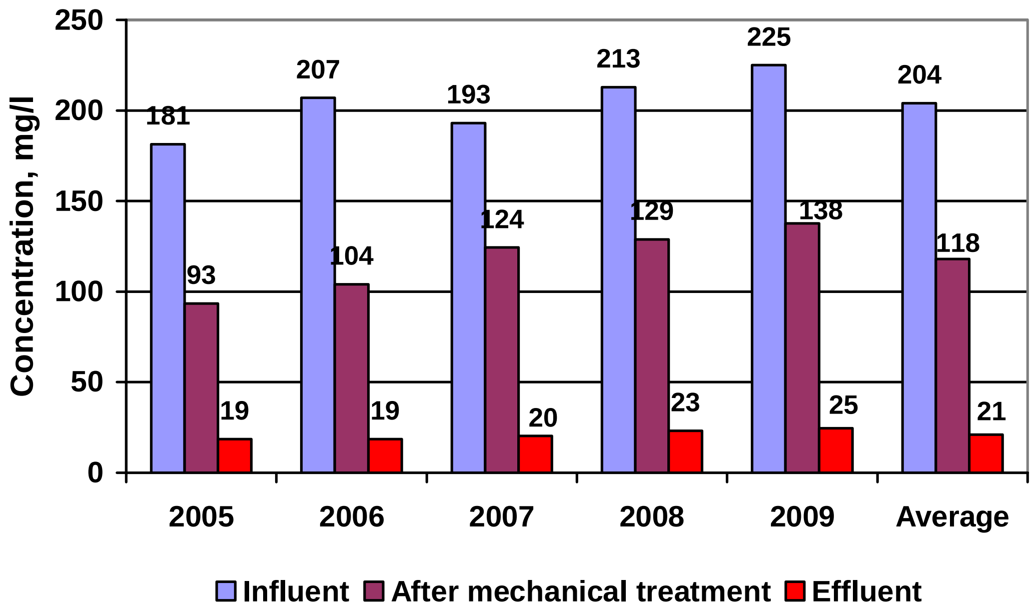

Fig.2.2. BOD_5 concentrations 2005-2009

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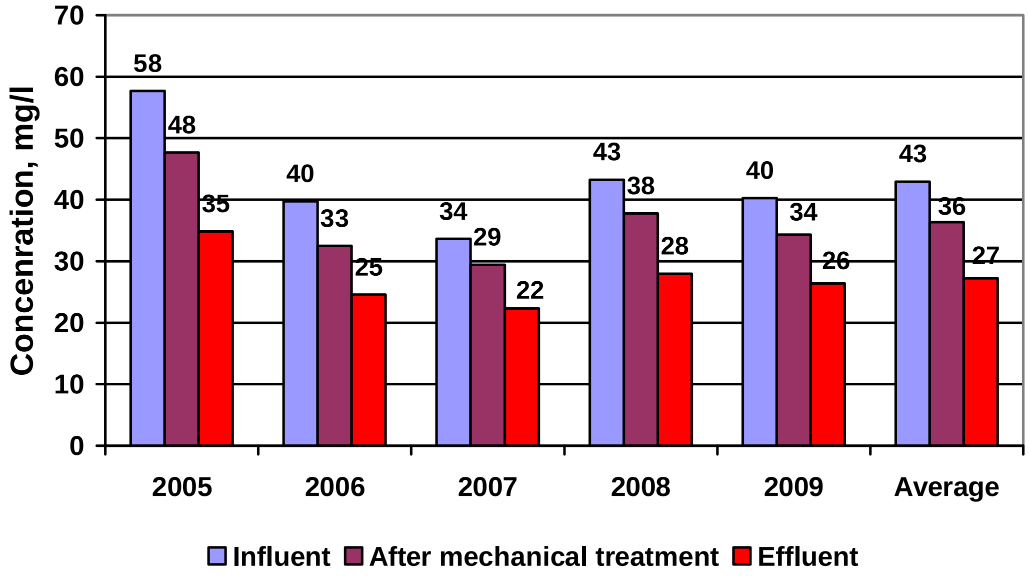

Fig.2.3. Ammonium nitrogen concentrations 2005-2009

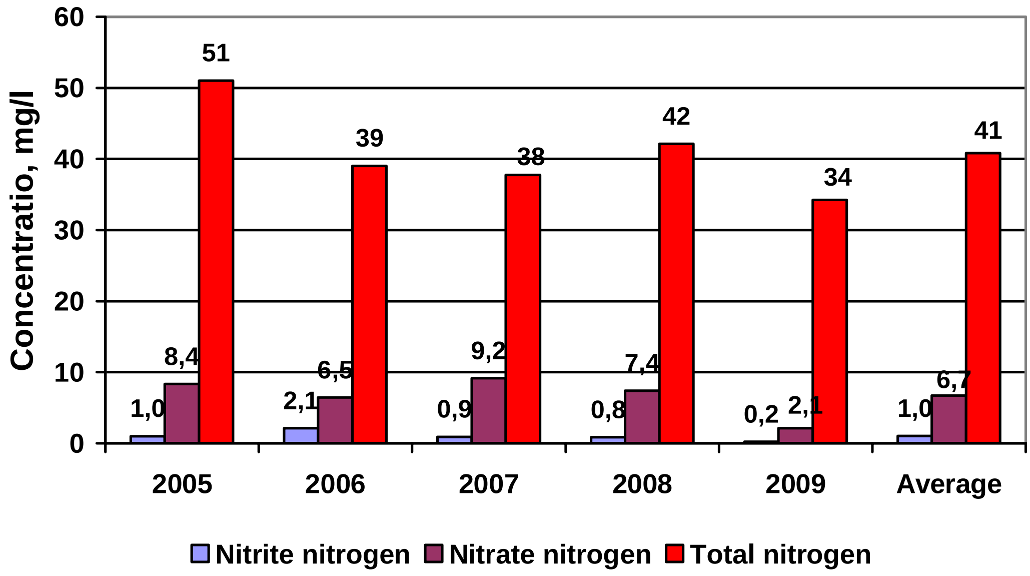

Fig.2.4. Concentrations of nitrite nitrogen, nitrate nitrogen and total nitrogen after secondary clarifiers 2005-2009

Baltic Sea Region
Programme 2007-2013
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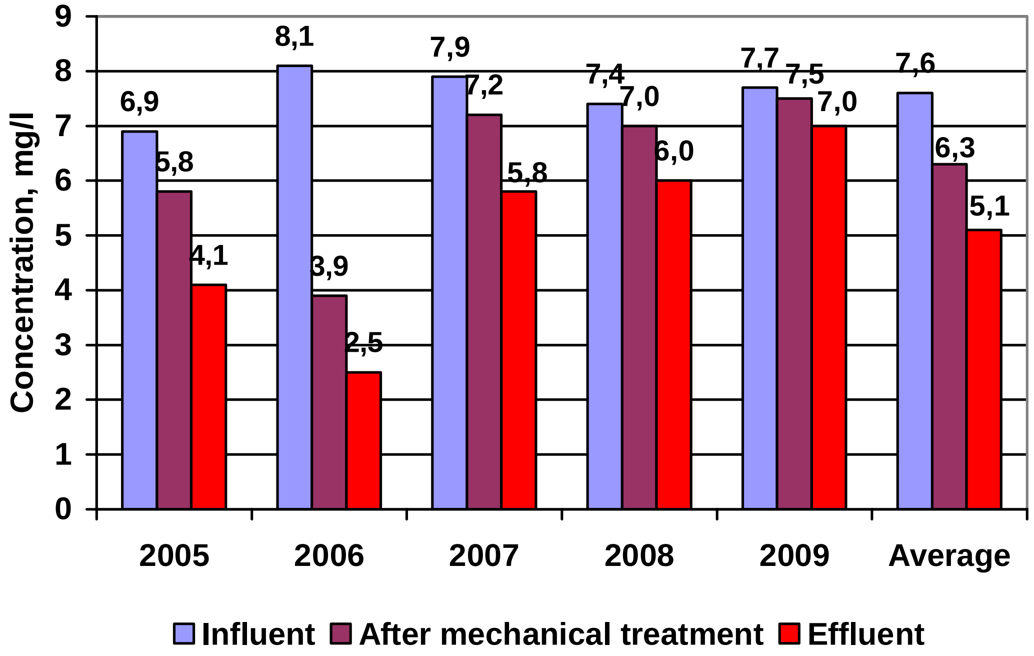

Fig.2.5. Phosphate phosphorus (PO4-P) concentrations 2005-2009

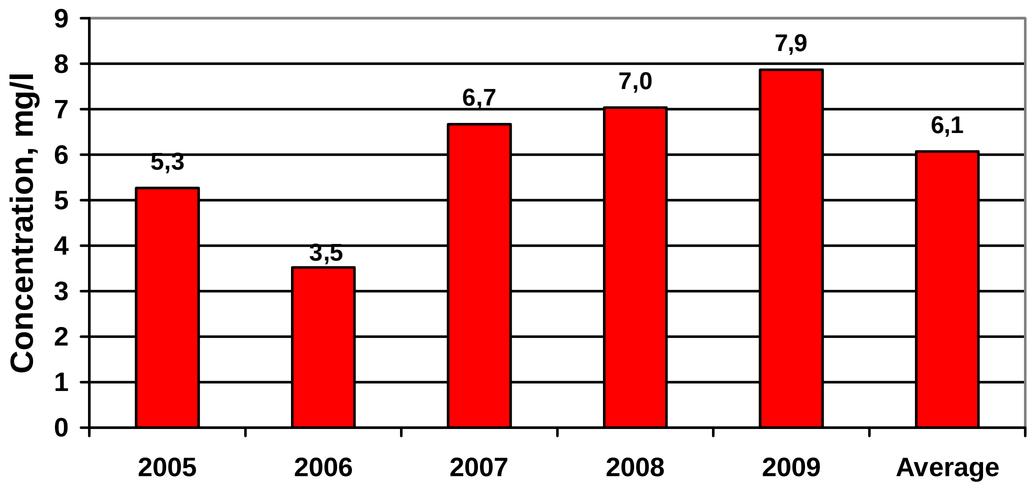

Fig.2.6. Total phosphorus concentration (estimated) after secondary clarifiers 2005-2009

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2. Wastewater flows for 2008-2010

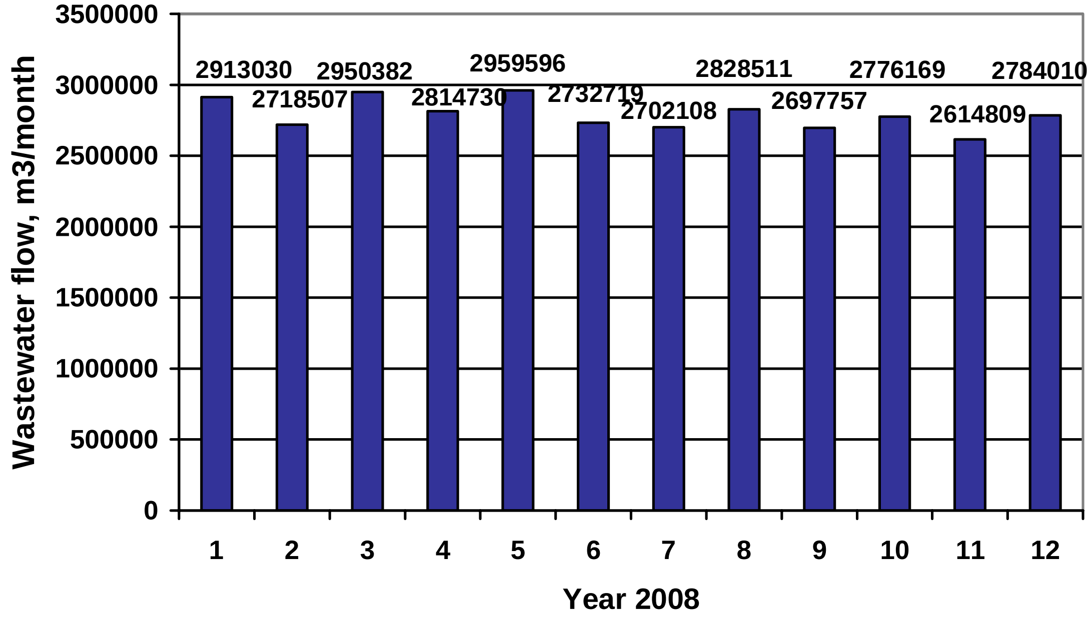

Fig.2.7. Annual wastewater flows in 2008.

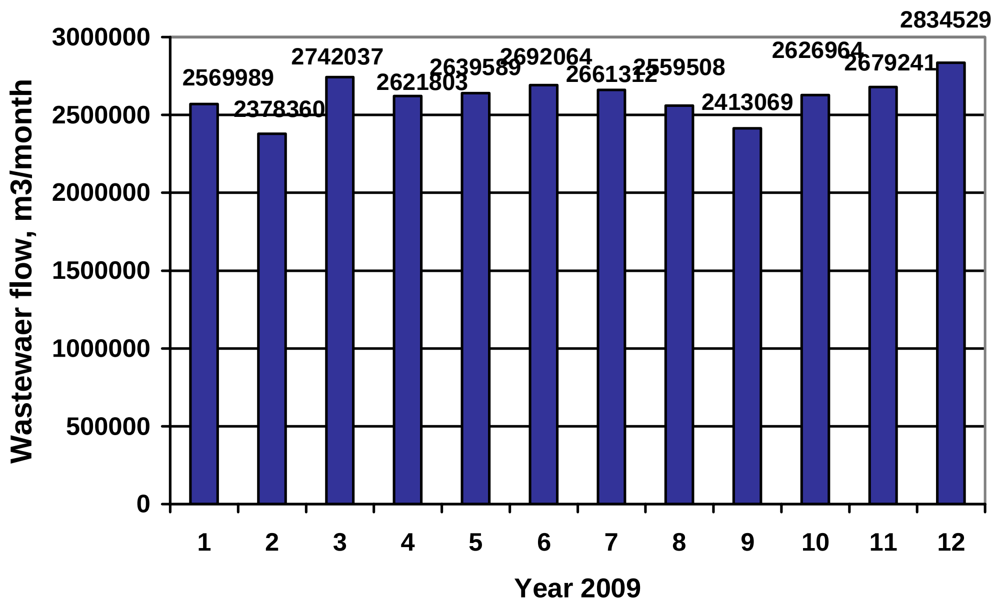

Fig.2.8. Annual wastewater flows in 2009

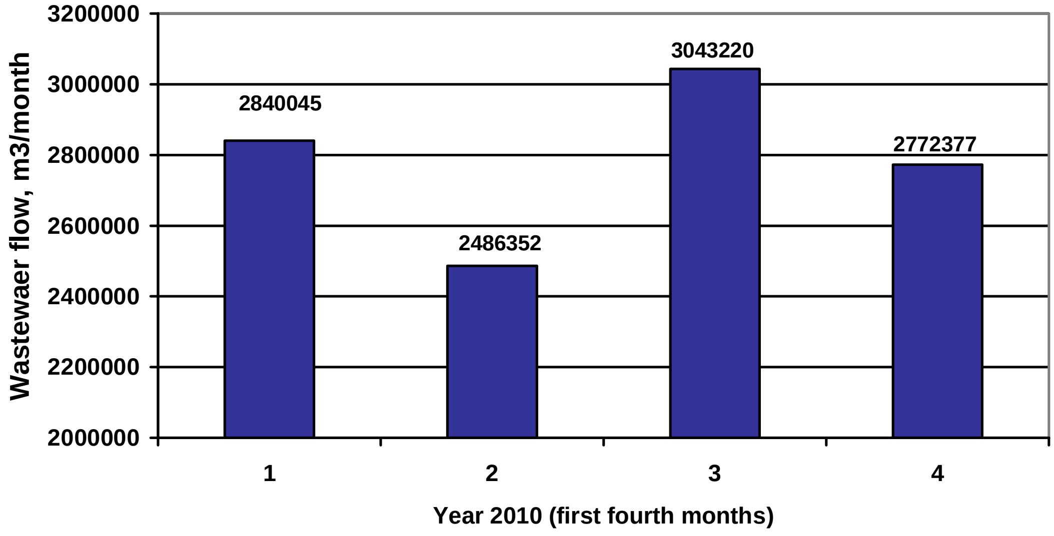

Fig2.9. Annual wastewater flow in 2010

The daily average wastewater flow for May of 2010 is shown on fig. 2.10.

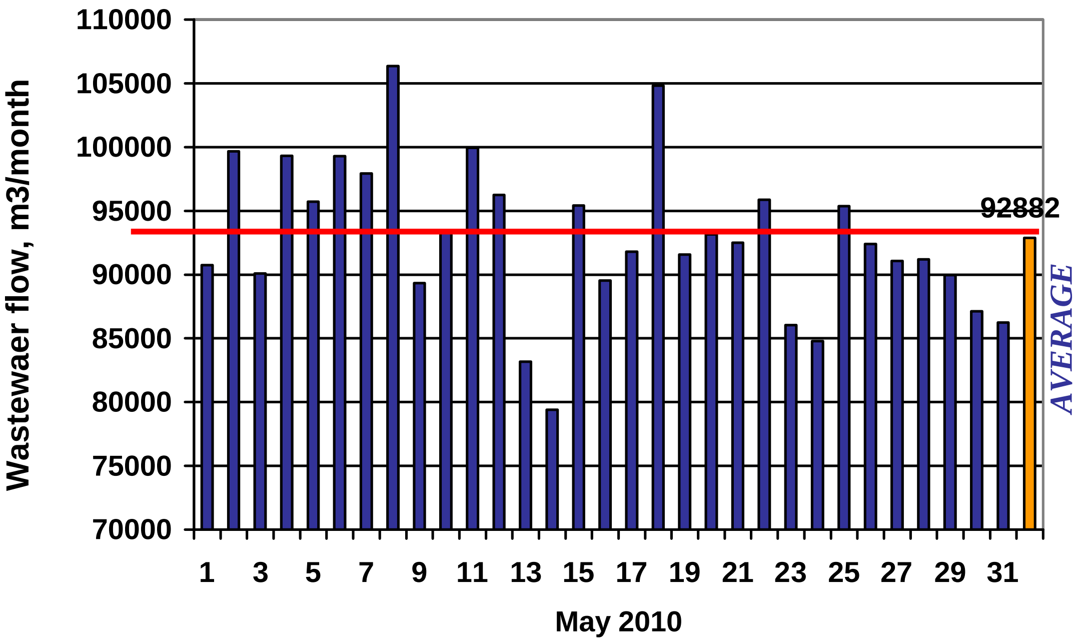

Fig. 2.10. The daily average wastewater flow during May of 2010