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November 24, 2010

John Nurminen Foundation

Technical Audit of the Jurmala Wastewater Treatment Plant

Establishment of the Most Feasible Way for Accelerated Phosphorus Removal

Competence. Service. Solutions.

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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 JURMALA WASTEWATER TREATMENT PLANT

2.1 General

The Jurmala wastewater treatment plant (WWTP) is situated in the Sloka region, on the bank of the Lielupe river. Approximately 74 % of the wastewater formed in the town of Jurmala (population 56 000) is directed into sewers. Of this amount, the Sloka plant treats approximately 70 %, and the rest is pumped to the Daugavgriva WWTP in Riga. In addition, approximately 90 % of the septic tank sludges collected in Jurmala are transported to the Sloka WWTP.

The plant has conventional primary treatment without primary sedimentation, activated sludge process for enhanced biological phosphorus and nitrogen removal and sludge treatment by mechanical thickening and dewatering.

The plant was built in 2007 and put into operation in 2008. The constructor has not commissioned the plant, because all guarantee values have not yet been met. The personnel of Jurmalas Udens are running the plant according to the instructions given by the constructor.

2.2 Wastewater flows and loads

The purpose of the audit is to propose measures to enhance nutrient removal and process stability primarily within the existing process tanks. Therefore, the investments to be planned will be based partly on the original dimensioning parameters, and partly on the existing wastewater loads and flows, namely the average influent values from the year 2009. These data are presented and analysed below in this chapter.

The wastewater is practically entirely of municipal origin. No significant industrial loaders are known.

The basic figures describing the wastewater amount and quality are presented in Table 2.1. Person equivalent values have been calculated on the basis of the BOD_5 load, assuming 1 P.E. = 0,06 $kgBOD_5$/p.e./d. The design flow has been calculated as follows:

$$q_{design} = k_d * Q_{average} / t_d$$

where

q_{design} = design flow, m^3/h
k_d = 1,3
t_d = 16 h

For comparison, also the original dimensioning values of the plant (YIT Environment Ltd, 2007) are given in Table 2.1.

Table 2.1. Wastewater data, Jurmala WWTP

Parameter	Unit	Dimensioning value*	Average 2009
Population	ca	32 440	28 780
Specific flow production	l/ca/d	277	259
$Q_{average}$	m^3/d	9 000	7 450
Q_{max}	m^3/d	18 000	13 530
$q_{design/average\ 2009}$	m^3/h	500	310
BOD_5	kg/d	2 140	1 525
	g/ca/d	66	53
	mg/l	238	200
COD_{Cr}	kg/d	4 460	4 189
	g/ca/d	137	146
	mg/l	496	560
Suspended solids	kg/d	2 320	1 479
	g/ca/d	72	51
	mg/l	258	200
Total nitrogen	kg/d	480	396
	g/ca/d	15	14
	mg/l	53	53
Total phosphorus	kg/d	80	56
	g/ca/d	2	1.9
	mg/l	8.9	7.0
Temperature, max	°C	>15	18.5
Temperature, min	°C	10	9

*) YIT Environment Ltd, 2007, design year 2015

The loading will increase slightly in the future when the sewer network is expanded. The expected increase in the number of customers is approximately 10 %.

2.2.1 Wastewater flow

Influent wastewater flow varied from 5 300 m^3/d to 13 500 m^3/d. The yearly average was 7 450 m^3/d. Only 2 % of the daily flow values exceeded the dimensioning flow value of 12 000 m^3/d. The influent flow during 2009 is shown in Figure 2.1

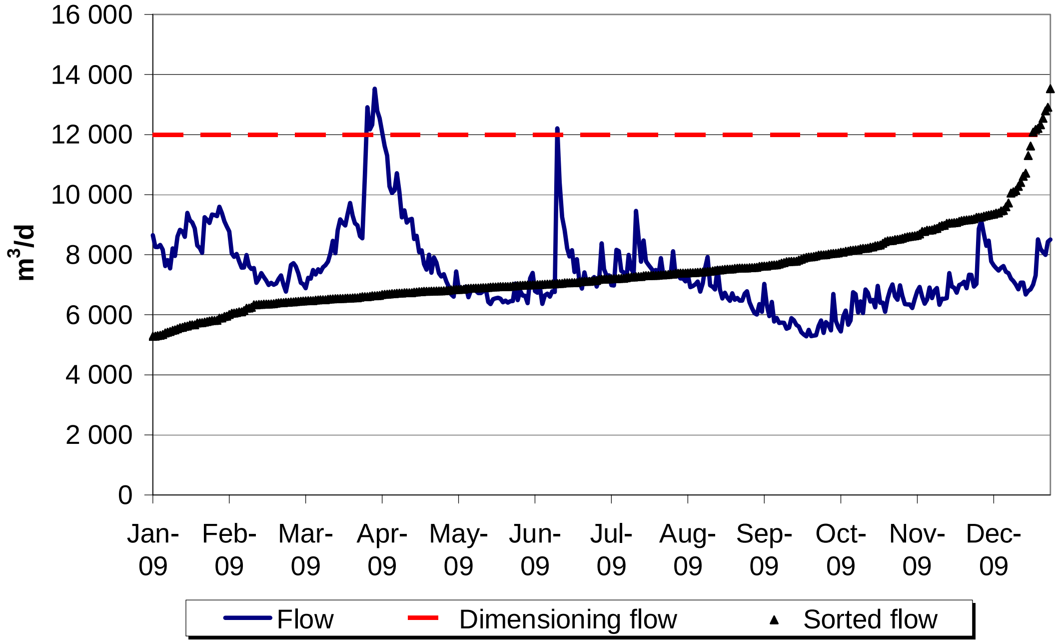

Figure 2.1. Influent wastewater flow, 2009.

The flow time curve shows a long period of rains and/or snow melting in March – April and individual rains in the summer. No significant increase of wastewater amounts is shown during the holiday season.

2.2.2 Wastewater loads

Organic load

The influent organic load was measured by BOD_5- measurements twice a week and by COD_{Cr}-measurements five times a week. BOD_5- load and concentration varied as shown in Table 2.2.The highest 10 % of the measurements exceeded the dimensioning BOD_5-value of 2 140 kg/d. The influent BOD_5- load during 2009 is shown in Figure 2.2.

Table 2.2 BOD_5 load and concentrations, 2009

BOD_5	Average	Min	Max
Concentration (mg/l)	213	77	400
Load (kg/d)	1 525	213	2 665

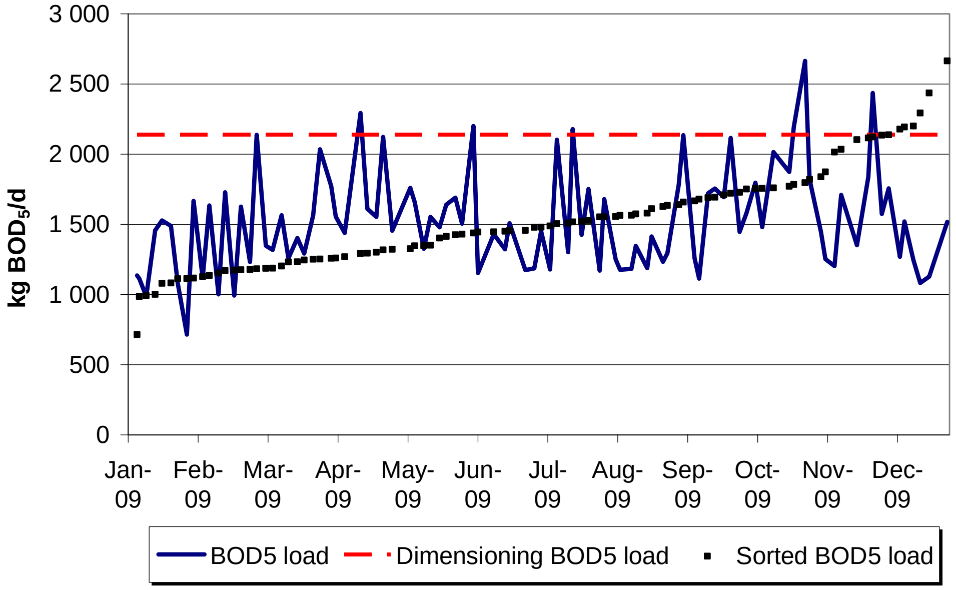

Figure 2.2. Influent BOD_5 load, 2009.

COD_{Cr}- load and concentration varied as shown in Table 2.3. The highest 30 % of the measurements exceeded the dimensioning COD_{Cr}-value of 4 460 kg/d. The influent COD_{Cr}- load during 2009 is shown in Figure 2.3.

Table 2.3 COD_{Cr} load and concentrations, 2009.

COD_{Cr}	Average	Min	Max
Concentration (mg/l)	579	285	925
Load (kg/d)	4 189	2 680	7 783

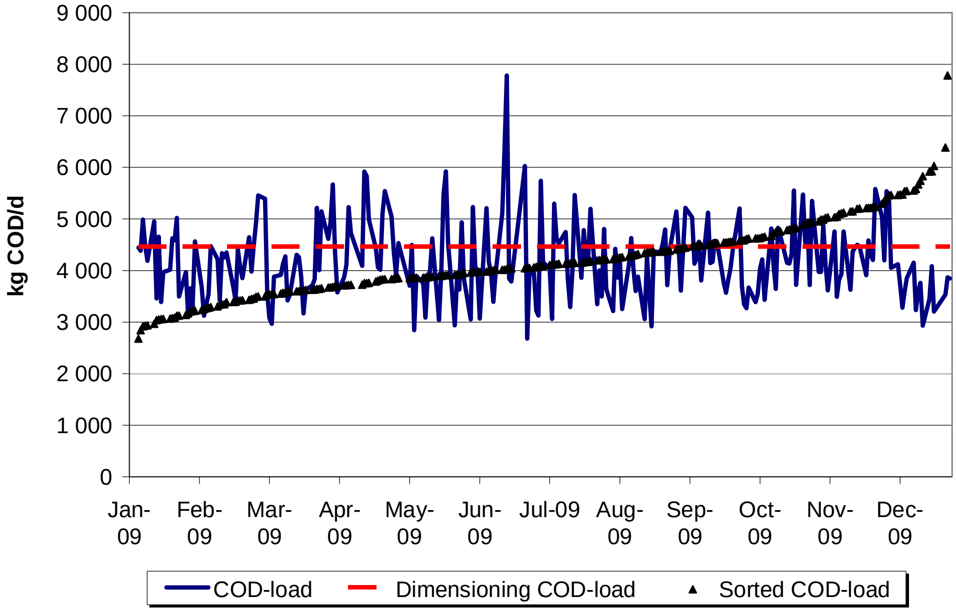

Figure 2.3. Influent COD_{Cr} load, 2009.

Apparently the COD/BOD ratio of the influent wastewater is higher than expected in the dimensioning calculations, since the dimensioning values of COD are exceeded more often than the dimensioning values for BOD. As shown in Figure 2.4, the COD/BOD ratio varies very much, which may be induced by the discharges of septic tank sludges. The average value of 2,8 indicates that the organic carbon in the influent is primarily of slowly biodegradable type.

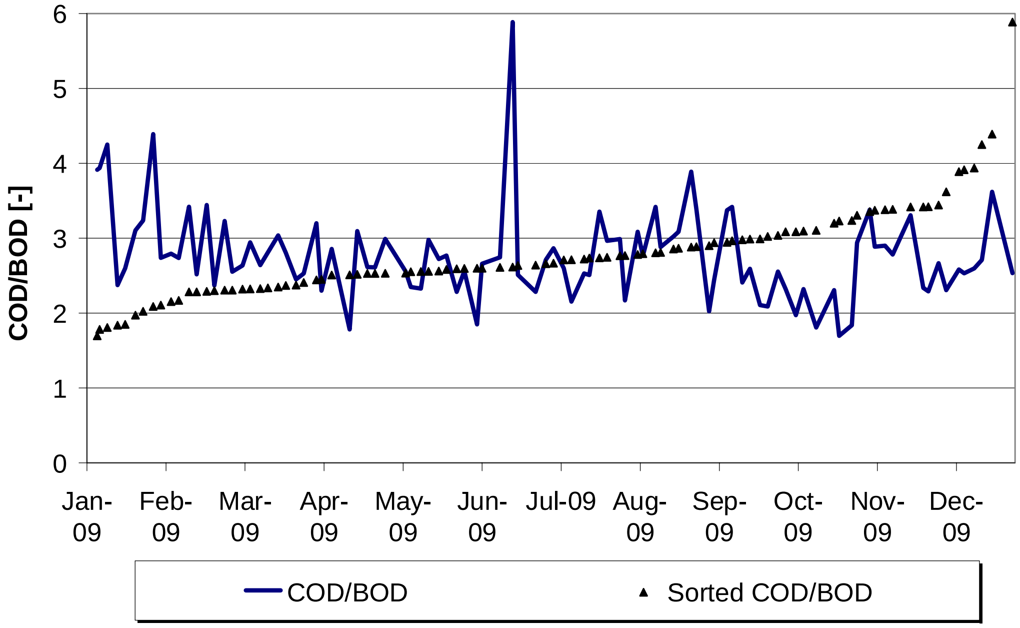

Figure 2.4. COD/BOD ratio, 2009.

On average, the BOD and COD loads stay on the same levels throughout the year. It seems evident that most of the wastewater from the holiday resort facilities is not directed to the WWTP, because no significant increase in load can be seen during the summer months. The fairly high day-by-day fluctuation of organic load may be connected to septic tank sludge deliveries.

Nutrient loads

Influent nutrient concentrations were measured five times a week. Influent phosphorus concentrations in Jurmala WWTP were typical values of municipal wastewater varying as shown in Table 2.4. The measured phosphorus load was mainly below the dimensioning P-value of 80 kg/d. The influent P- load during 2009 is shown in Figure 2.5.

Table 2.4. Influent phosphorus load and concentrations, 2009

Phosphorus	Average	Min	Max
Concentration (mg/l)	7.7	4.2	10.9
Load (kg/d)	56	39	87

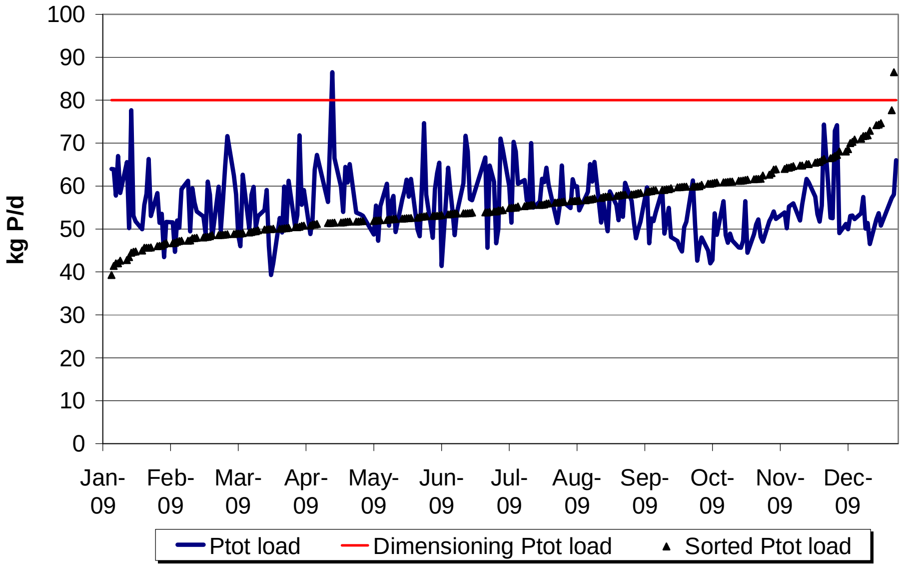

Figure 2.5. Influent phosphorus load, 2009.

Influent nitrogen concentrations in Jurmala WWTP varied as shown in Table 2.5. Occasionally the nitrogen concentrations were higher than typical values for municipal wastewater; 25 % of the measured concentrations were above 60 mg N/l. However, only 5 % of the measured load values exceeded the dimensioning load of 480 kgN/d. The influent N- load during 2009 is shown in Figure 2.6. Typical BOD_5/N-ratio in influent wastewater was 3,9.

Table 2.5. Influent nitrogen load and concentrations, 2009

Nitrogen	Average	Min	Max
Concentration (mg/l)	55	29	99
Load (kg/d)	396	279	695

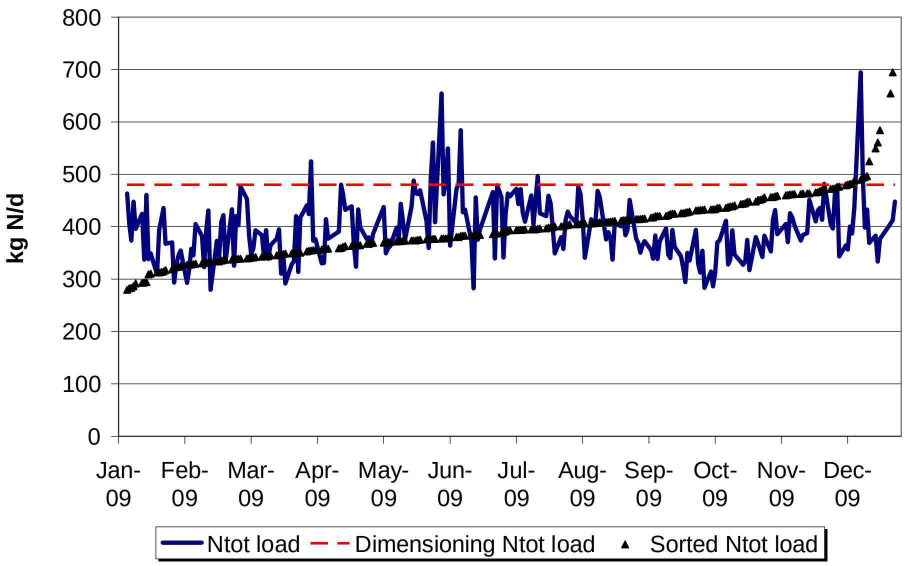

Figure 2.6. Influent nitrogen load, 2009.

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Suspended solids

Influent suspended solid concentrations were measured five times a week. The loads and concentrations in Jurmala WWTP varied as shown in Table 2.6. The dimensioning value of 2 320 kg SS/d was exceeded in 5 % of the measurements. The influent SS- load during 2009 is shown in Figure 2.7.

Table 2.6. Influent suspended solid loads and concentrations, 2009

Suspended solids	Average	Min	Max
Concentration (mg/l)	207	58	579
Load (kg/d)	1 479	418	3 985

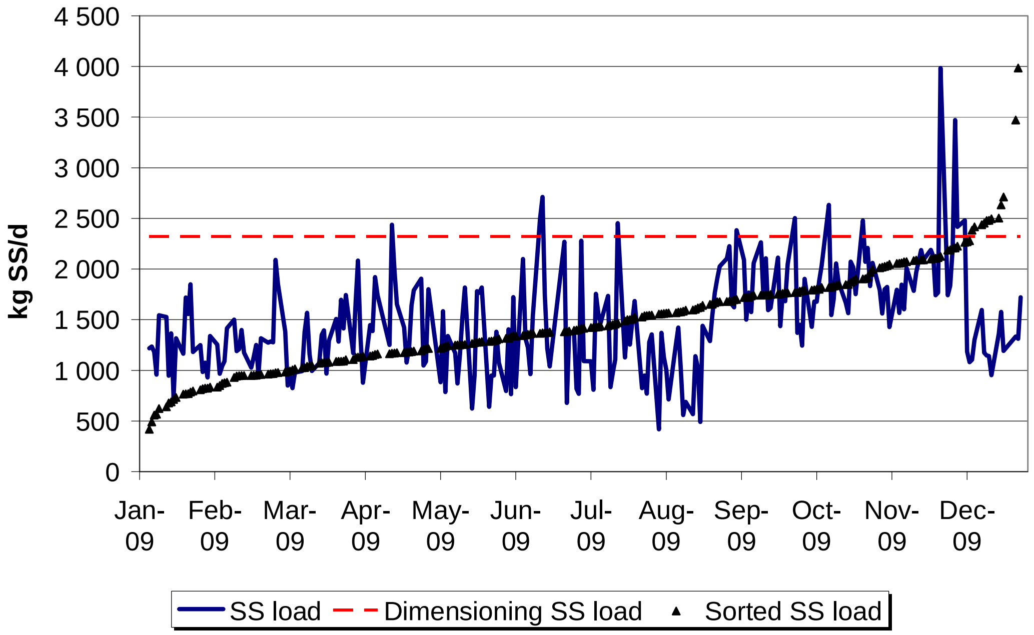

Figure 2.7. Influent suspended solids load, 2009.

2.2.3 Temperature

Influent wastewater temperature ranged from 9,0 to 18,6 ^{o}C and was on average 13,9 ^{o}C. 11 % of values were under the dimensioning temperature of 10 ^{o}C (Figure 2.8).

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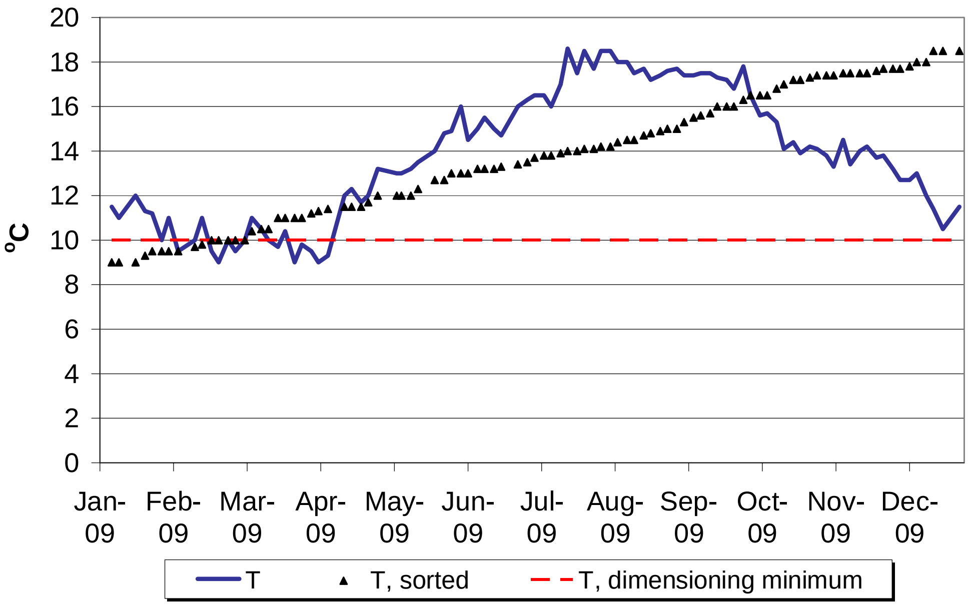

Figure 2.8. Influent wastewater temperature, 2009.

2.3 Treatment requirements and state of nutrient removal

The required quality (guarantee values) of effluent wastewater and the achieved average values from the year 2009 are shown in Table 2.7. The aim is to reach the required results at all times. In this table, the results are compared both to the current demands and to the recommendations of HELCOM.

Table 2.7. Achieved effluent quality compared to demands and HELCOM recommendations, 2009

Parameter	Demand	HELCOM recommendations		Achieved (average 2009)	
	mg/l	mg/l	%	mg/l	%
Suspended solids	35	-	-	3	99
COD_{Cr}	125	-	-	40	80
BOD_5	25	15	80	4	98
Total nitrogen	15	15	70 - 80	15	72
Total phosphorus	2	0.5	90	0.35	95

The required effluent concentrations were achieved well throughout the year for all parameters except total nitrogen. The total nitrogen levels were higher than the demands during certain months of the year due to incomplete nitrification. Total nitrogen in effluent wastewater varied between 17 – 25 mg/l from January 2009 to April 2009, and nitrification rate during that time was around 70 %. Complete nitrification was achieved by May 2009 and nitrogen requirements (15 mg N/l) were fulfilled during rest of the year. The effluent nitrogen concentrations are shown in Figure 2.9.

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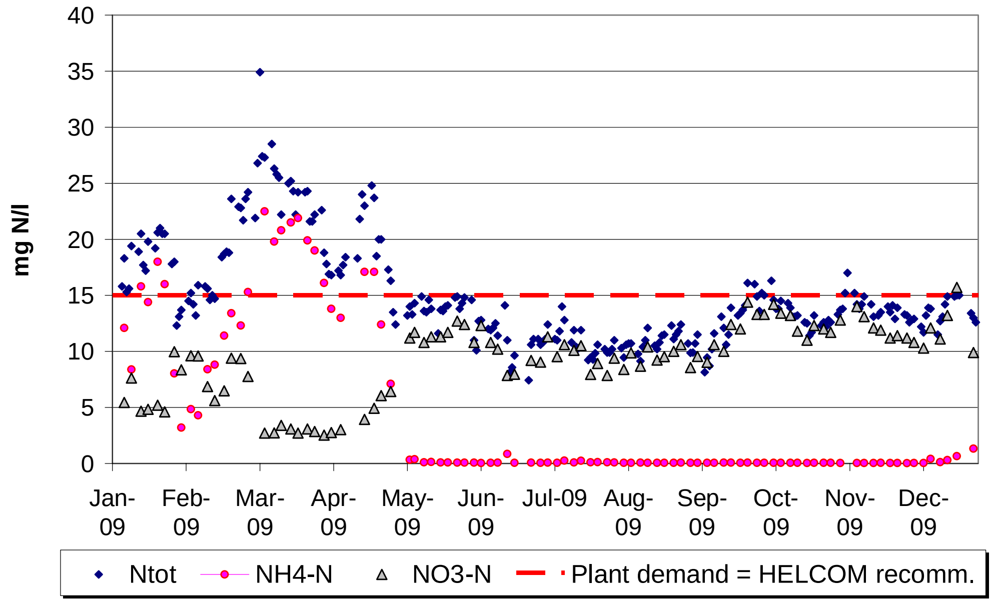

Figure 2.9. Effluent nitrogen concentrations, 2009.

Phosphorus requirements were reached without difficulties. The reached levels were clearly below the target value of < 2 mg P/l as shown in Figure 2.10. The HELCOM recommendation of 0,5 mg/l was occasionally exceeded. The highest effluent P-concentration 2009 was 1,72 mg/l.

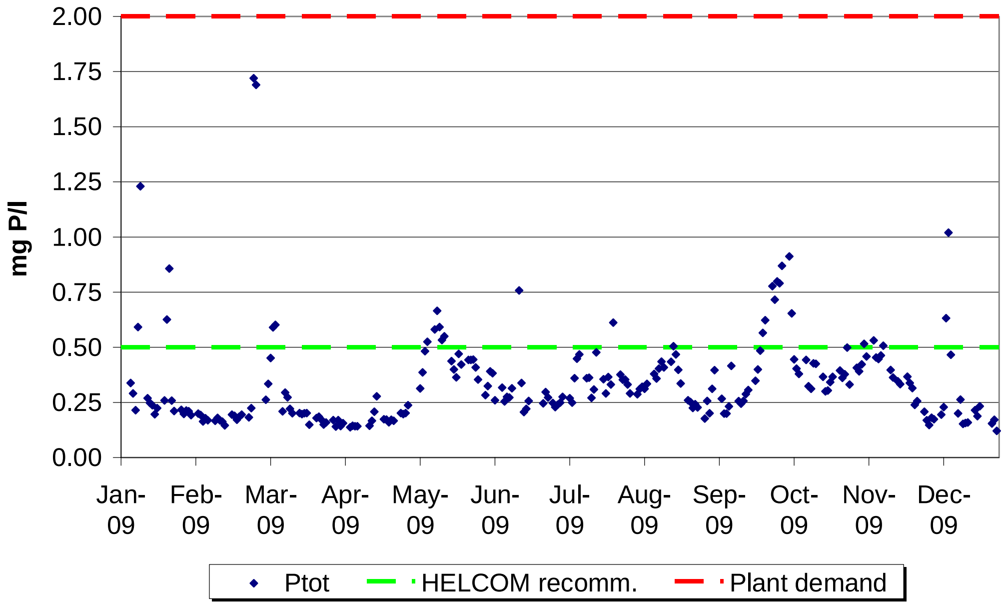

Figure 2.10. Effluent total phosphorus concentrations, 2009.

The effluent values of suspended solids and organic matter measures as BOD_5 and COD_{Cr} were clearly below effluent requirements throughout the year.

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2.4 Process description

The technical and aspects of the process are described here concisely. A more detailed description can be found in the laudably thorough process manual written by the constructor.

Wastewater from two inlet sewers and screened septic tank sludge from a separate reception unit enter a common inlet chamber, from which they flow by gravity through the whole plant. The plant has no inlet pumps. There is a bypass via overflow from the inlet chamber.

The inlet chamber is followed by pre-aeration and two 3-mm automatic fine screens. These units are all covered. The main purpose of pre-aeration is to reduce hydrogen sulphide and thus prevent odour formation. The screenings conveyors are totally cased and equipped with ventilation. The automatic samplers for influent and effluent wastewater are located in the pre-treatment hall.

Screening is followed by two rectangular, aerated grit removal basins. Grit and sand are pumped to a classifier screw which lifts them to a container. Grease and scum are removed by manually operated surface troughs to a grease pit. The accumulated grease is removed by suction to a tank truck, and the underflow is directed to the reject water pumping station.

From grit removal the water is directed to a common chamber from which there is a bypass possibility via an overflow weir. From this chamber, the water is divided to two biological treatment lines. The first unit is a pit, where water is mixed with return sludge. From the pit, the mixture of wastewater and return sludge is transported via and underground pipe to the biological process.

Bypass waters from the inlet chamber and after grit removal are coarse screened before they are directed to the outlet chamber.

The biological process consists of two round basins, in which the activated sludge process (ASP) is located on the perimeter and secondary sedimentation at the center. The ASP is designed for biological phosphorus and nitrogen removal according to ADN(D) principle, i.e. A_2O process with post-denitrification during warm period. First, there is an anaerobic zone with a design HRT of 2 hours. This is followed by the main anoxic (D) zone, aerobic (N) zone and two switch zones, which can be operated either anoxically (warm period) or aerobically (cold period). The effluent weir is located between the two switch zones. The nitrate recycling pumps (1 per line) are located in the first switch zone and pump into the second switch zone.

The depth of the aeration basin is 5,0 m and that of the settler basin 4,8 m.

The A, D and switch zones are equipped with horizontal-flow submersed propeller mixers. The N and switch zones are equipped with membrane-type fine-bubble plate aerators (Sanitaire 225 mm). Oxygen is measured in one point, which is located approximately at 2/3 of the length of the aerobic zone. Aeration air is supplied by three Kaeser rotary piston compressors (one per line and one in reserve). The compressors are equipped with frequency converters, which are controlled directly by the oxygen measurement. The air flow is not measured.

Effluent from the ASP is directed to secondary sedimentation via a center well. Water flows out of the well downwards through an opening between the well bottom plate and settler center structure. The feeding depth is about 2,0 m from the surface. The single effluent through is located at the perimeter of the settler. Return sludge is removed via a suction scraper to a sludge well and transported by gravity to a chamber located in the grit removal complex. From this chamber, excess sludge is pumped to sludge treatment. Excess sludge flow is measured from the pipe. Return sludge pumps lift the sludge to the pit where it is mixed with wastewater coming from grit removal. Return sludge flow is measured by measuring the water level above the overflow weir between the return sludge chamber and the mixing pit.

Excess sludge is first directed to two sludge storage tanks, which are continuously aerated to prevent anaerobic conditions and secondary release of phosphorus. From the tanks the sludge is pumped to a screw thickener (Siljan Allards RotoMaster SF 35). Before the thickener there is an injection point of polymer, a hydraulic mixer and a mixing vessel equipped with propeller mixer. The screw thickener discharges to an intermediate silo from which the sludge is pumped to centrifuges. Before the centrifuges there is another injection point of polymer

The plant has two centrifuges. The one primarily in use is new, procured to replace the old one. The old centrifuge was originally transferred from the old treatment plant and found problematic to use. According to personnel, the dried sludge contains 15 – 17 % of dry solids. However, on visual inspection the sludge looked drier than that.

Treated effluent and bypass waters are directed to a distribution chamber located at the perimeter of the plant site. From this chamber, the water can be directed either to a pond for tertiary sedimentation or directly to the Lielupe river. From the pond, there is an overflow connection back to the distribution chamber.

The plant has a modern system of instrumentation, automation and SCADA. The maintenance of all main instruments and the whole automation system is covered by a maintenance contract between Jurmalas Udens and ABB.

2.5 Operation

The period of guarantee will end in November 2010. Until then the plant personnel will run the plant according to instructions from the constructor. The constructor is still tuning the unit processes, notably sludge treatment, to reach the guarantee values.

2.5.1 Operation practice

Operational modes

The activated sludge process is operated according to the constructor's manual. The basic operational scheme is explained below.

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Operation during cold period (Figure 2.11): The flow is directed from the anaerobic zone via a penstock directly to the main D-zone and then to the aerobic zone. The first switch zone is aerated. The second switch zone is mixed (post-D and gas removal) except for the coldest temperatures, during which it is aerated. Effluent is removed from the second switch zone and recycle is directed to the main D-zone via a penstock. Thus, the whole process scheme can be described as ADNN(D).

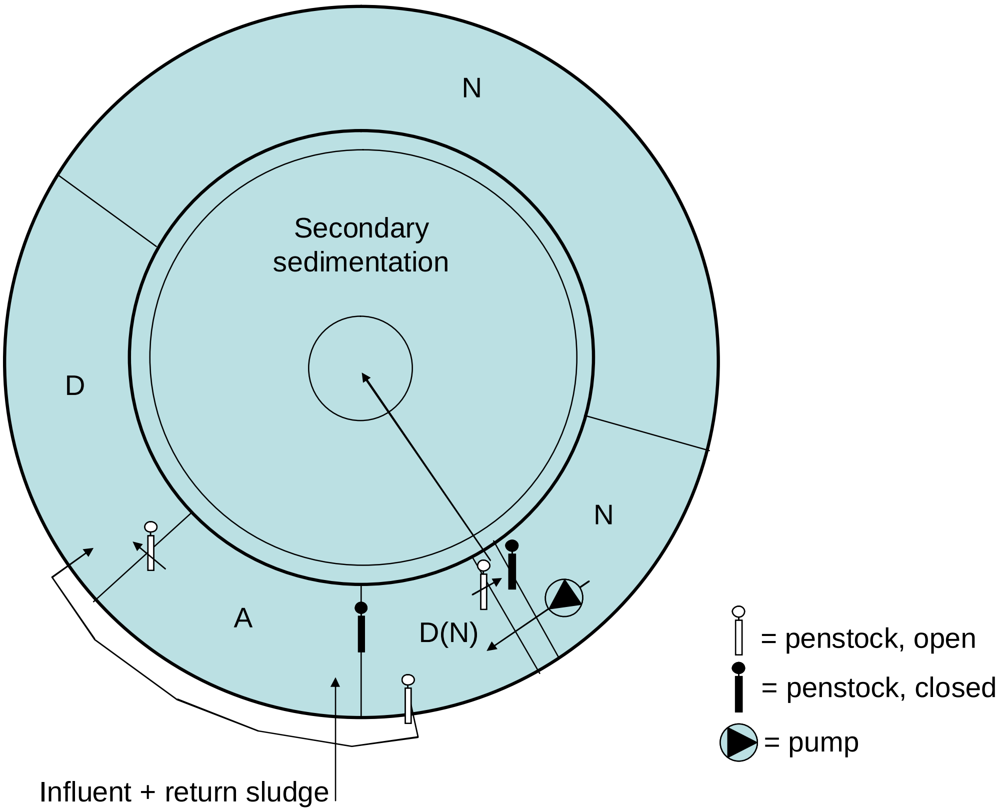

Figure 2.11. Operation of the activated sludge process during cold period.

Operation during warm period (Figure 2.12): The flow is directed from the anaerobic zone via a penstock to the second switch zone, which is mixed, and then to the main D-zone. Both switch zones are mixed, and effluent is removed from the first switch zone. Thus, the whole process scheme can be described as ADDND.

The threshold temperature between "cold" and "warm" period is not explicitly defined in the design documents. However, the design calculations are presented for temperatures of 10 ^{o}C and 15 ^{o}C. 15 ^{o}C could be considered an approximate threshold for change of operational mode. Wastewater temperature was higher than 15 ^{o}C for about 40 % of the year 2009 (see Figure 2.8).

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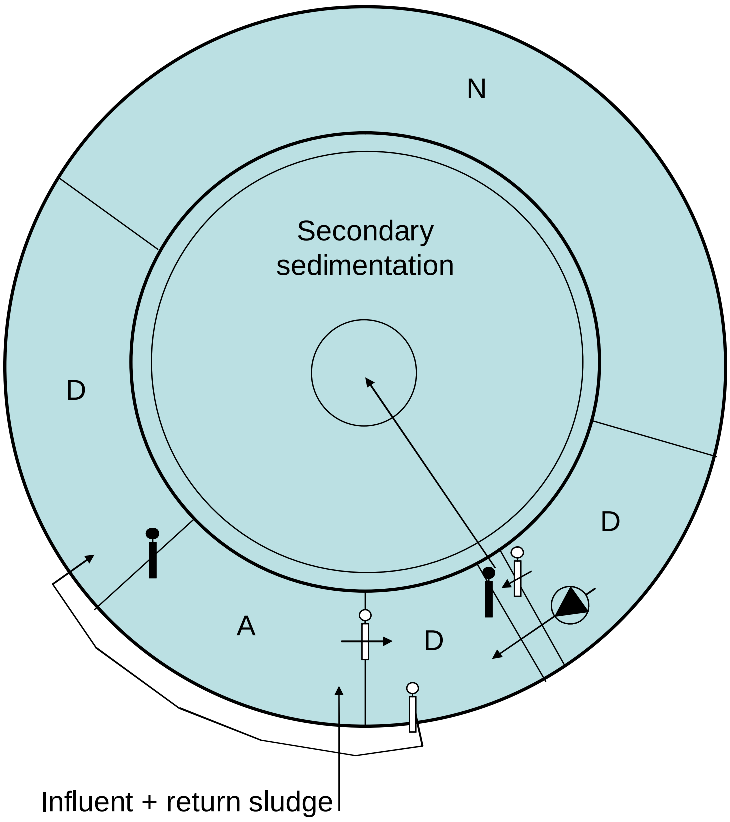

Figure 2.12. Operation of the activated sludge process during warm period.

Aeration

According to the design, the compressors are controlled directly by the DO measurement, i.e. the measurement controls the speed value of the frequency controllers. This connection has been decoupled by plant personnel, and the compressors are operated manually. The reason for this is that the amount of air needed to maintain the target DO concentration of 2,0 gO_2/m^3 in the process was not enough to keep the sludge in suspension. In addition, the compressors were continuously turned on and off by the DO-control.

DO is measured manually from several points in the activated sludge basin. This data is not recorded in electronic form. The automatically measured DO was not included in the data reports delivered by Jurmala Water, although it is probably recorded.

Sludge retention time and MLSS concentration

The maximum target sludge retention time (SRT) recommended by the constructor is 20 d and the minimum 12 d.

In 2009, return sludge concentration and excess sludge flow were measured 5 – 7 times per week. The average amount of removed sludge was 1 700 kg TS/d. On the basis of the BOD_5 and suspended solids loads in 2009, the specific sludge production was 30 – 40 % higher than expected in the dimensioning calculations. Mixed liquor suspended solids (MLSS) concentration in the aeration basins was measured 4 – 5 times per week.

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The average MLSS concentration in 2009 was 2,8 g/l varying between 2,0 and 3,7 g/l as shown in Figure 2.13.

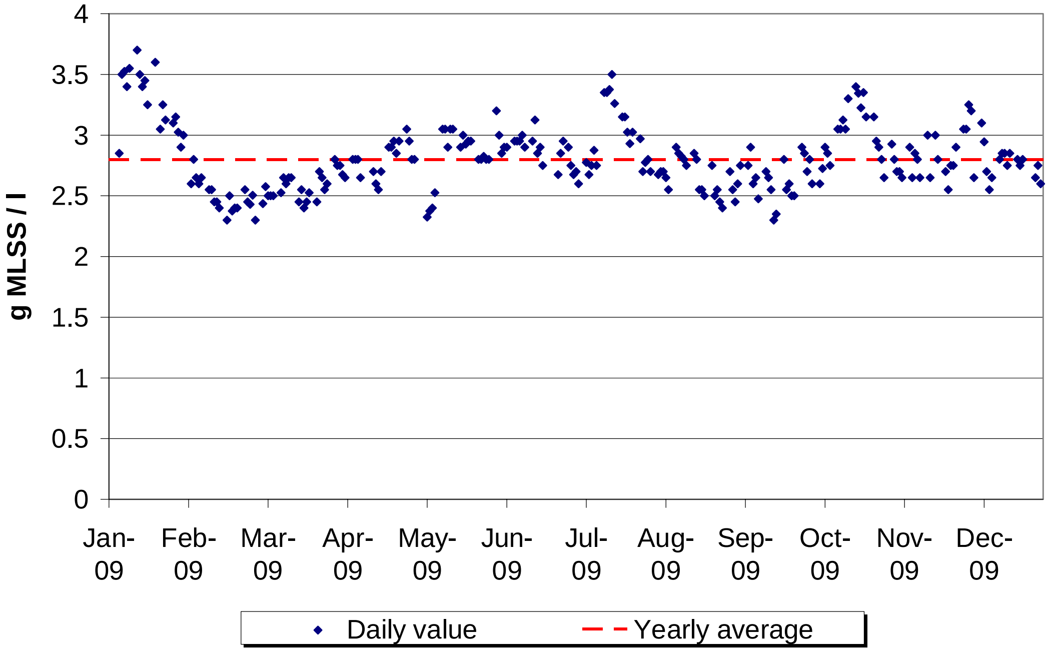

Figure 2.13. MLSS concentration, 2009.

The average total sludge retention time in 2009 was 18 d. The 14-day moving average (which is, in case of SRT, a more informative parameter than daily values) ranged from 10,7 to 34,5 d as shown in Figure 2.14.

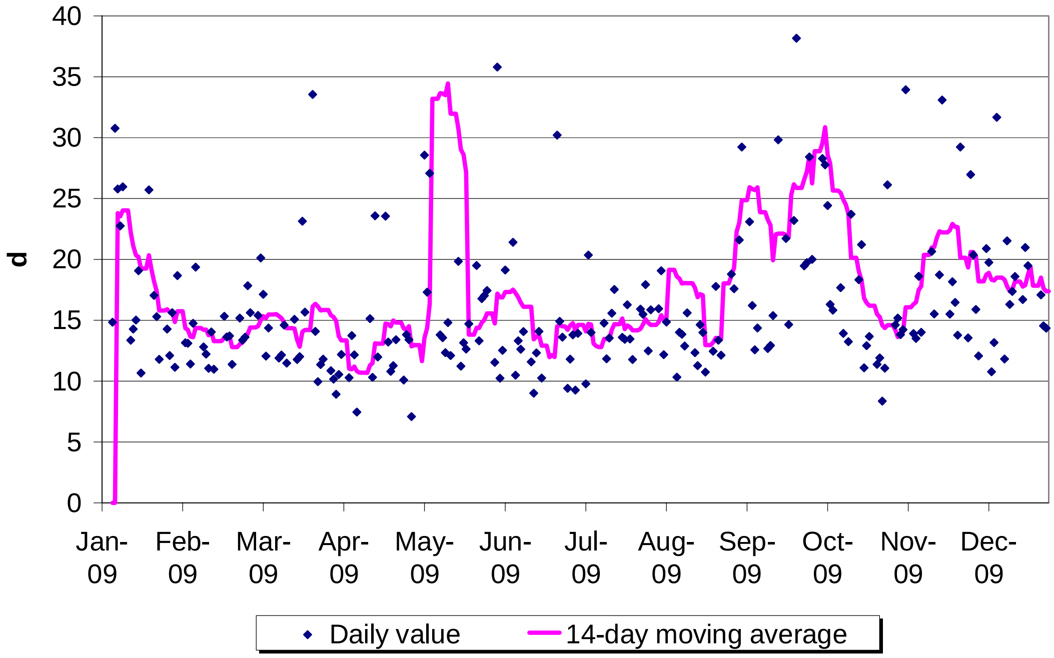

Figure 2.14. Sludge retention time, 2009.

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It is remarkable that there is no clear difference in the length of summertime and wintertime SRTs. In the autumn there have been two periods of elevated SRT.

In the winter and spring of 2010, the maximum target SRT has been 20 – 25 d in order to reach a target MLSS concentration of 4,5 kg/m^3. While operating with long SRT, it was observed that the sludge "died" and rose to the surface. At the time of visit (May 2010), solids were visible in the effluent wastewater. According to the personnel, the transition from long winter SRT to short summer SRT was currently in progress. In the summer of 2009, during shorter SRT, there were no apparent process problems. This is reflected in the low SVI values of that time, see Figure 2.15.

Return sludge and nitrate circulation flow rates

The applied return sludge ratio has been 35 % - 100 %. The nitrate circulation rate has been kept at minimum, which means that the frequency converter setting has been 18 Hz. On the basis of the dimensioning documents and the average wastewater flow of 2009, this would create an average circulation ratio of approximately 100 %.

Secondary sedimentation and sludge volume index

Surface load in secondary sedimentation was 0,28 m/h on average. Hourly flow rates were not available, but according to the process manual, the bypass threshold is 750 m^3/h. Thus, the maximum surface load would be 0,6 m/h.

The sludge volume index (SVI) was, on average, 143 ml/g (67…323). The values from 2009 are presented below. The SVI is high during wintertime and drops steeply when the wastewater temperature rises. The SVI seems to correlate better with temperature than with SRT (see Figure 2.14), although the increase of SRT in autumn probably has a connection with the SVI. There is no significant difference in SVI values between the two process lines.

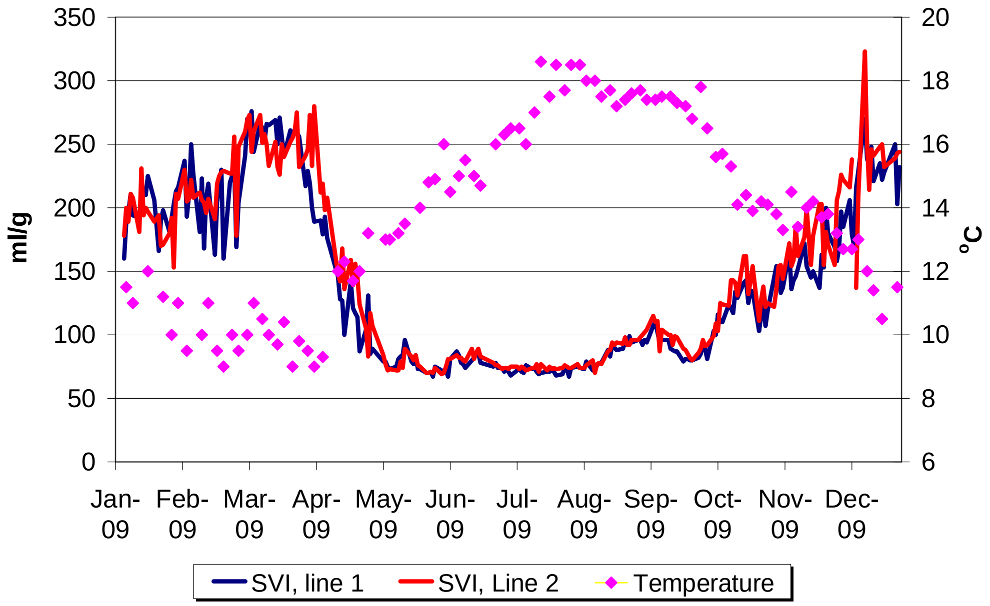

Figure 2.15. Sludge volume index and influent temperature, 2009.

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2.5.2 Loading of the activated sludge process

BOD_5 load

The F/M-ratio (organic load) and volumetric load to aeration for the year 2009 are presented below in Figure 2.16. The average values were 0,064 kgBOD$_5$/kgMLSS/d (0,026…0,108) and 0,18 kgBOD$_5$/m^3/d (0,08…0,31). The dimensioning values are 0,055 kg BOD$_5$/kg MLSS/d and 0,25 kg BOD$_5$/m^3/d, respectively. The values have been calculated according to the volume of the activated sludge basins without the anaerobic zone.

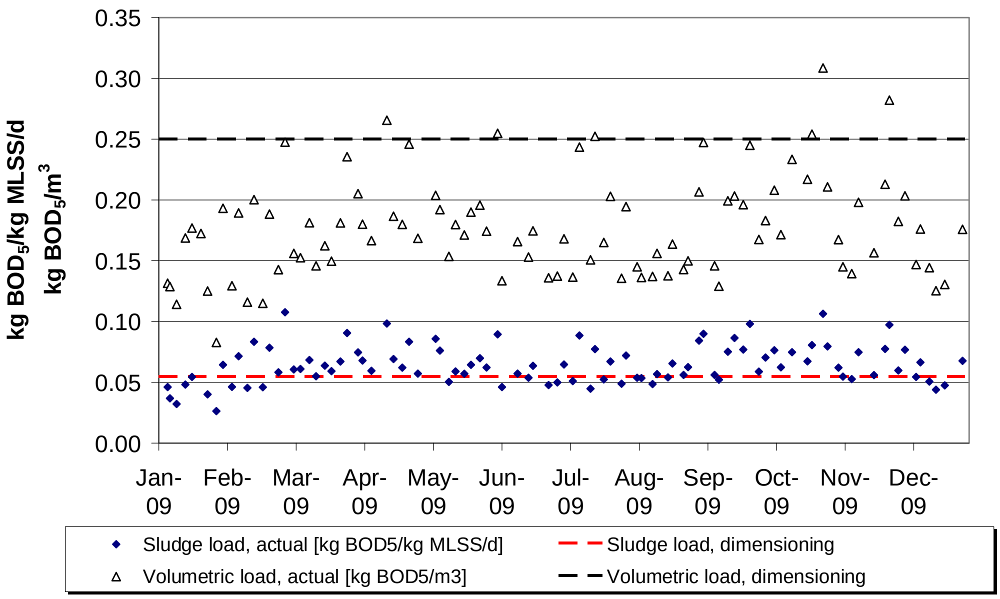

Figure 2.16. Organic load to aeration, 2009.

Nitrogen load

The nitrogen load per kgMLSS and per aeration basin volume is plotted in Figure 2.17. The average values for 2009 were 0,016 kgN/kgMLSS/d (0,010…0,029) and 0,046 kgN/m^3/d (0,032…0,080). The values have been calculated according to the volume of the activated sludge basins without the anaerobic zone. These parameters have not been used in process dimensioning, but their typical dimensioning values for plants which have to operate in temperatures of less than 10 ^{o}C are on the order of 0,025 kgN/kgMLSS/d and 0,10 kgN/m^3/d.

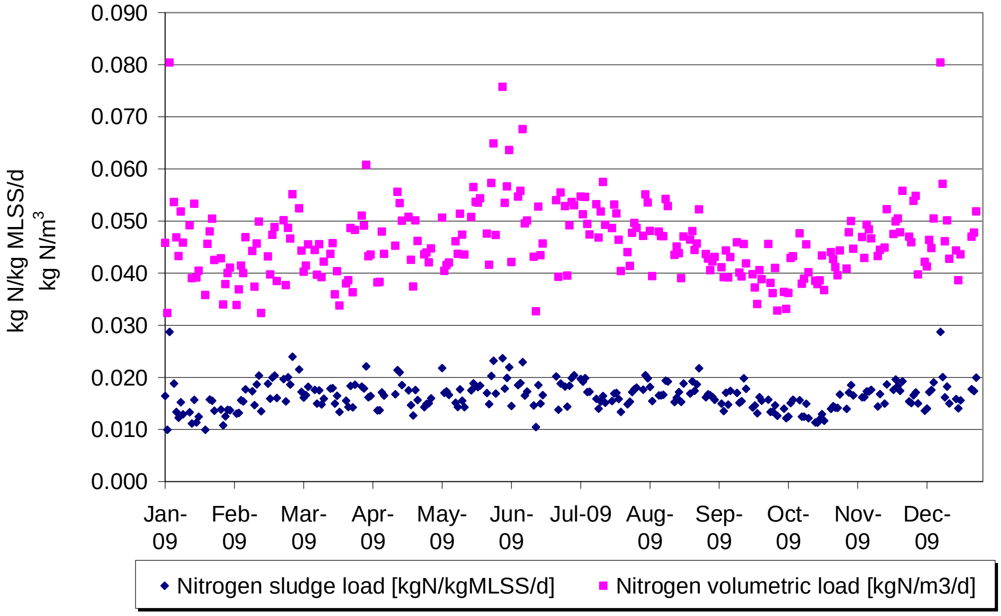

Figure 2.17. Nitrogen volumetric load to aeration, 2009.

2.5.3 Phosphorus balance

The Technical University of Riga will order extra sampling and analyses and calculate phosphorus balance for the entire plant during the summer of 2010. The results can be added to the Technical Audit when they are completed. The phosphorus balance will enable a detailed examination of the functioning of enhanced biological phosphorus removal (EBPR).

2.5.4 Typical operational problems

The main operational problems of the plant are heavy accumulation of surface sludge and foam and the unstable performance of the mechanical (screw) thickener. Large amounts of solids are sometimes escaping in the reject of the thickener, increasing the internal solids load of the wastewater treatment process. At the time of visit, approximately half of the anoxic zone and the center wells of the settlers were full of thick, dry surface sludge, which creates odours and attracts insects. In addition, the aerobic zone was completely covered with bulking sludge. This prevented the visual inspection of the distribution of aeration air.

In the anaerobic zone and at the beginning of the anoxic zone there was no foam. However, small scraps which should be retained in the screens were visible.

Balancing nitrogen and phosphorus removal has been problematic. Return and DN circulation pumpings have occasionally transported nitrate to the anaerobic zone undermining the activity of EBPR.

Submersible mixers and pumps need new seals. Water was found in 30 % of the devices in 2009. The recommended frequency of changing seals is 4 – 5 years. The mixers are of type Flygt 4650 with a jet ring.

Scraps are clogging the suction pipes of DN recirculation pumps.

The connection between DO measurement and compressors has been decoupled, and the compressors are operated manually. The reason for this is that the amount of air needed to maintain 2,0 gO_2/m^3 in the process was not enough to keep the sludge in suspension. In addition, the compressors were continuously turned on and off by the DO-controller.

The basins have no emptying facilities. Emptying can be done only with a sump pump and a hose, which takes at least 4 – 5 d. Accurate figures cannot be given, because the basins have never been totally emptied.

Only one polymer can be used for all sludge treatment units. One and the same polymer are often not optimal for eg. thickening and dewatering. Tests have been conducted (Ashland ltd, Germany), where one polymer good for both units was found, but it was also established that two polymers would be a better solution.

The operational problems described above have been occurring for a long time and are more or less independent on season.

3 ANALYSIS AND PROPOSED IMPROVEMENTS

3.1 Analysis of plant conditions

3.1.1 Technical conditions and performance

The plant is new, and thus in excellent structural and mechanical condition. The machinery and instrumentation are modern. Process dimensioning and basic design solutions are adequate with regard to the amount, quality and temperature of the raw wastewater and the treatment requirements.

The effluent targets have been reached mostly with clear marginal, especially for phosphorus. Nitrogen targets have occasionally not been reached; balancing nitrogen and phosphorus removal has been problematic. Seasonal poor settleability of sludge has induced occasional washout of suspended solids.

In general, the generous dimensioning of the treatment plant (see e.g. Item 2.5.2) makes it possible to reach the effluent targets also in the future, taking into account that the influent loading is expected to increase by approximately 10 %. Even a higher increase in load (say, 30 %) could probably be treated without difficulties, although the original design idea of one treatment line being sufficient would then not apply.

Although phosphorus removal is mostly on excellent level and clearly meets the current demands, the HELCOM recommendation of 0,5 mg/l is occasionally exceeded. This is mostly due to nitrate being transported to the anaerobic zone and disturbing the EBPR – i.e., incomplete balancing of phosphorus and nitrogen removal. In addition, the EBPR is notorious for its instability and prone to occasional rapid breakdowns. Possibility for controlled chemical precipitation to assist the biological process during periods of low COD/P ratio or operational problems should be considered.

3.1.2 Design issues

Phosphorus removal may be undermined by the entrance of nitrate into the anaerobic zone. The retention time in the mixing chamber of return sludge and pre-treated wastewater is probably not enough to remove all nirate. This unit and the whole activated sludge process, especially the balancing of nitrogen and phosphorus removal, could be controlled better with the help of more instrumentation.

With the current design, the DN recirculation pump must pump both the recycle flow and the return sludge flow during the operation mode of cold periods. This is not energy efficient.

The anaerobic zone should be divided into two or three internal, consecutive zones to ensure plug-flow conditions. This is an empirically proven way to reduce the formation of bulking sludge by enhancing the selector effect of the anaerobic zone. In addition, possible short-circuit flows inside the anaerobic zone would be eliminated and, thus, sufficient anaerobic retention time would be ensured. The solution would require one or two light-structured (eg. wooden) walls and one or two new mixers. Implementation of such an arrangement is possible, although somewhat challenging, as the flow from the anaerobic zone is directed to different directions in cold vs. warm weather operation modes.

The light wall separating the main anoxic and aerobic zones in the activated sludge tank is too high. It reaches above the basin surface and prevents surface sludge from moving from the anoxic zone to the aerobic zone, where it might be disintegrated by increasing aeration.

The compressors are over-dimensioned for the current loading. Even if the required airflow corresponded better to the output of the machines, better energy efficiency could be achieved with some more instrumentation and advanced control. The recommended strategy is described in Item 3.2.3.

There is a risk that free oxygen will be transported from the end of the aeration line to the anoxic zone during cold weather operation (last zone aerated), undermining denitrification. At the same time, free oxygen would be transported to secondary settler, worsening the settling properties of activated sludge.

Optimization of sludge treatment would probably benefit from a possibility to use two polymers instead of one. However, care must be taken that the two polymers are suitable for use in consecutive process units. If this is not guaranteed by the polymer manufacturer, the polymers may “cancel out” each other, which will worsen the final dewatering result. The choice of polymers should be done based on thorough pilot tests at site. At first, the one polymer good for both thickening and dewatering, which was already pointed out in the tests performed at the plant, should be tried in operation.

The overall design of sludge treatment line and the chosen unit processes are correct. However, the poor performance of the screw thickener is causing problems. Personnel would prefer a gravity thickener, which would undeniably be simpler, cheaper to operate and less prone to mechanical or electrical disturbances. However, gravity thickeners are less suitable for plants with EBPR than are mechanical thickeners. If the sludge is retained in gravity thickeners for several days, anaerobic conditions may induce release of biologically bound phosphorus from the sludge. Purchasing a mechanical thickener with better yield than the present one could be considered. The present thickener is operating in horizontal position, where gravity does not help the separation of solids from the water phase. An inclined screw thickener or gravity belt thickener could perform better.

3.1.3 Process stability and operational problems

The plant is low-loaded in terms of organic, nutrient and hydraulic loads. The activated sludge process has been dimensioned so that it can treat the dimensioning load with only one of the two lines, but two lines have continuously been operated. The low loading may be connected to the operational problems.

The low loading combined with high SRTs especially in winter has caused disintegration of flocs and promoted growth of filamentous micro-organisms. These phenomena, together with internal solids load from the screw thickener, have induced accumulation of surface sludge and foam. The end result is an evil circle where the filaments are continuously enriched in the process: the surface sludge acts as a breeding ground and the removed cells are returned into the basin in sludge treatment rejects.

The operation of screening should be checked. On the basis of what we saw in the aeration basin, some scraps are coming through the screens and, according to personnel, the nitrate recycling pumps have been clogged.

The operating instructions and trouble-shooting tables given in the constructor’s process manual are correct and accurate. However, at the present situation it seems that the problems have escalated because the accumulation of bulking sludge has not been tackled immediately and the bulking sludge has not been removed from the process.

There is no possibility for pH or alkalinity control. On the basis of treatment results, effluent pH is almost the same as influent pH, but alkalinity is not analysed. Alkalinity can become a limiting factor of nitrification in the future, and it should be monitored regularly.

3.2 Recommended actions

3.2.1 General

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The explicit goal of this project is to propose investments which support more efficient removal of phosphorus. At Jurmala WWTP, taking into account the dimensioning of the plant and the present, good results of phosphorus removal, the removal of phosphorus could be supported and further improved by fulfilling the following goals (Table 3.1):

Table 3.1. Goals and strategies of supporting more efficient removal of phosphorus

Goal	Strategy
Prevent escape of phosphorus in effluent solids	Ensure good settleability of sludge
Maximize the efficiency of EBPR	Minimize operational problems of the activated sludge process and help the operators to balance nitrogen and phosphorus removal
Create a "safety catch" for quick reaction to operational problems	Implement controlled complementary precipitation of phosphorus during problems of EBPR

The concrete actions to achieve the above are explained in detail below. In addition, some suggestions to improve the plant's energy efficiency are given.

3.2.2 Operation of existing units

Bulking sludge must be attacked immediately when its formation is observed. It should be disintegrated by water sprays or, preferably, collected with tank trucks and transported away from the plant eg. to a landfill or composting. The latter is the only way of preventing the filamentous organisms from enriching in the process. If the sludge is allowed to accumulate and dry up, it is hard to remove.

To decrease the bulking potential of the sludge, the SRT should be kept as low as possible without compromising nitrification and the sludge circulation rates (return and nitrate recycle) should be kept as low as possible without compromising total nitrogen removal and functioning of secondary sedimentation. In addition, internal loading from sludge treatment should be minimized.

Operation using only one line could be considered, at least in the summertime. The design documents explicitly state that this is possible, which is in accordance with the calculated functional parameters of the year 2009. Thus the process would receive higher loading, which would benefit floc formers and undermine filamentous growth. However, this may be too risky especially during cold weather eg, due to insufficient retention times for phosphorus release and nitrification.

Only one compressor should be used to aerate both lines during periods of low loading. This is possible according to the process manual.

Analysis of alkalinity should be included in the monitoring program of the plant. If effluent alkalinity is often below 2,0 mmol/l, implementing addition of alkalinity chemical (eg. sodium carbonate) should be considered.

3.2.3 New investments

On the basis of the above, taking into account the wishes and comments of plant personnel as well as the available funding of 300 000 EUR, we propose the following investments for consideration. They are listed in the order of priority.

1. Improve the yield of sludge thickening
   a) Try changing the applied polymer using the present equipment
   b) If desired effects are not achieved, install one additional polymer station to enable the use of two polymers: one for thickening, one for dewatering. Choose polymer based on pilot tests in order to avoid negative interaction with the dewatering polymer

2. Lower the walls separating the anoxic and aerobic zones so that their upper edge is a few centimetres below the water surface. This will enable surface sludge to be transported to the aerobic basin, where it may be disintegrated by aeration.

3. Support process operation with online-measurements
   - redox measurements in mixing chambers of pre-treated wastewater and return sludge (total 2 pc)
     - monitor nitrate concentration of influent to the anaerobic zone
     - → manual setting of return sludge pumping rate
   - redox measurements in anoxic and anaerobic zones (total 4 pc)
     - monitor the extent of anaerobic conditions
     - monitor denitrification rate
     - → manual setting of nitrate recycling rate
   - ammonium nitrogen at the outlet channel of aeration basins (total 2 pc)
     - monitor nitrification rate
     - → automatic or manual setting of DO setpoint in the last aerated zone
     - → manual setting of target sludge retention time
   - phosphate phosphorus in plant effluent (total 1 pc)
     - trend of phosphorus removal and early warning of problems
     - placed indoors in the pre-treatment building

4. Divide the anaerobic zone into two internal compartments to create plug-flow conditions and ensure sufficient anaerobic retention time

5. Improve aeration control
   - divide the main aerobic zone to two internal zones
   - equip both these zones and the first switch zone (anox/aer) with one oxygen meter each (total 4 new meters procured, 2 old meters used)
   - implement constant-pressure control of compressors and regulate DO concentration with air delivery valves (total 4 electric control valves)

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- install two thermal air flow meters to monitor the actual air flow rate to both aeration lines
- in addition, the DO setpoint of the last aerobic zone could also be controlled with online measurement of ammonium nitrogen from the effluent channel of the aeration basin (not included in cost calculations)
- these measures will bring the following gains:
  - reduce energy costs due to more efficient use of air
  - minimize residual oxygen at the end of aeration line → more efficient post-denitrification and protection of anaerobic compartment from free oxygen during cold weather operation

The proposed investments support the general objectives of Table 3.1 as follows:

Item	Sludge settleability	Process stability
1. Improve thickener yield	X	X
2. Lower separation walls	X	
3. Online measurements		X
4. Division of ANA zone	X	X
5. Optimize aeration	X	X

In addition, the consultant recommends implementing complementary chemical precipitation of phosphorus as a “safety catch”, which could be used when there are temporary problems with the EBPR. In addition, if thickener performance cannot be improved to the desired level by polymers, we recommend replacing the existing mechanical thickener with a new, inclined screw or belt thickener. Inclined screw thickeners have been used e.g. in the WWTPs of Lahti and Jyväskylä, Finland, with good results.

3.3 Dimensioning, implementation and operation of new units

The new units and modifications described below are presented graphically in the Annexes 1 – 5.

3.3.1 New polymer station

The polymer station (40PE02) will be dimensioned for the dimensioning sludge production of the plant (1930 kgTS/d) and operated, basically, in a similar manner as the current one. The consultant proposes that the new station be implemented so that both stations can serve either the thickener or the centrifuges (or, in exceptional cases, both units), according to the choice of the operator. This approach will provide operational flexibility. The Contractor shall design the detailed implementation and operation.

3.3.2 Online measurements and analyses

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The measurements QI-07, -08, -09, -10, -14, -15 (redox) and QIC-11, QIC-12 (ammonium nitrogen) are implemented as electrode measurements performed at site.

The measurement QI-13 (phosphate) is executed by an analyser, which is situated indoors in the pre-treatment building. The samples are pumped to the analysers continuously from the effluent channel beneath the pre-teratment building. 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 operator can give on/off commands to the analyser via the central automation system of the WWTP. However, the analyser shall always perform the ongoing analysis to the end before stopping on request from the central automation system.

3.3.3 Modification of the anaerobic zone

The purpose of the modifications in the anaerobic zone is to enhance the selector effect of this zone and, consequently, to improve sludge settling properties and reduce surface sludge formation. In addition, the objective is to ensure long enough anaerobic retention time by avoiding short-cut flows.

The preliminary plan for this modification is as follows.

1. The influent pipe is continued in the direction of the radius of the basin to a point approximately 0,5 m from the pipe which connects the main anoxic zone with secondary anoxic zone. The end of the extension of the influent pipe is cut as pictured in the drawings 16WWE0473ME-3001 and -3002.

2. A new, longitudinal division wall is constructed in the middle of the anaerobic zone. The wall is placed so that it divides the anaerobic zone in a volumetric ratio of approximately 1:2, the smaller volume being the one closer to the center of the spherical basin, i.e. the one into which the mixture of wastewater and return sludge is introduced from the extended influent pipe. The wall is left open by 0,10 – 0,50 m from all sides as shown in the drawings 16WWE0473ME-3001 and -3002. In addition, two openings of approximately 1,0 x 1,0 m are cut in the lower edge of the wall.

3. A new mixer is installed to the smaller internal anaerobic zone.

3.3.4 Improved aeration control

The general strategy of improved aeration control is as follows. Target pressure is maintained in the air delivery main by the compressors. Air distribution to the aeration basin zones is regulated based on oxygen demand. The oxygen concentration meters QIC-03, -03/1, -04, -04/1 control the air valves CV-01, -02, -03, -04 located in the air distribution pipes.

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The compressors' own control system must be modified so that it enables constant pressure control, i.e. keeps up constant pressure (PIC-10) according to a target value received from a local process station and the reading of pressure measurement from the air delivery main.

The concentration of dissolved oxygen (DO) in the two sections created to the main aerobic zone and the air flow directed to each of these sections are controlled directly with valve-specific control loops. The operator enters loop-specific DO setpoints to the system. DO measurements are used to control the position of air control valves. Each loop will also have a manual option, in which the control valve can be driven inside the position range 0...100 % by remote operation from the control room. The operator can choose automatic or manual control to each control loop specifically.

The control offset is corrected with steps of 3 %. New control values are calculated at 6 min intervals. If the DO measurement differs from the setpoint substantially (15 % or more), control interval is shortened (by 2 min).

The operator can enter upper and lower limits for line-specific air flows (FI-12, FI-13) in order to protect the aerators from excessive air flows and, respectively, to ensure sufficient mixing during periods of low loading. In addition, the position of the automatic air control valves can be limited with mechanical restraints.

Alarms:
The following alarms shall be programmed for aeration:
– conflict alarms and common alarms of the compressors
– upper limit alarms of control offsets
– upper and lower limit alarms of line-specific air flows

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