Upgrading of Wastewater Treatment Plants in Poland

PHASE II

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Abstract:

During the first Phase, diagnostic studies have been carried out at selected treatment plants in order to identify problems and how to improve treatment efficiency (Report 1st. Phase).

The report in hand (2nd. Phase) gives recommendations for upgrading/rehabilitation and other improvements based on full scale experiments at selected treatment plants.

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For the Administration

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Municipal Engineering Centre, Warsaw

UPGRADING OF WASTEWATER TREATMENT PLANTS IN POLAND PHASE II

Oslo, December 1994

Svein Stene-Johansen
Project Manager

Preface

The project described below is part of the Programme of Cooperation between the Norwegian Ministry of Environment and the Ministry of Environmental Protection, National Resources and Forestry in the Republic of Poland.

The project has been executed by the Norwegian Institute for Water Research, NIVA in cooperation with Aquateam A/S. As Polish cooperation partner, the Polish Ministry appointed Centrum Techniki Budownictwa Komunalnego (TBK).

The team engaged in the project consisted of the following members:

Mr. Leslaw Borzyn	CTBK
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Mrs. Granzyna Englund	NIVA
Mr. Johan Ahlfors	NIVA

Particular thanks to the director of CTBK, Mr. Jan Zambrzycki, and to Mr. Andrzej Braun who kindly commented on this report.

The project manager would especially like to thank the main author of this report, Mr. Bjarne Paulsrud, who also acted as project manager during my long time visit to India in 1993/94.

December 1994

Svein Stene-Johansen
Project Manager

Table of Contents

1 Introduction

This report summarizes the results obtained during Phase II of the joint Polish/Norwegian project "Upgrading of Wastewater Treatment Plants in Poland". In Phase I of this project three existing biological wastewater treatment plants were selected for full scale testing with chemical pre-precipitation. These plants were situated in Plonsk, Lomza and Minsk Mazowiecki. General information about the plants, results of preliminary jar tests and test programmes for the full scale trials were included in the Phase I-report.

In general, the main problem of the three plants was caused by periodically organic overloading, due to discharge of untreated and non-equalized industrial wastewaters. The normal way of handling such problems would be to install proper pretreatment of the industrial wastewater at the factories, but for economical reasons this could only be a long term solution. In the meantime the joint project wanted to demonstrate how pre-precipitation with ferric-sulphate (PIX) at the municipal wastewater treatment plant could reduce the negative effects of the industrial wastewater discharges. An additional effect of dosing coagulants will be a reduced discharge of phosphorus to the receiving waters.

For each plant the effect of chemical pre-precipitation was determined by taking composite samples at three different places:

1. The influent (raw wastewater) before any return streams (surplus activated sludge etc.) are mixed with the wastewater.
2. The influent to the aeration tank (after pre-precipitation and primary sedimentation).
3. The effluent from the plant (after secondary sedimentation).

Automatic samplers (controlled by a timer) were installed at the three places and for each of them, 3 samples were collected every week; one covering Monday and Tuesday (48 hours composite sample), one covering Wednesday and Thursday (48 hours composite sample) and the last one covering Friday through Monday (72 hours composite sample).

The samples were analysed for

- BOD_5
- COD
- Suspended solids (TSS)
- Total phosphorus
- Orthophosphate

at laboratories in Lomza and Warsaw.

In addition pH-values were measured every day in the influent to the aeration tank and in the plant effluent.

2 Plonsk Wastewater Treatment Plant

2.1 General

Plonsk wastewater treatment plant is a conventional activated sludge plant with an average wastewater flow of about 5000 m^3/d. The plant receives wastewater from a fruit and vegetables processing factory in the period June-November, and this increases the organic load of the plant to such an extent that sludge bulking occurs and causes loss of activated sludge in the plant effluent.

The full scale tests with pre-precipitation were performed during one month from October 16 to November 17, 1992 (at the end of the season for discharges of high organic industrial wastewater). The coagulant (ferric-sulphate) was mixed with incoming wastewater at the upper end of the grit chamber, and the dosage was controlled by the on-off switch of the inlet pumping station. The coagulant dosage (g/m3) was based upon previous jar tests.

2.2 Results

All the results from analyses and wastewater flow measurements are summarized in Appendix 1. The variations in BOD_5, COD and orthophosphate concentrations in raw wastewater, pre-precipitated wastewater and final effluent are presented in Figures 1-3 and the average pollutant loads and removal rates for each coagulant dosage are shown in Tables 1 and 2.

Table 1. Plonsk wastewater treatment plant. Test period 16/10/92 - 30/10/92. PIX-dosage = 300 g/m³

Parameter	Raw wastewater	After pre-precipitation		Final effluent	
	Average load (kg/d)	Average load (kg/d)	Removal rate (%)	Average load (kg/d)	Removal rate (%)
BOD_5	1797	997	45	61	97
COD	7003	3160	55	275	96
TSS	1510	740	51	148	90
Ortho-P	20	1.5	93	0.58	97

Table 2. Plonsk wastewater treatment plant. Test period 30/10/92 - 17/11/92. PIX-dosage = 230 g/m³.

Parameter	Raw wastewater	After pre-precipitation		Final effluent	
	Average load (kg/d)	Average load (kg/d)	Removal rate (%)	Average load (kg/d)	Removal rate (%)
BOD_5	1496	848	43	49	97
COD	3793	1982	48	222	94
TSS	1705	940	45	143	92
Ortho-P	20	0.84	96	0.84	96

These results clearly demonstrate that pre-precipitation with ferric-sulphate has been very successful. Even with high BOD_5 and COD concentrations in the influent, the effluent concentrations have been constantly below effluent standards (BOD_5 = 32 mg O_2/l, COD = 150 mg O_2/l). The removal of phosphorus seems also very good, although there is a lack of total phosphorus data to fully support that statement.

Comparing the two periods with different coagulant dosage (Tables 1 and 2), the removal rates for both organic matter and phosphorus are quite similar. However, the organic loading was much higher in the first test period, and there are no reason to believe that the same results could have been achieved with the lowest coagulant dosage (230 g/m^3) in this period. The optimum PIX-dosage will change with the varying characteristics of the incoming wastewater, and should be controlled according to experiences from continued testing in the actual plant.

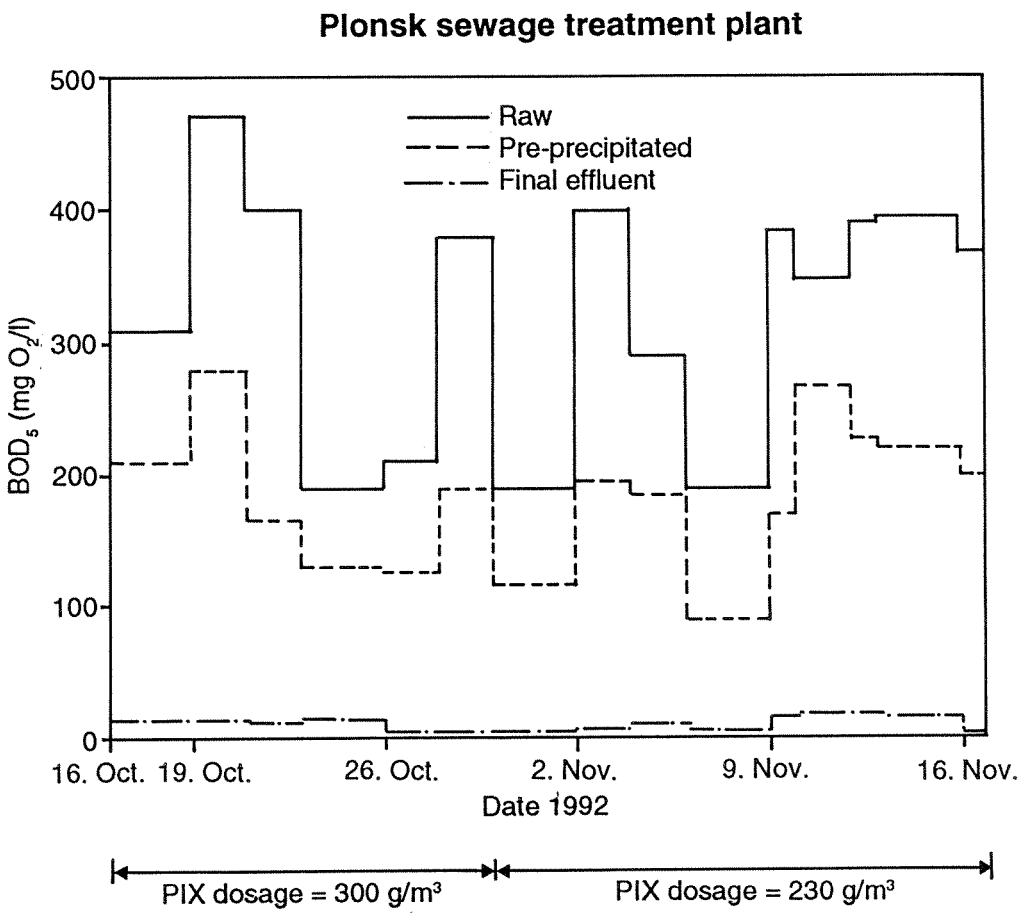


Fig. 1. Variations in BOD_5 concentrations of raw wastewater, pre-precipitated wastewater and final effluent

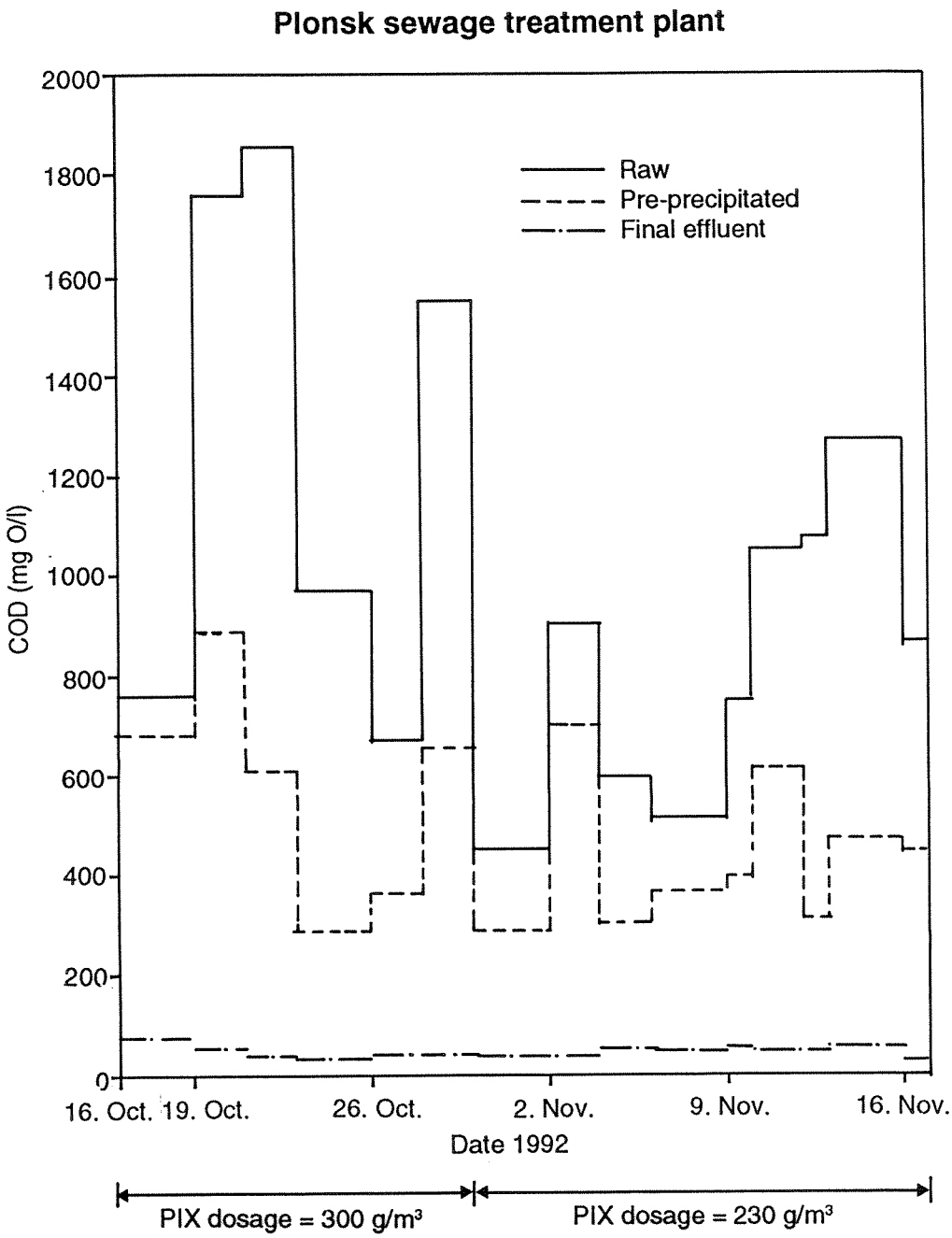


Fig. 2. Variations in COD concentration of raw wastewater, pre-precipitated wastewater and final effluent

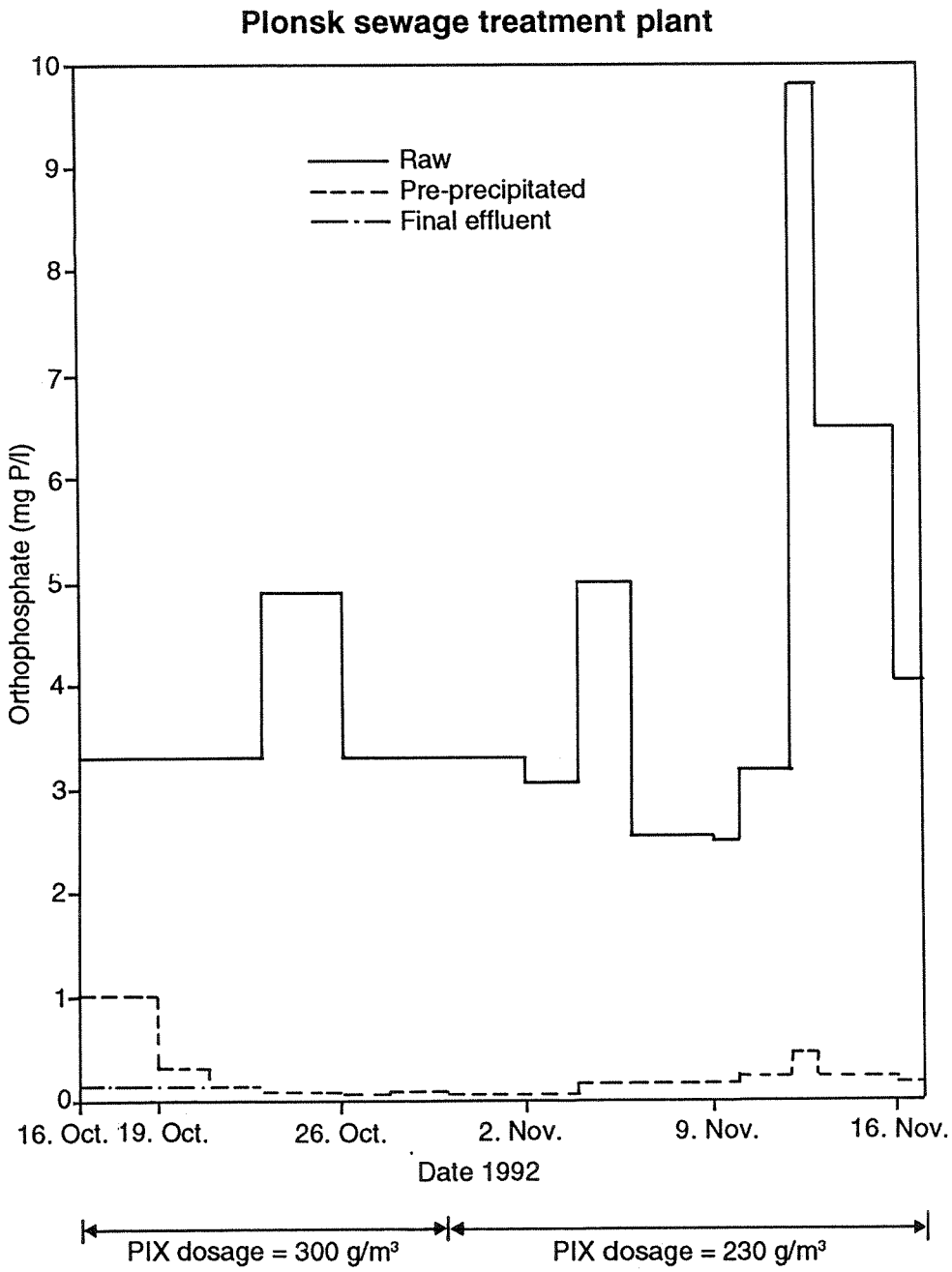


Fig. 3. Variations in orthophosphate concentration of raw wastewater, pre-precipitated wastewater and final effluent

3 Lomza Wastewater Treatment Plant

3.1 General

Lomza wastewater treatment plant is a conventional activated sludge plant with an average wastewater flow of about 15.000 m^3/d. The plant receives wastewater from a large textile factory which under normal operation discharges 3000-4000 m^3/d to the municipal sewer network. The industrial wastewater represents an extra organic load on the plant that often creates operational problems. However, during the test period the discharge of industrial wastewater was reduced due to low activity at the factory (economical problems).

The full scale tests with pre-precipitation were performed for about 3 weeks from November 24 to December 16, 1992. The coagulant (ferric sulphate) was mixed with incoming wastewater after the inlet pumping station, and the dosage was controlled by the on-off switch of the pumps. The coagulant dosage (g/m^3) was based upon previous jar tests.

3.2 Results

All the results from analyses and wastewater flow measurements are summarized in Appendix 2. The variations in BOD_5, COD, ortho-P and total-P concentrations in raw wastewater, pre-precipitated wastewater and final effluent are presented in Figures 4-7.

The average pollutant loads and removal rates for each coagulant dosage are shown in Tables 3 and 4.

Table 3. Lomza wastewater treatment plant. Test period 24/11/92 - 07/12/92. PIX dosage = 150 g/m^3

Parameter	Raw wastewater	After pre-precipitation		Final effluent	
	Average load (kg/d)	Average load (kg/d)	Removal rate (%)	Average load (kg/d)	Removal rate (%)
BOD_5	1723	1049	39	224	87
COD	6440	3535	45	814	87
TSS	1872	429	77	85	96
Ortho-P	51	6	88	3.3	94
Total-P	74	12	84	12	84

Table 4. Lomza wastewater treatment plant. Test period 08/12-92 - 16/12/92. PIX dosage = 200 g/m^3

Parameter	Raw wastewater	After pre-precipitation		Final effluent	
	Average load (kg/d)	Average load (kg/d)	Removal rate (%)	Average load (kg/d)	Removal rate (%)
BOD_5	1857	968	48	252	86
COD	6128	3702	40	1108	82
TSS	2149	772	64	301	86
Ortho-P	78	7	91	5.5	93
Total-P	109	31	72	13	88

Figures 4 and 5 show that in the test period the incoming wastewater had a concentration of organic matter (BOD and COD) that is quite normal for municipal wastewater, and the discharges from the textile factory must have been small. There was an increase in the influent phosphorus concentration throughout the test period (Figures 6 and 7), but the reason for this is unknown.

With PIX-dosages of 150-200 g/m^3, the removal of organic matter (BOD_5) over the pre-precipitation step has been 39-48 percent, and the overall BOD_5-removal was 86-87 percent. The average effluent concentration of BOD_5 was 16 mg/l. The removal of total phosphorus was acceptable with an average effluent concentration of 0.85 mg P/l, corresponding to an overall P-removal of 84-88 percent. In the second part of the test period the PIX-dosage was increased from 150 g/m^3 to 200 g/m^3 to compensate for the higher influent phosphorus concentration. With higher coagulant dosages we would have expected even better P-removals.

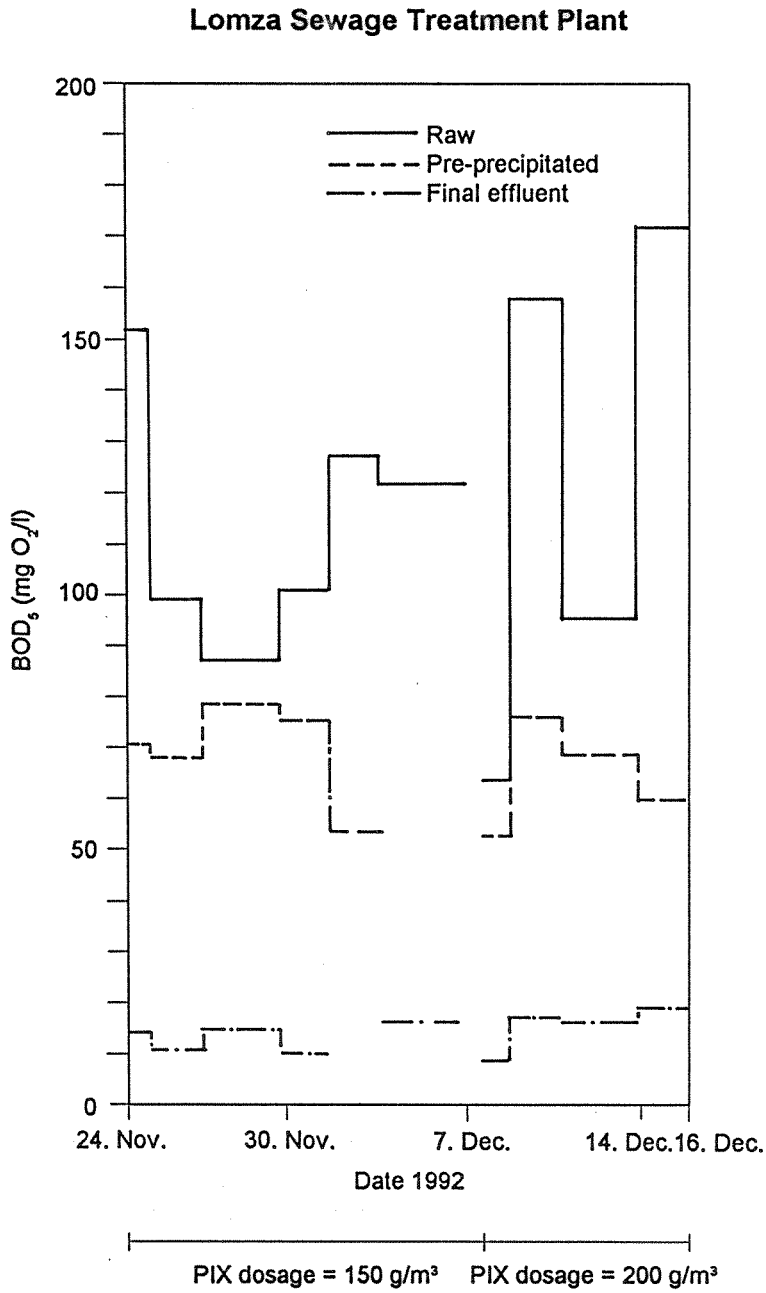


Fig. 4. Variations in BOD_5 concentrations of raw wastewater, pre-precipitated wastewater and final effluent

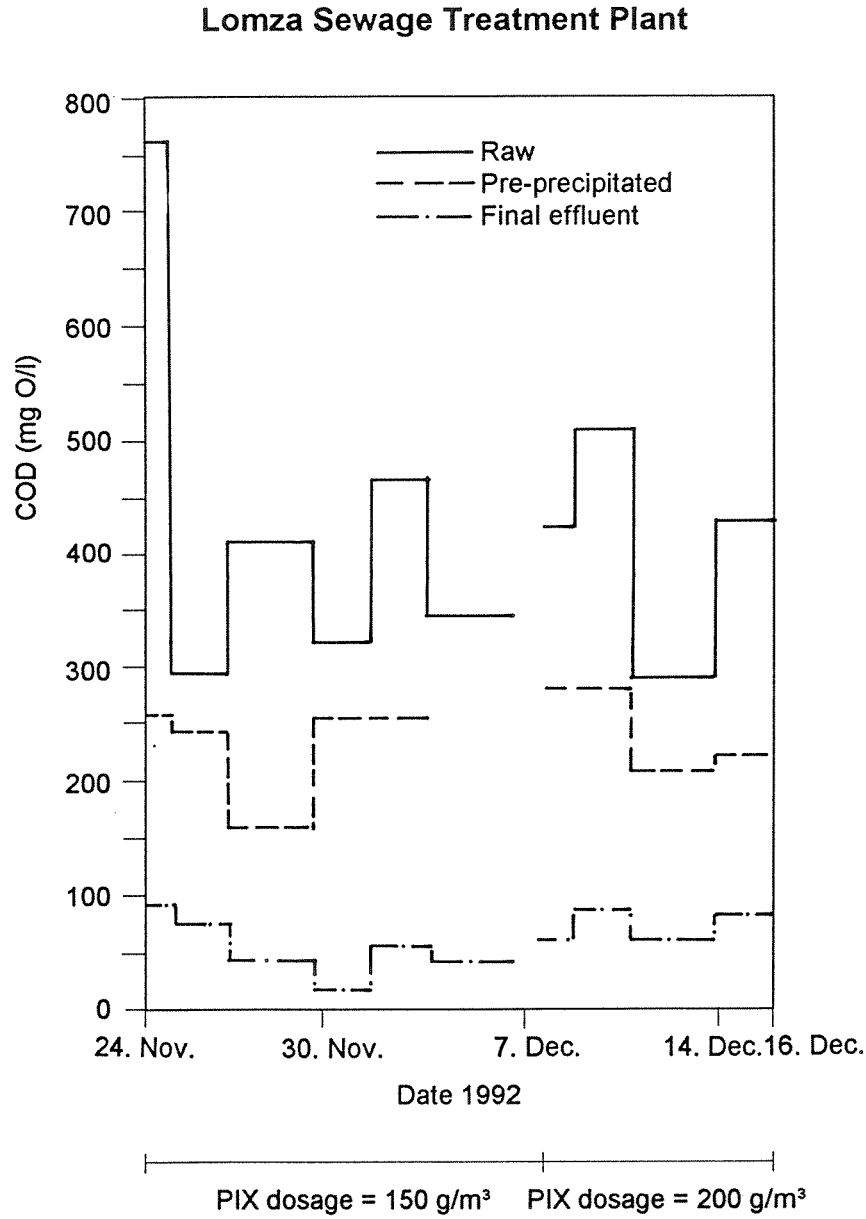


Fig. 5. Variations in COD concentration of raw wastewater, pre-precipitated wastewater and final effluent

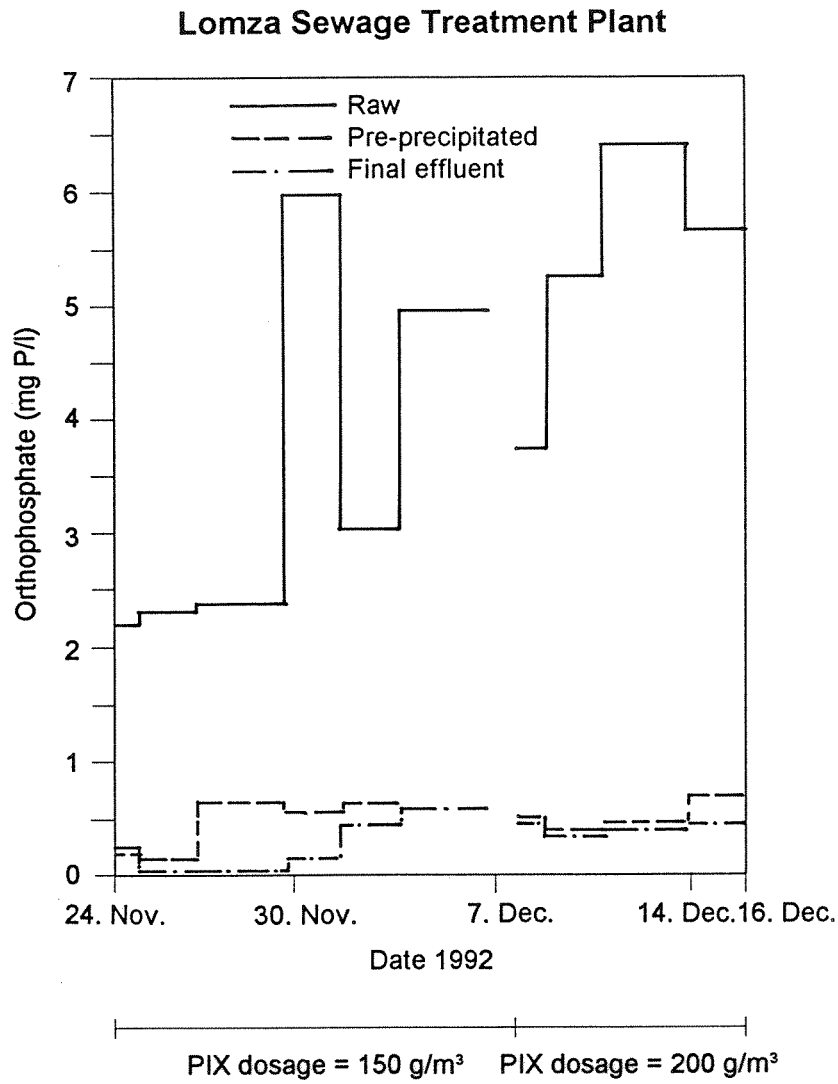


Fig. 6. Variations in orthophosphate concentration of raw wastewater, pre-precipitated wastewater and final effluent

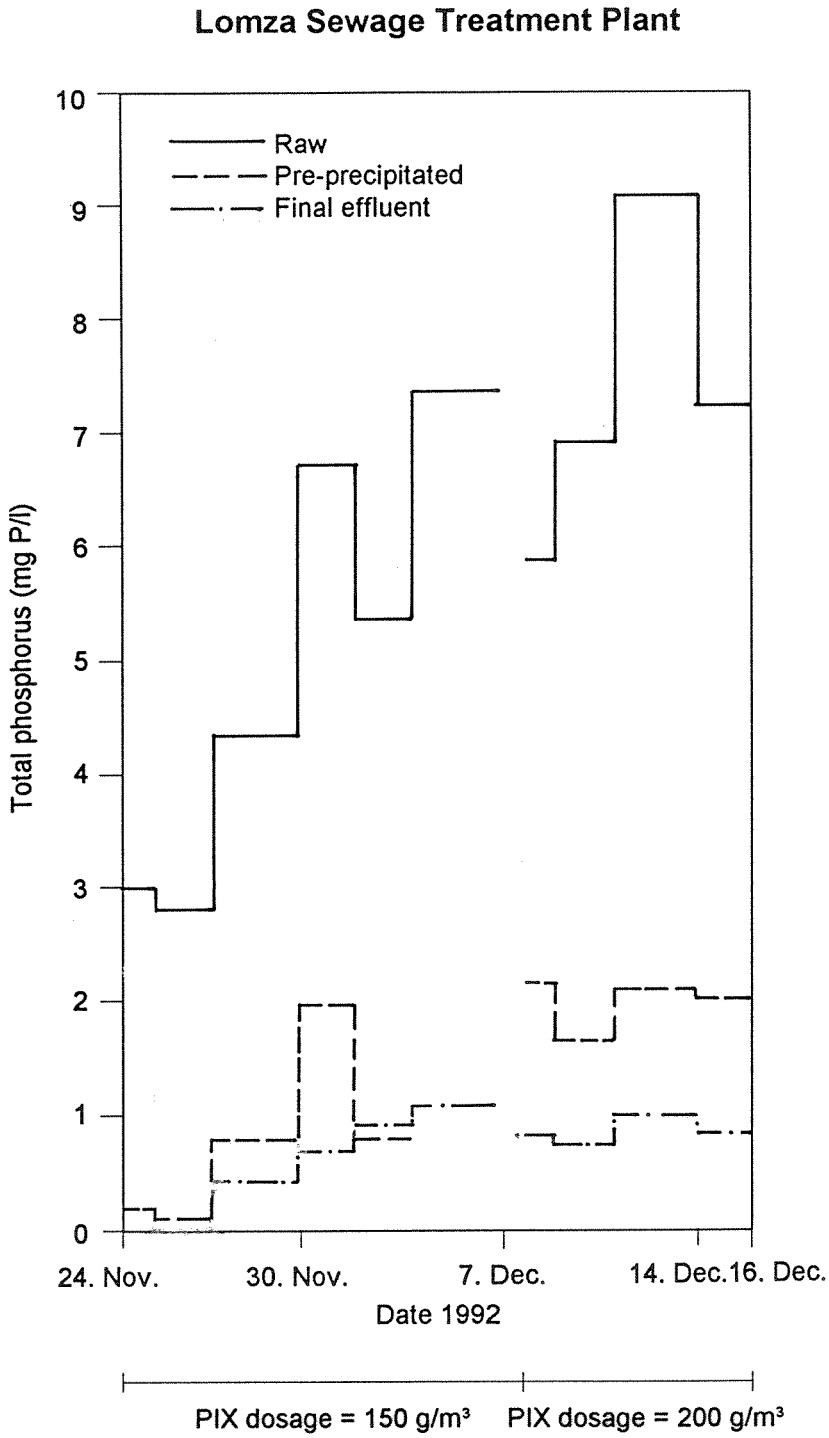


Fig. 7. Variations in total phosphorus concentration of raw wastewater, pre-precipitated wastewater and final effluent

4 Minsk Mazowiecki Wastewater Treatment Plant

4.1 General

Minsk Mazowiecki wastewater treatment plant is a conventional activated sludge plant with an average wastewater flow of about 6500 m^3/d. The plant receives periodically high-organic wastewater from a dairy, and this increases the organic load of the plant to such an extent that sludge bulking (filamentous bacteria) occurs and causes loss of activated sludge in the plant effluent. This was also the situation during most of the test period.

The full scale tests with pre-precipitation were performed during one month from September 17 to October 18, 1993. This was about 8 months later than originally planned, due to several operational problems at the plant and waiting periods for the coagulant storage and dosing equipment. The coagulant (ferric sulphate) was mixed with incoming wastewater just after the inlet pumping station, and the dosage was controlled by the on-off switch of the pumps. The coagulant dosage (g/m^3) was determined at the plant at time of test startup and not based upon the previous jar tests.

4.2 Results

All the results from analyses and wastewater flow measurements are summarized in Appendix 3. The variations in BOD_5, COD, ortho-P and total-P concentrations in raw wastewater, pre-precipitated wastewater and final effluent are presented in Figures 8-11. The average pollutant loads and removal rates for the two main coagulant dosages are shown in Tables 5 and 6.

Table 5. Minsk Mazowiecki wastewater treatment plant. Test period 17/09/93 - 29/09/93. PIX-dosage = 120 g/m^3

Parameter	Raw wastewater	After pre-precipitation		Final effluent	
	Average load (kg/d)	Average load (kg/d)	Removal rate (%)	Average load (kg/d)	Removal rate (%)
BOD_5	2651	640	76	389	85
COD	5551	2130	62	1062	81
TSS	1760	509	71	657	63
Ortho-P	45	9	80	5	89
Total-P	65	32	51	24	63

Table 6. Minsk Mazowiecki wastewater treatment plant. Test period 04/10/93 - 18/10/93. PIX-dosage = 75 g/m^3

Parameter	Raw wastewater	After pre-precipitation		Final effluent	
	Average load (kg/d)	Average load (kg/d)	Removal rate (%)	Average load (kg/d)	Removal rate (%)
BOD_5	3879	1052	73	357	91
COD	7254	2052	72	743	90
TSS	2147	849	60	374	82
Ortho-P	50	14	72	6	88
Total-P	71	30	58	16	77

Figures 8 and 9 show that there have been several days in the test period with high influent concentrations of BOD_5 and COD, and this is probably caused by wastewater discharges from the dairy. At test start-up the treatment plant experienced substantial problems with sludge bulking and loss of activated sludge in the effluent, causing high discharges of suspended solids, organic matter and phosphorus. This situation was not desirable for demonstrating the effect of pre-precipitation on the whole treatment plant (including the activated sludge step), but the pre-precipitation itself exhibited very good removal rates for organic matter (73-76% BOD_5-removal). The removal of total phosphorus, however, was not very good, but that could be expected with the low coagulant dosages (120 and 75 g/m^3), which were not sufficient to precipitate all the orthophosphate in the raw wastewater.

About two weeks after the test start-up (September 30, 1993), sludge from the anaerobic digester was pumped to the plant inlet in order to increase the sludge content of the aeration tanks. Waste activated sludge was also pumped back to the inlet of the primary clarifier. All this resulted in a very high pollutant load on the primary clarifier, and the effect of pre-precipitation was reduced, even with a higher coagulant dosage (140-150 g/m^3). From October 4, 1993 the activated sludge plant gradually recovered, but the effluent concentration of BOD and COD was still exceeding effluent standards (BOD_5 = 25 mg O_2/l). For some reason (probably economic) the ferric sulphate dosage was reduced to 75 g/m^3 in the last part of the test period, and the phosphorus removal rate was correspondingly low, even with a better capture of particulate phosphorus in the final clarifier.

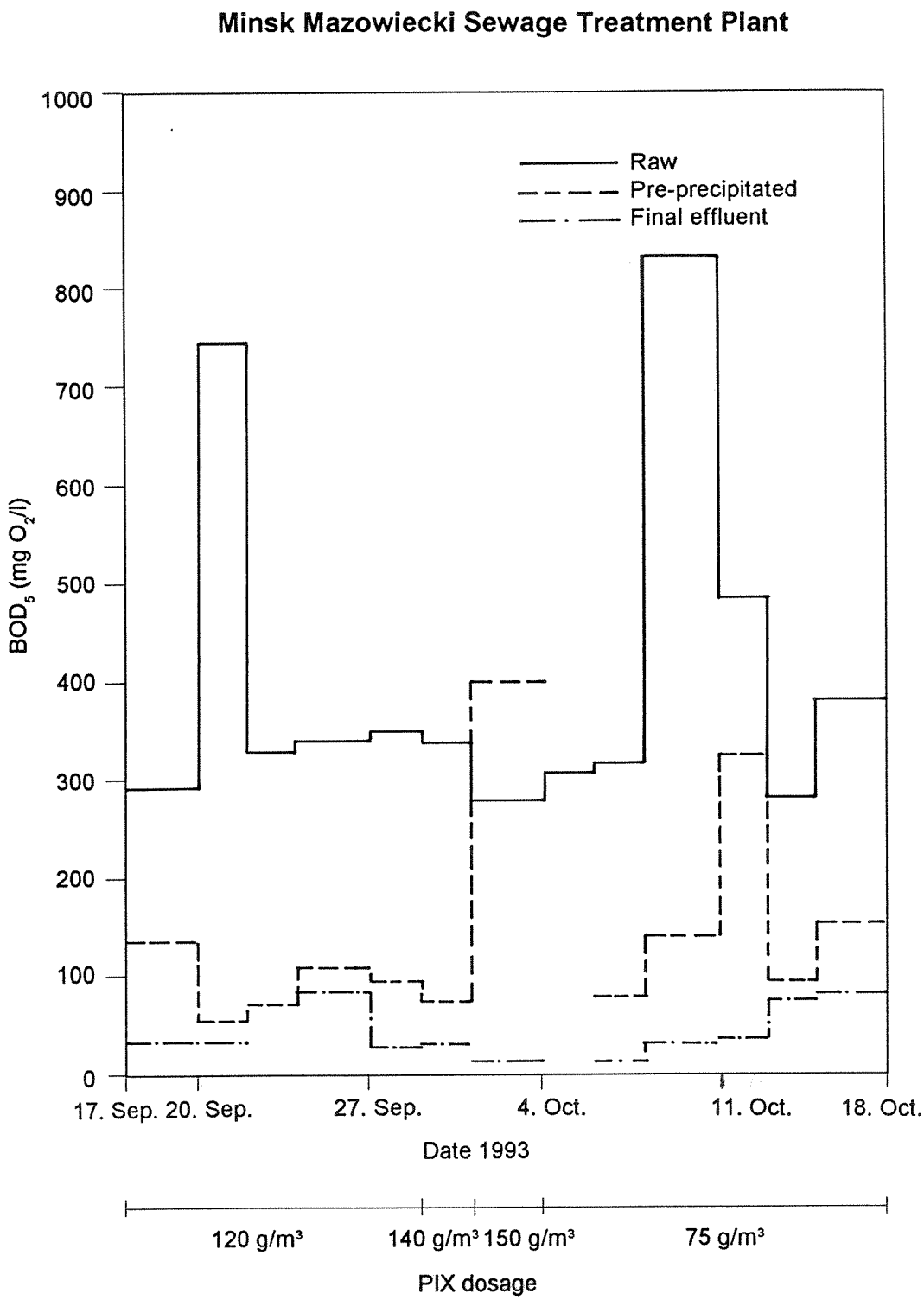


Fig. 8. Variations in BOD_5 concentrations of raw wastewater, pre-precipitated wastewater and final effluent

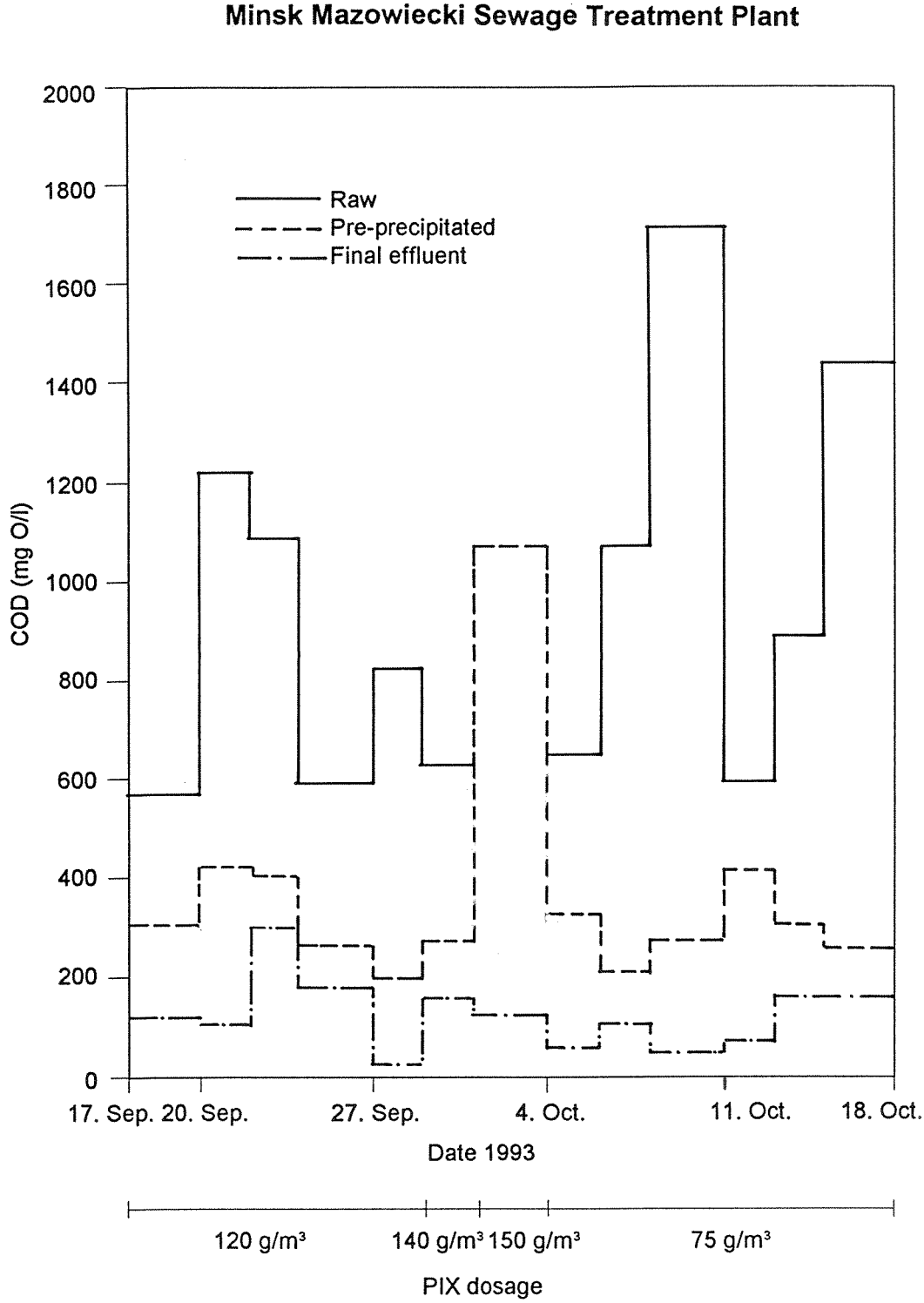


Fig. 9. Variations in COD concentration of raw wastewater, pre-precipitated wastewater and final effluent

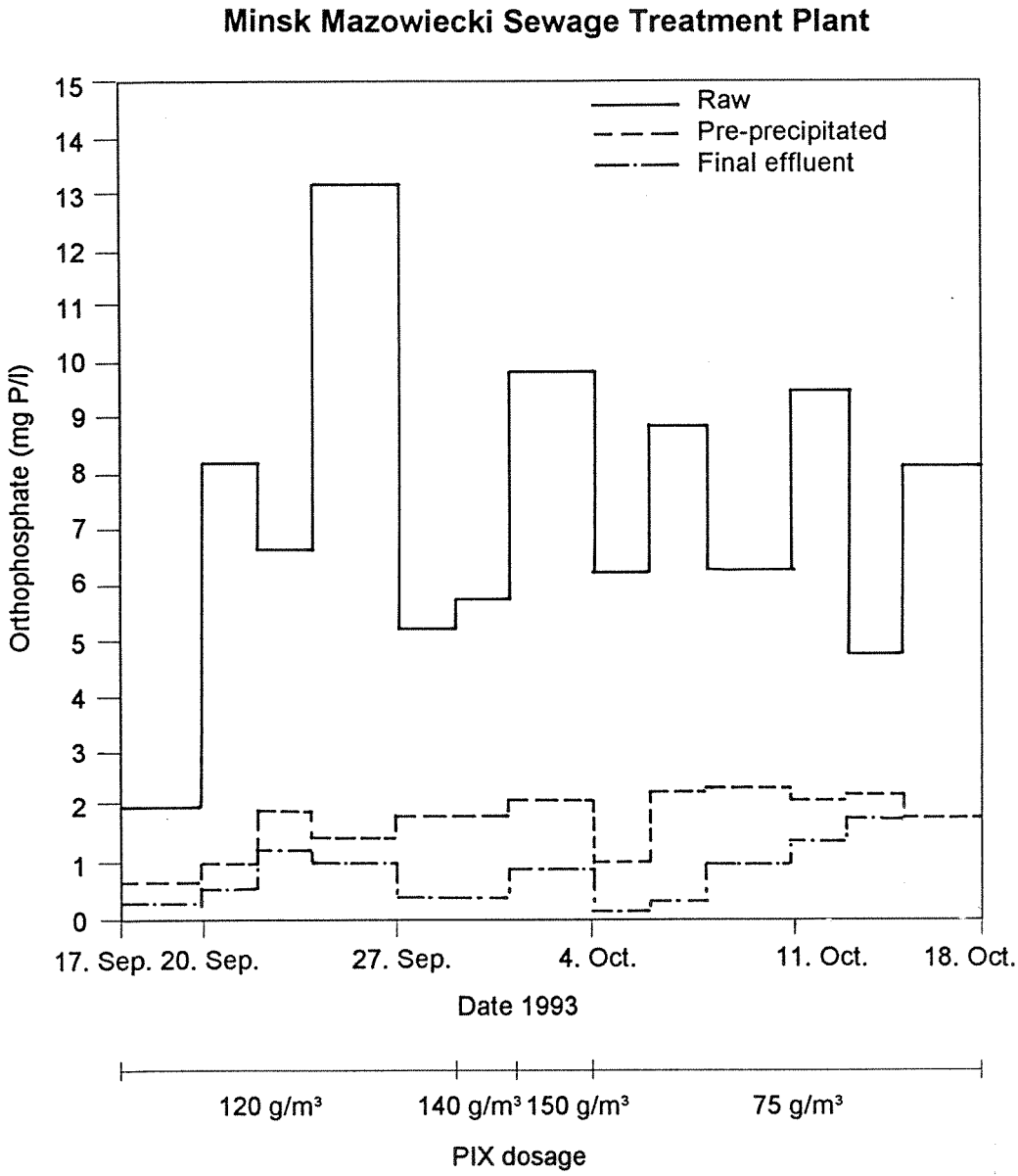


Fig. 10. Variations in orthophosphate concentration of raw wastewater, pre-precipitated wastewater and final effluent

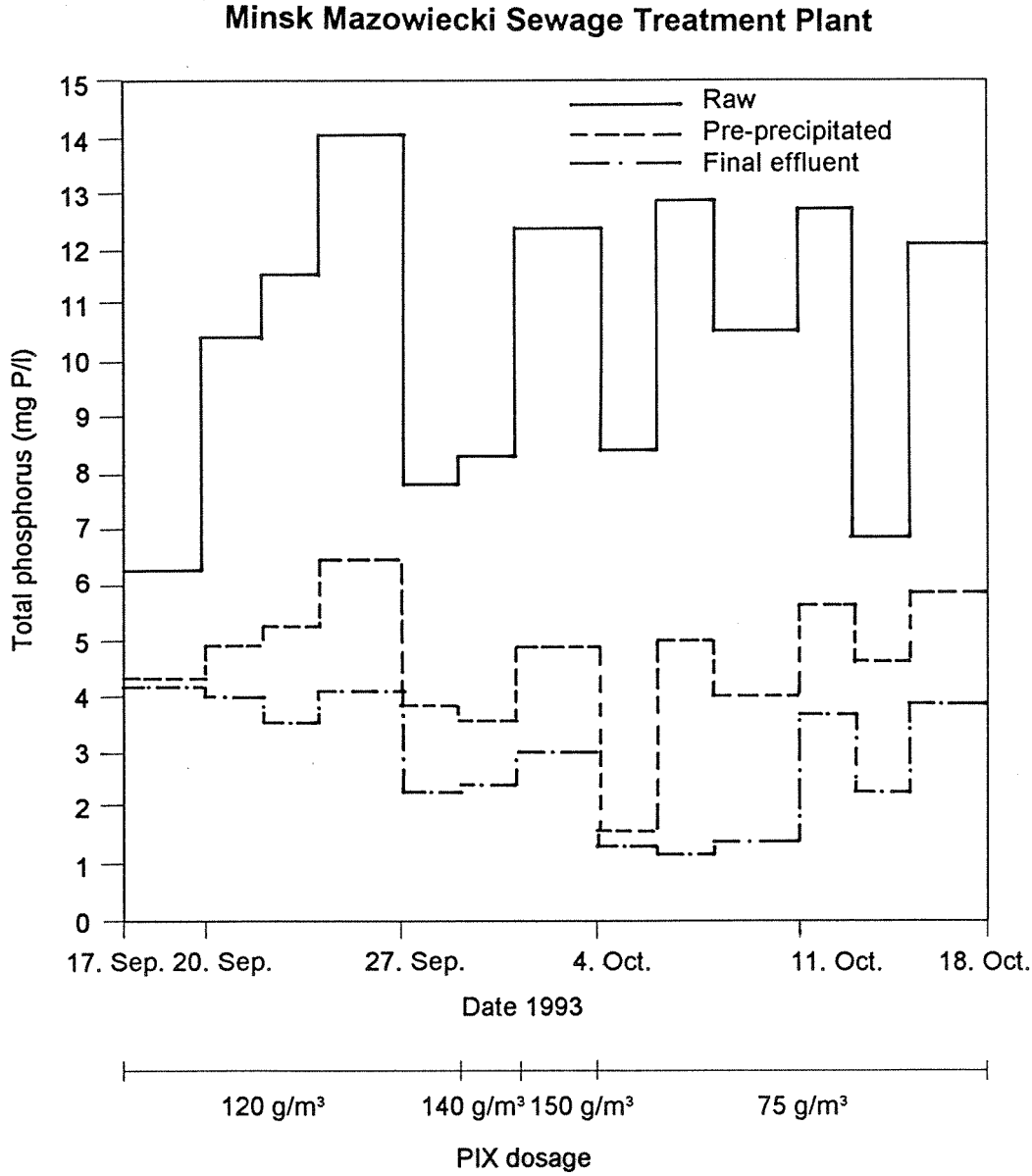


Fig. 11. Variations in total phosphorus concentration of raw wastewater, pre-precipitated wastewater and final effluent

Appendix 1. Plonsk wastewater treatment plant. Results from full scale testing of pre-precipitation with ferric sulphate

RESULTS FROM FULL SCALE TESTING OF PRE-PRECIPITATION WITH FERRISULPHATE (PIX)
PLONSK SEWAGE TREATMENT PLANT

Periods for composite sampling / Parameter	From Friday 16.10.92 at 16.00 to Monday 19.10.92 at 08.00		
PIX-dosage (g/m^3)	300		
Wastewater flow (m^3/d) (for each day in sampl. period	5000 4680 4872		
Sampling Point	Raw	Pre-prec.	Effluent
BOD_5 (mgO_2/l)	311	210	15
COD (mg O/l)	760	684	76
TSS (mg/l)	120	155	44
Total-P (mg P/l)	-	-	-
Ortho-P (mg P/l)	3.3	1.0	0.16
Periods without PIX-dosing	From 18.10.92 at 03.00 to 19.10.92 at 13.00		

Periods for composite sampling / Parameter	From Monday 19.10.92 at 08.00 to Wednesday 21.10.92 at 08.00		
PIX-dosage (g/m^3)	300		
Wastewater flow (m^3/d) (for each day in sampl. period	4680 4884		
Sampling Point	Raw	Pre-prec.	Effluent
BOD_5 (mgO_2/l)	470	280	16
COD (mg O/l)	1763	882	56
TSS (mg/l)	258	125	23
Total-P (mg P/l)	-	-	-
Ortho-P (mg P/l)	3.3	0.33	0.16
Periods without PIX-dosing	From 19.10.92 at 08.00 to 19.10.92 at 13.00		

Periods for composite sampling / Parameter	From Wednesday 21.10.92 at 08.00 to Friday 23.10.92 at 08.00		
PIX-dosage (g/m^3)	300		
Wastewater flow (m^3/d) (for each day in sampl. period	5880 5928		
Sampling Point	Raw	Pre-Prec.	Effluent
BOD_5 (mgO_2/l)	400	165	12
COD (mg O/l)	1854	608	42
TSS (mg/l)	542	140	43
Total-P (mg P/l)	-	-	-
Ortho-P (mg P/l)	3.3	0.16	0.16
Periods without PIX-dosing	From 20.10.92 at 17.00 to 21.10.92 at 13.30		

Periods for composite sampling / Parameter	From Friday 23.10.92 at 08.00 to Monday 26.10.92 at 08.00		
PIX-dosage (g/m^3)	300		
Wastewater flow (m^3/d) (for each day in sampl. period	5640 6144 4680		
Sampling Point	Raw	Pre-prec.	Effluent
BOD_5 (mgO_2/l)	190	130	15
COD (mg O/l)	973	289	35
TSS (mg/l)	211	123	24
Total-P (mg P/l)	-	-	-
Ortho-P (mg P/l)	4.9	0.07	0.07
Periods without PIX-dosing			

Periods for composite sampling / Parameter	From 26.10.92 at 08.00 to Wednesday 28.10.92 at 08.00		
PIX-dosage (g/m^3)	300		
Wastewater flow (m^3/d) (for each day in sampl. period	6240 6120		
Sampling Point	Raw	Pre-Prec.	Effluent
BOD_5 (mgO_2/l)	210	125	5
COD (mg O/l)	669	365	47
TSS (mg/l)	309	100	22
Total-P (mg P/l)	-	-	-
Ortho-P (mg P/l)	3.3	0.03	0.03
Periods without PIX-dosing			

Periods for composite sampling / Parameter	From Wednesday 28.10.92 at 08.00 to Friday 30.10.92 at 08.00		
PIX-dosage (g/m^3)	300		
Wastewater flow (m^3/d) (for each day in sampl. period	6228 6000		
Sampling Point	Raw	Pre-Prec.	Effluent
BOD_5 (mgO_2/l)	380	190	5
COD (mg O/l)	1550	653	46
TSS (mg/l)	195	159	23
Total-P (mg P/l)	-	-	-
Ortho-P (mg P/l)	3.3	0.07	0.07
Periods without PIX-dosing			

RESULTS FROM FULL SCALE TESTING OF PRE-PRECIPITATION WITH FERRISULPHATE (PIX)
PLONSK SEWAGE TREATMENT PLANT

Periods for composite sampling / Parameter	From Friday 30.10.92 at 08.00 to Monday 2.11.92 at 08.00		
PIX-dosage (g/m^3)	230		
Wastewater flow (m^3/d) (for each day in sampl. period	4920 5640 4750		
Sampling Point	Raw	Pre-prec.	Effluent
BOD_5 (mgO_2/l)	190	115	4
COD (mg O/l)	456	289	39
TSS (mg/l)	203	108	21
Total-P (mg P/l)	5.9	0.62	0.29
Ortho-P (mg P/l)	3.3	0.02	0.02
Periods without PIX-dosing			

Periods for composite sampling / Parameter	From Monday 2.11.92 at 08.00 to Wednesday 4.11.92 at 08.00		
PIX-dosage (g/m^3)	230		
Wastewater flow (m^3/d) (for each day in sampl. period	4440 4680		
Sampling Point	Raw	Pre-prec.	Effluent
BOD_5 (mgO_2/l)	396	195	7
COD (mg O/l)	912	699	42
TSS (mg/l)	251	147	22
Total-P (mg P/l)	4.9	0.56	0.26
Ortho-P (mg P/l)	3.1	0.07	0.07
Periods without PIX-dosing			

Periods for composite sampling / Parameter	From Wednesday 4.11.92 at 08.00 to Friday 6.11.92 at 08.00		
PIX-dosage (g/m^3)	230		
Wastewater flow (m^3/d) (for each day in sampl. period	4400 4498		
Sampling Point	Raw	Pre-Prec.	Effluent
BOD_5 (mgO_2/l)	290	188	11
COD (mg O/l)	595	308	61
TSS (mg/l)	201	123	24
Total-P (mg P/l)	6.9	1.0	0.49
Ortho-P (mg P/l)	5	0.16	0.16
Periods without PIX-dosing			

Periods for composite sampling / Parameter	From Friday 6.10.92 at 08.00 to Monday 9.10.92 at 08.00		
PIX-dosage (g/m^3)	230		
Wastewater flow (m^3/d) (for each day in sampl. period	4560 4440 3960		
Sampling Point	Raw	Pre-prec.	Effluent
BOD_5 (mgO_2/l)	190	87	4
COD (mg O/l)	518	365	53
TSS (mg/l)	180	164	18
Total-P (mg P/l)	-	-	-
Ortho-P (mg P/l)	2.6	0.16	0.16
Periods without PIX-dosing			

Periods for composite sampling / Parameter	From Monday 9.11.92 at 08.00 to Tuesday 10.11.92 at 08.00		
PIX-dosage (g/m^3)	230		
Wastewater flow (m^3/d) (for each day in sampl. period	4560		
Sampling Point	Raw	Pre-Prec.	Effluent
BOD_5 (mgO_2/l)	385	170	16
COD (mg O/l)	749	394	62
TSS (mg/l)	582	229	35
Total-P (mg P/l)	-	-	-
Ortho-P (mg P/l)	2.5	0.16	0.16
Periods without PIX-dosing			

Periods for composite sampling / Parameter	From Tuesday 10.11.92 at 08.00 to Thursday 12.11.92 at 08.00		
PIX-dosage (g/m^3)	230		
Wastewater flow (m^3/d) (for each day in sampl. period	4584 4620		
Sampling Point	Raw	Pre-Prec.	Effluent
BOD_5 (mgO_2/l)	350	268	18
COD (mg O/l)	1056	614	47
TSS (mg/l)	482	286	65
Total-P (mg P/l)	-	-	-
Ortho-P (mg P/l)	3.2	0.26	0.26
Periods without PIX-dosing			

RESULTS FROM FULL SCALE TESTING OF PRE-PRECIPITATION WITH FERRISULPHATE (PIX)
PLONSK SEWAGE TREATMENT PLANT

Periods for composite sampling / Parameter	From Thursday 12.11.92 at 08.00 to Friday 13.11.92 at 08.00		
PIX-dosage (g/m^3)	230		
Wastewater flow (m^3/d) (for each day in sampl. period	4500		
Sampling Point	Raw	Pre-prec.	Effluent
BOD_5 (mgO_2/l)	390	230	18
COD (mg O/l)	1075	317	47
TSS (mg/l)	438	298	28
Total-P (mg P/l)	-	-	-
Ortho-P (mg P/l)	9.8	0.42	0.42
Periods without PIX-dosing			

Periods for composite sampling / Parameter	From Friday 13.11.92 at 08.00 to Monday 16.11.92 at 08.00		
PIX-dosage (g/m^3)	230		
Wastewater flow (m^3/d) (for each day in sampl. period	4560 4596 4320		
Sampling Point	Raw	Pre-prec.	Effluent
BOD_5 (mgO_2/l)	395	221	16
COD (mg O/l)	1267	470	57
TSS (mg/l)	356	198	13
Total-P (mg P/l)	-	-	-
Ortho-P (mg P/l)	6.5	0.26	0.26
Periods without PIX-dosing			

Periods for composite sampling / Parameter	From Monday 16.11.92 at 08.00 to Tuesday 17.11.92 at 08.00		
PIX-dosage (g/m^3)	300		
Wastewater flow (m^3/d) (for each day in sampl. period	4584		
Sampling Point	Raw	Pre-Prec.	Effluent
BOD_5 (mgO_2/l)	368	198	3
COD (mg O/l)	864	451	31
TSS (mg/l)	666	304	54
Total-P (mg P/l)	-	-	-
Ortho-P (mg P/l)	4.1	0.16	0.16
Periods without PIX-dosing			

Periods for composite sampling / Parameter	From		
PIX-dosage (g/m^3)			
Wastewater flow (m^3/d) (for each day in sampl. period			
Sampling Point	Raw	Pre-prec.	Effluent
BOD_5 (mgO_2/l)			
COD (mg O/l)			
TSS (mg/l)			
Total-P (mg P/l)			
Ortho-P (mg P/l)			
Periods without PIX-dosing			

Periods for composite sampling / Parameter	From		
PIX-dosage (g/m^3)			
Wastewater flow (m^3/d) (for each day in sampl. period			
Sampling Point	Raw	Pre-Prec.	Effluent
BOD_5 (mgO_2/l)			
COD (mg O/l)			
TSS (mg/l)			
Total-P (mg P/l)			
Ortho-P (mg P/l)			
Periods without PIX-dosing			

Periods for composite sampling / Parameter	From		
PIX-dosage (g/m^3)			
Wastewater flow (m^3/d) (for each day in sampl. period			
Sampling Point	Raw	Pre-Prec.	Effluent
BOD_5 (mgO_2/l)			
COD (mg O/l)			
TSS (mg/l)			
Total-P (mg P/l)			
Ortho-P (mg P/l)			
Periods without PIX-dosing			

Appendix 2. Lomza wastewater treatment plant. Results from full scale testing of pre-precipitation with ferric sulphate

RESULTS FROM FULL SCALE TESTING OF PRE-PRECIPITATION WITH FERRIC SULPHATE (PIX)
LOMZA SEWAGE TREATMENT PLANT

Periods for composite sampling / Parameter	From Tuesday 24.11.92 at 08.00 to Wednesday 25.11.92 at 08.00		
PIX-dosage (g/m^3)	150		
Wastewater flow (m^3/d) (for each day in sampl. period	14950		
Sampling Point	Raw	Pre-prec.	Effluent
BOD_5 (mgO_2/l)	151	72	16
COD (mg O/l)	760	260	90
TSS (mg/l)	240	28	10
Total-P (mg P/l)	3	0.23	-
Ortho-P (mg P/l)	2.2	0.20	0.23

Periods for composite sampling / Parameter	From Wednesday 25.11.92 at 08.00 to Friday 27.11.92 at 08.00		
PIX-dosage (g/m^3)	150		
Wastewater flow (m^3/d) (for each day in sampl. period	15600 14900		
Sampling Point	Raw	Pre-prec.	Effluent
BOD_5 (mgO_2/l)	99	68	13
COD (mg O/l)	290	240	75
TSS (mg/l)	65	48	12
Total-P (mg P/l)	2.8	0.24	-
Ortho-P (mg P/l)	2.2	0.15	0.02

Periods for composite sampling / Parameter	From Friday 27.11.92 at 08.00 to Monday 30.11.92 at 08.00		
PIX-dosage (g/m^3)	150		
Wastewater flow (m^3/d) (for each day in sampl. period	14300 13650 14440		
Sampling Point	Raw	Pre-Prec.	Effluent
BOD_5 (mgO_2/l)	87	79	16
COD (mg O/l)	410	160	40
TSS (mg/l)	165	48	0
Total-P (mg P/l)	4.4	0.79	0.53
Ortho-P (mg P/l)	2.3	0.58	0.02

Periods for composite sampling / Parameter	From Monday 30.11.92 at 08.00 to Wednesday 2.12.92 at 08.00		
PIX-dosage (g/m^3)	150		
Wastewater flow (m^3/d) (for each day in sampl. period	15600 14950		
Sampling Point	Raw	Pre-prec.	Effluent
BOD_5 (mgO_2/l)	102	76	13
COD (mg O/l)	320	260	20
TSS (mg/l)	17	20	0
Total-P (mg P/l)	6.7	2.0	0.73
Ortho-P (mg P/l)	5.9	0.53	0.12

Periods for composite sampling / Parameter	From Wednesday 02.12.92 at 08.00 to Friday 04.12.92 at 08.00		
PIX-dosage (g/m^3)	150		
Wastewater flow (m^3/d) (for each day in sampl. period	15600 15550		
Sampling Point	Raw	Pre-Prec.	Effluent
BOD_5 (mgO_2/l)	128	55	-
COD (mg O/l)	460	250	60
TSS (mg/l)	160	0.8	0
Total-P (mg P/l)	5.3	0.81	0.92
Ortho-P (mg P/l)	3.0	0.58	0.40

Periods for composite sampling / Parameter	From Friday 04.12.92 at 08.00 to Monday 07.12.92 at 08.00		
PIX-dosage (g/m^3)	150		
Wastewater flow (m^3/d) (for each day in sampl. period	9750 14950 19500		
Sampling Point	Raw	Pre-Prec.	Effluent
BOD_5 (mgO_2/l)	122	-	18
COD (mg O/l)	340	-	40
TSS (mg/l)	106	-	12
Total-P (mg P/l)	7.3	-	1.1
Ortho-P (mg P/l)	4.9	-	0.55

RESULTS FROM FULL SCALE TESTING OF PRE-PRECIPITATION WITH FERRIC SULPHATE (PIX)
LOMZA SEWAGE TREATMENT PLANT

Periods for composite sampling / Parameter	From Tuesday 08.12.92 at 12.00 to Wednesday 09.12.92 at 08.00		
PIX-dosage (g/m^3)	200		
Wastewater flow (m^3/d) (for each day in sampl. period	14300		
Sampling Point	Raw	Pre-prec.	Effluent
BOD_5 (mgO_2/l)	64	53	10
COD (mg O/l)	415	280	66
TSS (mg/l)	116	40	12
Total-P (mg P/l)	5.8	2.2	0.85
Ortho-P (mg P/l)	3.7	0.42	0.47

Periods for composite sampling / Parameter	From Wednesday 09.12.92 at 08.00 to Friday 11.12.92 at 08.00		
PIX-dosage (g/m^3)	200		
Wastewater flow (m^3/d) (for each day in sampl. period	14250 14950		
Sampling Point	Raw	Pre-prec.	Effluent
BOD_5 (mgO_2/l)	157	76	18
COD (mg O/l)	500	280	86
TSS (mg/l)	152	80	50
Total-P (mg P/l)	6.9	1.7	0.71
Ortho-P (mg P/l)	5.2	0.35	0.28

Periods for composite sampling / Parameter	From Friday 11.12.92 at 08.00 to Monday 14.12.92 at 08.00		
PIX-dosage (g/m^3)	200		
Wastewater flow (m^3/d) (for each day in sampl. period	15350 16200 12350		
Sampling Point	Raw	Pre-Prec.	Effluent
BOD_5 (mgO_2/l)	95	68	17
COD (mg O/l)	290	210	62
TSS (mg/l)	68	56	16
Total-P (mg P/l)	9.0	2.2	1.1
Ortho-P (mg P/l)	6.3	0.42	0.35

Periods for composite sampling / Parameter	From Monday 14.12.92 at 08.00 to Wednesday 16.12.92 at 08.00		
PIX-dosage (g/m^3)	200		
Wastewater flow (m^3/d) (for each day in sampl. period	16850 16250		
Sampling Point	Raw	Pre-prec.	Effluent
BOD_5 (mgO_2/l)	171	61	20
COD (mg O/l)	425	220	80
TSS (mg/l)	225	32	4
Total-P (mg P/l)	7.2	2.1	0.88
Ortho-P (mg P/l)	5.5	0.65	0.39

Periods for composite sampling / Parameter	From		
PIX-dosage (g/m^3)			
Wastewater flow (m^3/d) (for each day in sampl. period			
Sampling Point	Raw	Pre-Prec.	Effluent
BOD_5 (mgO_2/l)			
COD (mg O/l)			
TSS (mg/l)			
Total-P (mg P/l)			
Ortho-P (mg P/l)			

Periods for composite sampling / Parameter	From		
PIX-dosage (g/m^3)			
Wastewater flow (m^3/d) (for each day in sampl. period			
Sampling Point	Raw	Pre-Prec.	Effluent
BOD_5 (mgO_2/l)			
COD (mg O/l)			
TSS (mg/l)			
Total-P (mg P/l)			
Ortho-P (mg P/l)			

Appendix 3. Minsk Mazowiecki wastewater treatment plant. Results from full scale testing of pre-precipitation with ferric sulphate

RESULTS FROM FULL SCALE TESTING OF PRE-PRECIPITATION WITH FERRIC SULPHATE (PIX). MINSK MAZOWIECKI SEWAGE TREATMENT PLANT

Periods for composite sampling / Parameter	From Friday 17.09.93 at 08.00 to Monday 20.09.93 at 08.00		
PIX-dosage (g/m^3)	120		
Wastewater flow (m^3/d) (for each day in sampl. period	6484 7122 5990		
Sampling Point	Raw	Pre-prec.	Effluent
BOD_5 (mgO_2/l)	295	140	44
COD (mg O/l)	572	314	143
TSS (mg/l)	73	41	41
Total-P (mg P/l)	6.2	4.4	4.3
Ortho-P (mg P/l)	2.1	0.78	0.46

Periods for composite sampling / Parameter	From Monday 20.09.93 at 08.00 to Wednesday 22.09.93 at 08.00		
PIX-dosage (g/m^3)	120		
Wastewater flow (m^3/d) (for each day in sampl. period	6388 6404		
Sampling Point	Raw	Pre-prec.	Effluent
BOD_5 (mgO_2/l)	740	64	44
COD (mg O/l)	1207	434	133
TSS (mg/l)	541	127	377
Total-P (mg P/l)	10.5	4.9	4.0
Ortho-P (mg P/l)	8.2	1.1	0.62

Periods for composite sampling / Parameter	From Wednesday 22.09.93 at 08.00 to Friday 24.09.93 at 08.00		
PIX-dosage (g/m^3)	120		
Wastewater flow (m^3/d) (for each day in sampl. period	6480 6868		
Sampling Point	Raw	Pre-Prec.	Effluent
BOD_5 (mgO_2/l)	330	76	86
COD (mg O/l)	1080	405	305
TSS (mg/l)	331	103	73
Total-P (mg P/l)	11.5	5.2	3.5
Ortho-P (mg P/l)	6.5	2.0	1.4

Periods for composite sampling / Parameter	From Friday 24.09.93 at 08.00 to Monday 27.09.93 at 08.00		
PIX-dosage (g/m^3)	120		
Wastewater flow (m^3/d) (for each day in sampl. period	6488 6482 6212		
Sampling Point	Raw	Pre-prec.	Effluent
BOD_5 (mgO_2/l)	340	115	92
COD (mg O/l)	596	279	193
TSS (mg/l)	202	78	126
Total-P (mg P/l)	14.1	6.4	4.1
Ortho-P (mg P/l)	13.1	1.5	1.2

Periods for composite sampling / Parameter	From Monday 27.09.93 at 08.00 to Wednesday 29.09.93 at 08.00		
PIX-dosage (g/m^3)	120		
Wastewater flow (m^3/d) (for each day in sampl. period	6332 6350		
Sampling Point	Raw	Pre-Prec.	Effluent
BOD_5 (mgO_2/l)	350	100	34
COD (mg O/l)	833	211	41
TSS (mg/l)	215	44	17
Total-P (mg P/l)	7.8	3.4	2.4
Ortho-P (mg P/l)	5.2	1.9	0.52

Periods for composite sampling / Parameter	From Wednesday 29.09.93 at 08.00 to Friday 01.10.93 at 08.00		
PIX-dosage (g/m^3)	140		
Wastewater flow (m^3/d) (for each day in sampl. period	6620 6378		
Sampling Point	Raw	Pre-Prec.	Effluent
BOD_5 (mgO_2/l)	340	80	36
COD (mg O/l)	630	280	171
TSS (mg/l)	729	450	238
Total-P (mg P/l)	8.3	3.5	2.5
Ortho-P (mg P/l)	5.8	2.0	0.5

RESULTS FROM FULL SCALE TESTING OF PRE-PRECIPITATION WITH FERRIC SULPHATE (PIX). MINSK MAZOWIECKI SEWAGE TREATMENT PLANT

Periods for composite sampling / Parameter	From Friday 01.10.93 at 08.00 to Monday 04.10.93 at 08.00		
PIX-dosage (g/m^3)	150		
Wastewater flow (m^3/d) (for each day in sampl. period	6378 6552 6334		
Sampling Point	Raw	Pre-prec.	Effluent
BOD_5 (mgO_2/l)	280	400	23
COD (mg O/l)	-	1067	144
TSS (mg/l)	295	302	109
Total-P (mg P/l)	12.3	4.8	3.0
Ortho-P (mg P/l)	9.8	2.2	1.0

Periods for composite sampling / Parameter	From Monday 04.10.93 at 08.00 to Wednesday 06.10.93 at 08.00		
PIX-dosage (g/m^3)	75		
Wastewater flow (m^3/d) (for each day in sampl. period	6796 7338		
Sampling Point	Raw	Pre-prec.	Effluent
BOD_5 (mgO_2/l)	310	-	-
COD (mg O/l)	651	331	72
TSS (mg/l)	422	231	22
Total-P (mg P/l)	8.3	1.6	1.4
Ortho-P (mg P/l)	6.2	1.1	0.29

Periods for composite sampling / Parameter	From Wednesday 06.10.93 at 08.00 to Friday 08.10.93 at 08.00		
PIX-dosage (g/m^3)	75		
Wastewater flow (m^3/d) (for each day in sampl. period	6410 6820		
Sampling Point	Raw	Pre-Prec.	Effluent
BOD_5 (mgO_2/l)	320	80	18
COD (mg O/l)	1070	224	104
TSS (mg/l)	464	43	37
Total-P (mg P/l)	12.8	5.1	1.2
Ortho-P (mg P/l)	8.8	2.4	0.39

Periods for composite sampling / Parameter	From Friday 08.10.93 at 08.00 to Monday 11.10.93 at 08.00		
PIX-dosage (g/m^3)	75		
Wastewater flow (m^3/d) (for each day in sampl. period	6630 7504 6614		
Sampling Point	Raw	Pre-prec.	Effluent
BOD_5 (mgO_2/l)	824	140	38
COD (mg O/l)	1700	280	60
TSS (mg/l)	155	61	23
Total-P (mg P/l)	10.5	4.0	1.5
Ortho-P (mg P/l)	6.4	2.5	1.1

Periods for composite sampling / Parameter	From Monday 11.10.93 at 08.00 to Wednesday 13.10.93 at 08.00		
PIX-dosage (g/m^3)	75		
Wastewater flow (m^3/d) (for each day in sampl. period	5570 6642		
Sampling Point	Raw	Pre-Prec.	Effluent
BOD_5 (mgO_2/l)	480	325	40
COD (mg O/l)	597	420	85
TSS (mg/l)	319	103	71
Total-P (mg P/l)	12.6	5.6	3.7
Ortho-P (mg P/l)	9.5	2.3	1.5

Periods for composite sampling / Parameter	From Wednesday 13.10.93 at 08.00 to Friday 15.10.93 at 08.00		
PIX-dosage (g/m^3)	75		
Wastewater flow (m^3/d) (for each day in sampl. period	5840 7362		
Sampling Point	Raw	Pre-Prec.	Effluent
BOD_5 (mgO_2/l)	280	95	80
COD (mg O/l)	880	304	166
TSS (mg/l)	257	117	109
Total-P (mg P/l)	6.7	4.6	2.3
Ortho-P (mg P/l)	4.7	2.3	1.9

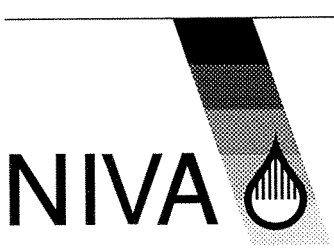
RESULTS FROM FULL SCALE TESTING OF PRE-PRECIPITATION WITH FERRIC SULPHATE (PIX). MINSK MAZOWIECKI SEWAGE TREATMENT PLANT

Periods for composite sampling / Parameter	From Friday 15.10.93 at 08.00 to Monday 18.10.93 at 08.00		
PIX-dosage (g/m^3)	75		
Wastewater flow (m^3/d) (for each day in sampl. period	8762 6974 6484		
Sampling Point	Raw	Pre-prec.	Effluent
BOD_5 (mgO_2/l)	380	155	85
COD (mg O/l)	1432	267	166
TSS (mg/l)	285	192	72
Total-P (mg P/l)	12.0	5.7	3.8
Ortho-P (mg P/l)	8.2	1.9	-

Periods for composite sampling / Parameter			
PIX-dosage (g/m^3)			
Wastewater flow (m^3/d) (for each day in sampl. period			
Sampling Point	Raw	Pre-prec.	Effluent
BOD_5 (mgO_2/l)			
COD (mg O/l)			
TSS (mg/l)			
Total-P (mg P/l)			
Ortho-P (mg P/l)			

Periods for composite sampling / Parameter			
PIX-dosage (g/m^3)			
Wastewater flow (m^3/d) (for each day in sampl. period			
Sampling Point	Raw	Pre-Prec.	Effluent
BOD_5 (mgO_2/l)			
COD (mg O/l)			
TSS (mg/l)			
Total-P (mg P/l)			
Ortho-P (mg P/l)			

Periods for composite sampling / Parameter			
PIX-dosage (g/m^3)			
Wastewater flow (m^3/d) (for each day in sampl. period			
Sampling Point	Raw	Pre-Prec.	Effluent
BOD_5 (mgO_2/l)			
COD (mg O/l)			
TSS (mg/l)			
Total-P (mg P/l)			
Ortho-P (mg P/l)			



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