WATER MANAGEMENT IN ST. PETERSBURG

Mikael Sillfors

Basic information

The service area of Vodokanal of St. Petersburg covers the city of St. Petersburg and the areas concentrated around the suburbs Sestroretsk (Kurotny), Kronstadt, Lomonosov, Pedrodvorets, Kolpino and Pushkin, as shown on Figure 1. The area of St. Petersburg is 604 km^2 and of the suburbs 783 km^2, totalling 1387 km^2. About 5 million people live in the Vodokanal service area. /1/

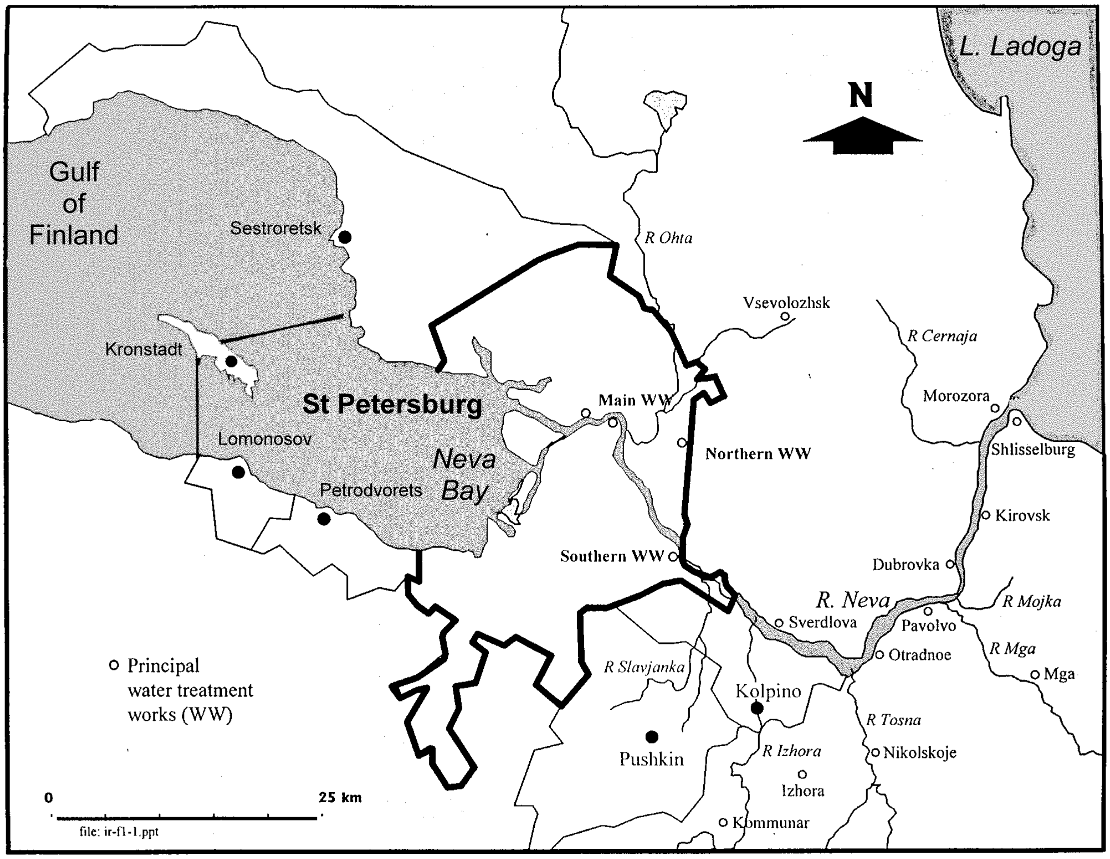

Figure 1. The service area of Vodokanal of St. Petersburg /1/.

The main water body connected to St. Petersburg is the River Neva, which flows through the city into the Gulf of Finland at the eastern end of the Baltic Sea. Other smaller rivers that drain through the city are the River Ohta, which joins the Neva within St. Petersburg, and the River Slavjanka, which joins the Neva at the upstream limit of the city (Fig. 1).

The average temperature in St. Petersburg varies between 17°C in summer months and -8 °C during the winter months.

The industrial production of the city used to be concentrated in the military sector. The dissolution of the former Soviet Union and the transition to a market economy, accompanied by radical cuts in military spending, have had a major effect on the city's economy and employment. The industrial production in 1996 was only about 25% of the level in 1990 /1/. Because of this, the load of pollutants entering the Gulf of Finland has decreased a lot, but researchers are already afraid of what will happen when the economy starts to recover /2/.

Vodokanal of St. Petersburg (Vodokanal Sankt-Peterburga) is a state unitary enterprise. Its assets are owned by the Municipality of St. Petersburg, but it operates at arm's length from the City Administration under a municipal statute. It has been financially self-sufficient for some years, aside from limited grants from federal and city authorities /1/.

Contact information: SUE "Vodokanal of St. Petersburg"
42 Kavalergardskaja Street
193015
Saint-Petersburg
RUSSIA

Sources of raw water

Raw water is mainly taken from the River Neva, or in some suburbs from local surface water supplies. Use of groundwater is only about 2% /1/.

The River Neva is rather short, only 74 km, and 32 km lie inside the city of St. Petersburg. The long-term mean discharge is about 2460 m^3/s and the river contributes 70-75% of the fresh water that flows into the Gulf of Finland. Its total drainage area is 285,000 km^2 /3/.

The quality of the water of Neva is generally poor. The main problems are eutrophication and poor microbiological quality. The high levels of contamination are caused by untreated domestic, industrial, agricultural and livestock wastes upstream and storm runoff sources. In the upper course of the Neva, the water quality is also influenced by eutrophication and pollution processes in Lake Ladoga /3/.

Appendices 1-4 provide data on the raw water quality in the South, North, Volkovskaja and Main Waterworks. The quality of the water is basically the same in the South, North and Volkovskaja Waterworks, but it is worse in the Main and Petrogradskaja Waterworks, especially from the microbial point of view /3/.

The Neva water quality and the raw water classification according to Russian and EU classification are presented in Table 1.

Table 1. The comparison between the reported Neva water quality (1995) and the raw water classification in Russia and the EU /3/.

Parameter	Observed Values in Neva Average	Maximum	Russian GOST Norm Maximum	EU Directive
Ammonia mg/l	0.008	0.19	2	A2
a-chlorophyll µg/l	-	5-6	-	-
Colour mg/l Pt	27	37	35	A2
COD_{Mn} mg/l	6.9	8.1	7	-
Coliforms (37°C)/l	<500	2,400,000	-	A3
Nitrate mg/l	1.6	2.1	45	A1
Nitrite mg/l	0.018	0.033	33	-
Oxygen mg/l	11.7	13.5	>4	A1
pH	7.4	7.8	6.5-8.5	A1
$Phosphorus_{tot}$ µg/l	-	27	-	-

A1 Simple physical treatment and disinfection needed.
A2 Normal physical and chemical treatment and disinfection needed.
A3 Intensive physical and chemical treatment and extended treatment and disinfection needed.

III DRINKING WATER NETWORK

3. Water treatment

The present water supply system of. St. Petersburg covers ten waterworks, of which the biggest five plants serve the city (Figure 2). There is no quantitative shortage of raw water, but the recommended capacity of the five city waterworks (2619 Ml/d) is 309 Ml/d less than the current mean demand and some 600 Mld below the current peak daily demand of 3220 Ml/d. As a result, even if the five city waterworks are currently operating at some 300 Ml/d above the recommended rate, the quality of the treated water is lower and peak water demands cannot be met/1/.

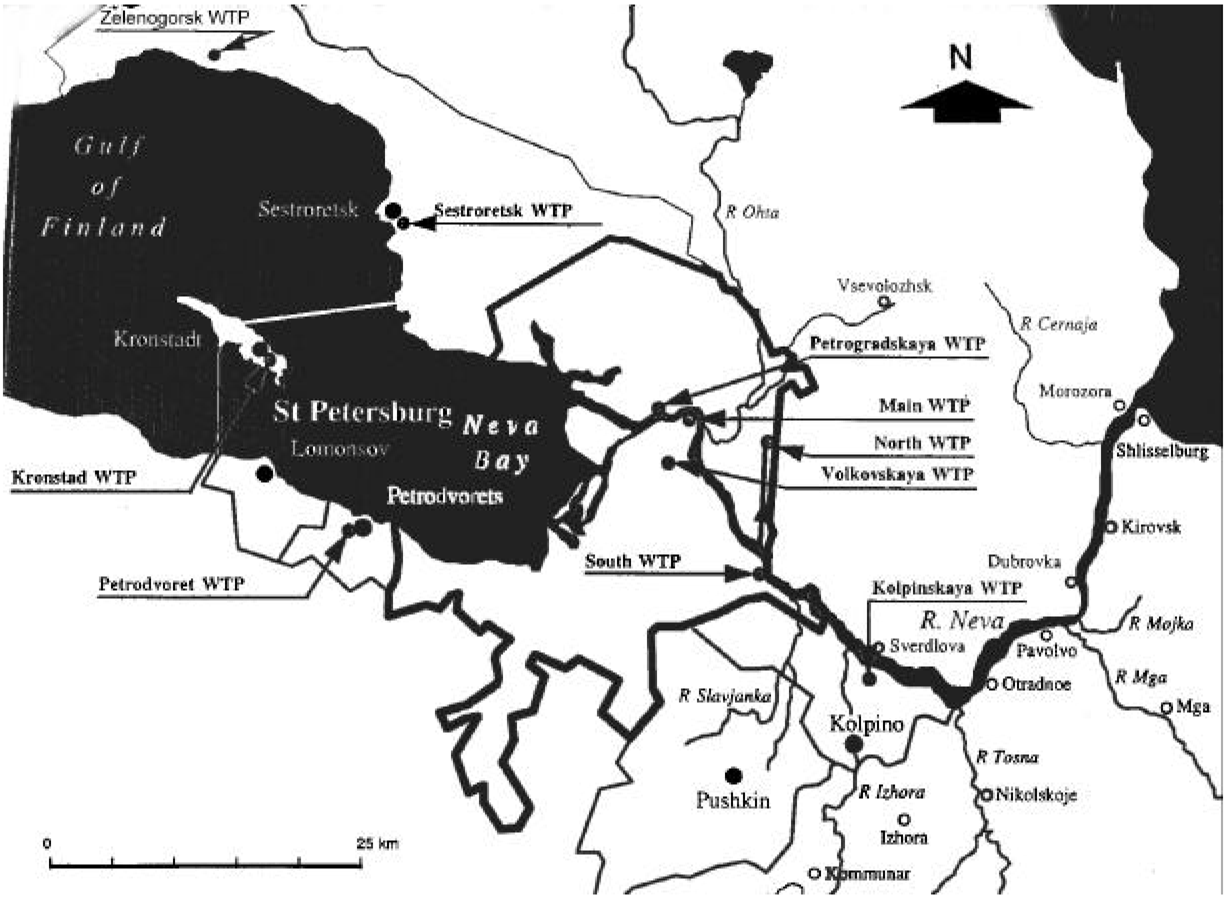

Figure 2. Water treatment plants.

Together, all ten water treatment works have a capacity of 3551 Ml/d and they operate at a current production rate of 3124 Ml/d /1/.

The following section is devoted to a summary of the individual treatment processes, capacities, intakes, chemicals used and clean water reservoirs of the five biggest water treatment plants.

South WTP Treatment capacity is 1,201,000 m^3/d. The raw water is taken from the shore of the Neva through 10 suction pipes, each of which is equipped with an electrically heated strainer. The water enters the plant through two pumping stations (a third is under construction).

The South WTP uses two different treatment processes: chemical flocculation, sedimentation and rapid sand filtration (capacity 360,00 m^3/d) and chemical flocculation with contact filtration (capacity 860,000 m^3/d).

Chlorine and ammonia are used for disinfection, aluminum sulphate as a flocculant and sometimes soda (Na_2CO_3) to elevate the pH. Polyacrylamide is used during the cold season as a coagulant aid in filtration, and in spring time potassium permanganate is added to prevent odour problems.

The treated water is stored in nine separate, clean water reservoirs with total volume of 122,000 m^3. /3 /

North WTP

Present capacity is 850,000 m^3/d. Raw water is taken from the Neva through six suction pipes with the help of an electrically heated strainer. The intake is equipped with six pumps,and the length of the raw water pressure main is 8 km.

The actual treatment process includes sieving and chemical flocculation simultaneously with contact filtration. The added chemicals correspond to those used at South WTP, except that polyacrylamine and potassium permanganate are not used at North WTP.

The treated water is stored in seven separate reservoirs with a total volume of 155,000 m^3. /3/

Main WTP Present treatment capacity is 705,000 m^3/d. The raw water is taken from the Neva through three intakes and ten suction pipes. The intakes are equipped with 14 pumps.

As is the case for the South WTP, two different treatment processes are used: chemical flocculation, sedimentation and rapid sand filtration (capacity 300,000 m^3/d) and sieving and chemical flocculation with contact filtration (capacity 405,000 m^3/d).

The use of chemicals corresponds to that of the Northern WTP. The treated waters are stored in reservoirs having a total volume of 111,000 m^3. /3/

Volkovskaja WTP Capacity is 300,000 m^3/d. Raw water is taken from the Neva through two suction pipes, and the intake is equipped with four pumps. The distance between the plant and the intake is about 5 km.

At present, the treatment process consists of sieving and contact filtration. The same chemicals are used as in the North WTP. The treated water is stored in five separate reservoirs with total volume of 65,000 m^3. /3 /

Petrogradskaja WTP Capacity is 100,000 m^3/d. Raw water is taken from the northern branch of the Neva (Bolshaja Nevka) through two intakes equipped with two suction pipes and four pumps.

The treatment process consists of chemical flocculation, sedimentation and rapid sand filtration. Chemical use is as for the

North WTP, and treated water is stored in one reservoir with a volume of 12,000 m^3. /3/

Other WTPs

In addition to these WTPs, several WTPs in suburban St. Petersburg use chlorine. Some of them are served by groundwater sources. The Kolpino waterworks has a new section (1985), and the treatment process used there is sieving and chemical flocculation simultaneously with contact filtration. The capacities of the suburban waterworks are listed in Table 2. /3/

Table 2. Suburban waterworks

Waterworks	Capacity (m^3/d)
Kolpino	325,000
Petrodvorets[1)]	90,000
Kronstad	33,000
Sestrotretsk	16,000
Zelenogorsk[1)]	15,000
TOTAL	479,000

[1)] groundwater source

Aluminium sulphate is added in at least five of the city's WTPs. /4/ Even if the quality of the treated water generally meets the requirements at the waterworks and main pipelines, there are serious problems with water quality at the tap. The parameters of treated water in some of the waterworks are indicated in Appendices 1 to 4. The drinking water quality norms are given in Appendix 5.

Chloration with chloramine works well, and the chlorine levels in the network are acceptable, but there are great microbiological risks because of the poor microbiological quality of the raw water and ineffective chemical treatment.

Inefficient algae removal negatively influences taste, odour and biological activity in the pipelines. There are also problems with excessive amounts of coagulant residues.

The treated water corrodes not only iron pipes but also copper pipes. This causes leakages, embrittlement of cast iron pipes, decreases in pipe capacities and fluctuations in water quality. High humus concentrations may act as corrosion inhibitors. The high amounts of humus substances are the main reason why 50% of the water is ineffectively filtered.

The most serious problem is the very poor hygienic quality of raw water, combined with the ineffective removal of organic material. The real hygienic risk is not coliform bacteria, but protozoa or other microorganisms. /3/

Most of the existing water treatment plants are very old, with exceptions on the southern and eastern extremes of the service area. The most common problems include corrosion of pipes and metal surfaces, failure of filter underdrains, and the fact that monitoring and control equipment is sometimes out of service. Table 3 lists some aspects of the general condition of the plants.

Table 3. General physical condition of water treatment plants /1/.

WTP	General condition	Comments
Main	Fair	Repairs of clarifiers and filters in the old lines. Problems with filter underdrains in the new lines.
South	Good	Generally good condition at both old and new treatment lines.
North	Very poor to good	Generally good condition, but progressive structural failure of line 1 and heavy corrosion in the filter pipe gallery.
Volkovskaja	Fair	Heavy corrosion, aged equipment.
Petrogradskaja	Very poor	Very heavy corrosion of structures and surfaces, outdated equipment.
Kolpino	Very good	New facility, but corrosion starting to appear in filter pipe gallery.

Petrodvorets	Good	Well maintained.
Kronstad	Good	Well maintained, but corroded pipes.
Sestroretsk	Good	Well maintained.
Zelenogorsk	Fair	Problems with disinfection system.

Water network

The total length of water pipelines in St. Petersburg was about 4510 km in 1995 /3/. The average age of the network is some 30 years, as shown in Figure 3. The distribution of materials and diameters is shown in Table 4.

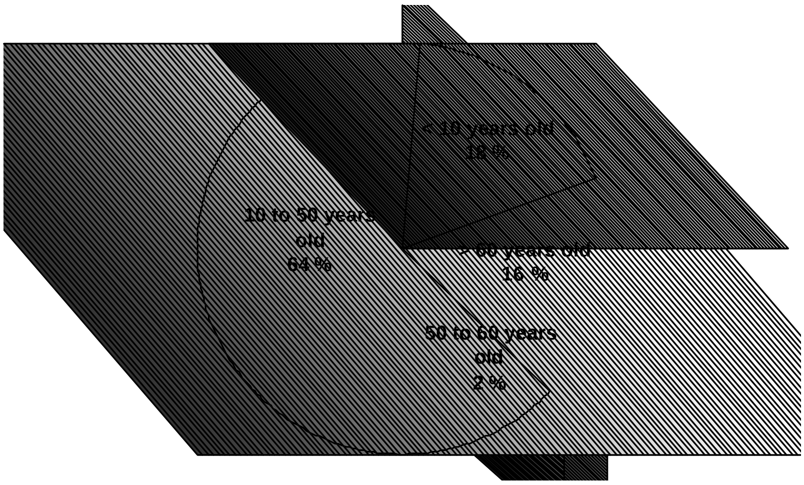

Figure 3. The age distribution of the water network of St Petersburg /1 p.2-7/.

The biggest problems in the water distribution network are water losses and the lack of sufficient water pressure and insufficient water reservoir volume. The water losses are presented in Table 5. Only 36-55% of the pumped water is actually used, and the rest is leaked and wasted. Nevertheless 2/3 of the total amount of water losses is caused by consumers, and only 1/3 of all losses are caused by the water supply system.

The main reason for the leakage in the distribution network is judged to be old and corroded water pipes. About 2600 pipeline breaks are recorded annually, and their frequency is about one for every 1.5 km, which is four times the frequency in Western countries.

Table 4. Summary of existing distribution pipe lengths by material and diameter /1/.

	Length of pipe by different material (km)				
Diameter (mm)	Cast iron	Steel	Reinforced concrete	PVC	Total (km)
800 to 1200	94	466	169	0	729
300 to 750	814	538	9	0	1360
25 to 250	1462	304	0	0.4	1767
Total (km)	2370	1308	179	0.4	3857

Table 5. Water use and losses in St. Petersburg 1992 /3/.

Water use	%	m^3/d
Real water use	45-64	1,300,000-1,850,000
Losses:		
Leakage of valves	2-4	58,000-116,000
Washing of streets	1-2	29,000-58,000
Distribution network	10-15	289,000-434,000
Heating network, hot water	10-15	289,000-434,000
After water meters		
Inside houses	6-12	148,000-321,000
Inside factories	About 7	202,000
Total losses:	36-55	1,015,000-1,565,000
TOTAL CONSUMPTION (excluding suburbs)	100	2,865,000

Reasons for water pressure problems are not only the huge water losses, but also problems and lack of automation in the pumping stations. The existing capacity of the clean water reservoirs of 792,000 m^3 is only 26% of the average daily water consumption in St. Petersburg; according to norms it should be at least 30%. In metropolitan cities like Paris and New York, the water reservoir volume is 100% of the average daily consumption/3/.

The parameters of water quality in the network are presented in Appendix 6. The average iron concentrations are clearly high, which derives from corrosion in consumer pipelines. That and sediment in pipes are also reasons for the high values of turbidity and colour /3/.

Water consumption

The water consumption in St. Petersburg has been quite stable during the last five years. The biggest water consumers are households, district heating and hot water, industry and hotels /3/. The mean daily consumption is currently about 3.20 million m^3 /5/, and the average water consumption per capita is 553 l/h/d, which is high compared to water consumption in big cities all over the world /6/.

The reasons for such high consumption and leaks in the household are the bad condition of sanitary engineering equipment, illegal connections, leaking gate valves, the system of collective water tariffs, low water tariffs which encourage uneconomical use, and bad habits of water consumers in wasting water. In addition, research shows that the Russian water meters indicate on average 20% lower values than French water meters /3/.

The long-term target in water demand management is to provide consumers with high quality drinking water at sufficient pressure and reasonable water prices. The estimated and forecast water demand data is presented in Table 6. At present, because of the low quality of the tap water, a lot of bottled water is drunk and many guide books advise against drinking tap water /7/.

The current and planned tariffs of water and wastewater are presented in Table 7.

Table 6. Water consumption /6/.

Item	1999 Estimate	2000 Forecast	2005 Forecast	2015 Forecast
Population served (millions)	4.7	4.6	4.5	4.7

Average gross per capita consumption (l/h/d)	553	548	544	506
Average domestic per capita consumption (l/h/d)	235	220	200	190
Unaccounted-for water (ufw)	23.0%	21%	18%	15%
Volume pumped to supply (Ml/d)	2600	2520	2450	2380

Table 7. Vodokanal's short- to medium-term tariff profile /6/.

Tariff Category	1999	2000	2001	2002	2003	2004	2005
Water Tariff:							
Domestic (Rbls/m^3)	0.99	1.44	2.26	2.84	3.41	3.99	4.67
Non-domestic (Rbls/m^3)	1.73	1.87	2.44	3.07	3.69	4.32	5.05
Wastewater Tariff:							
Domestic (Rbls/m^3)	0.99	1.44	2.26	2.84	3.41	3.99	4.67
Non-domestic (Rbls/m^3)	1.71	1.85	2.44	3.07	3.69	3.32	5.05

All tariffs exclude VAT, are in nominal prices and are given as the annual average

SEWERAGE SYSTEM

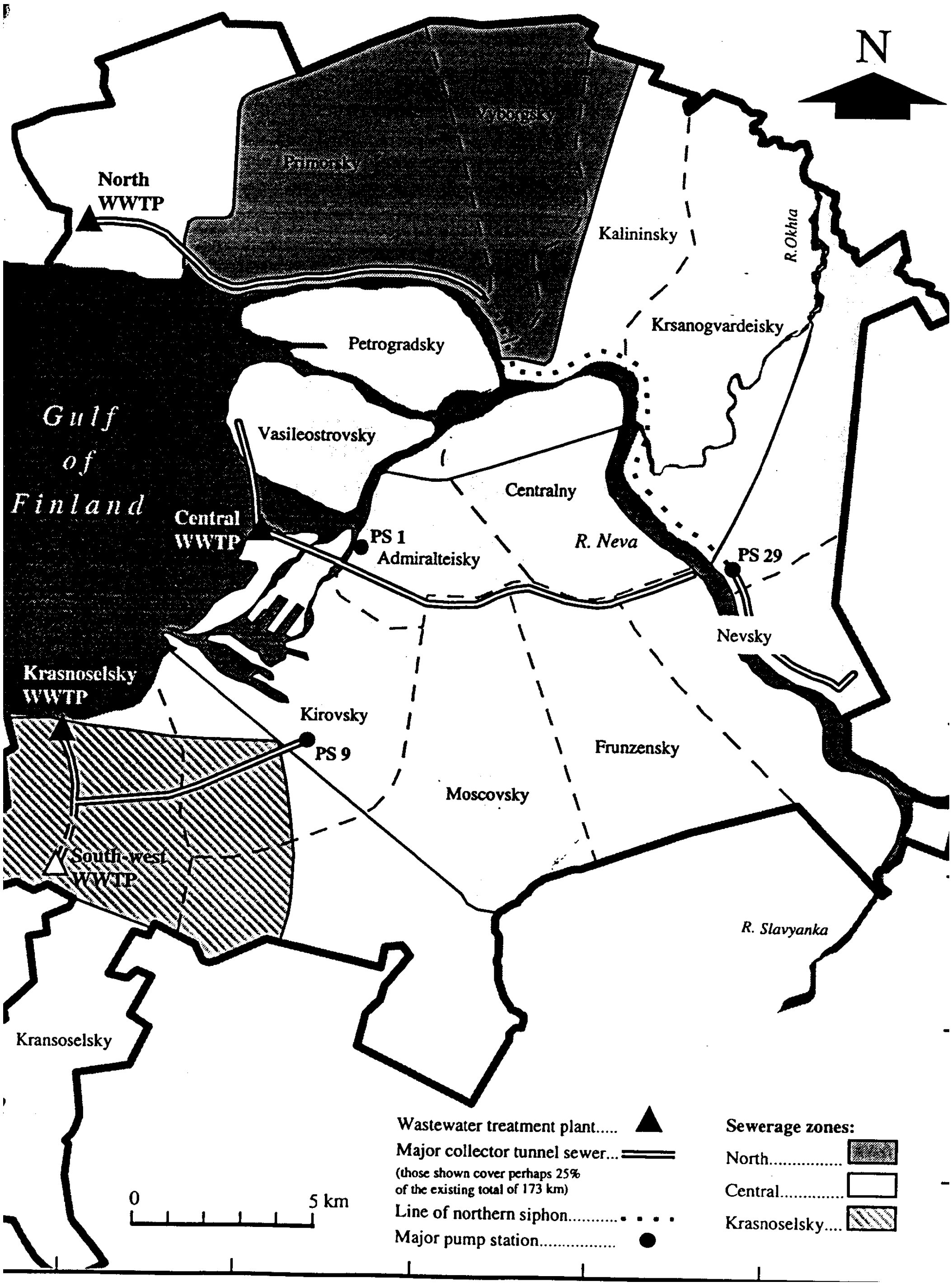

Figure 4. St. Petersburg sewerage zones /1/.

Wastewater network

There are some 5960 km of sewers, including 173 km of large tunnel collectors and 36 main pumping stations, in the city of St. Petersburg. The sewerage zones of the city centre and major tunnel collectors are shown in Figure 4, and the sewerage areas of the whole metropolitan area in Figure 6. The ages and materials of the sewerage network are given in Table 8.

1750 km of these sewers have exceeded their theoretical life expectancy, and of the almost 1200 km that are listed as defective, 103 km require urgent attention to avoid a combination of surface collapse and sewer blockage. The present rate of repairs of about 15 km per year and a similar rate of new sewer construction are not enough.

Common causes of such poor condition are not only age, but also pipe corrosion, cracks and progressive wear, ineffective joints and damaged manholes /1/.

Table 8. Materials and age of the sewerage network in the city centre /1/.

	Length by construction material (km)			Total	
Age (years)	Wood	Concrete	Other[1)]	Km	%
<10	0	881	120	1001	17
10 to 15	0	800	90	891	15
15 to 30	0	1695	142	1837	31
30 to 50	0	1203	217	1420	24
>50	2	693	118	813	13
Total (km)	2	5273	687	5962	100

The fundamental weakness of the existing sewerage network is its failure to intercept 384 direct discharges /1/. The majority of direct discharge points is in the historical centre of the city, with its listed masterpieces of art and architecture of world importance. This is a factor that makes the reconnection of those discharge points more difficult /8/. 206 of these points are fed by the Vodokanal network (overflow because of insufficient treatment capacity) and 178 points by industrial enterprises and non-sewered areas /1/.

Of the total volume of 3.5 million m^3 of wastewater generated in the city each day, about 830,000 m^3/d is discharged without treatment. The pollutant terms are summarized in Table 9. This is a large injection of pollutants, which also include harmful heavy metals derived from the electroplating and other industries /1/. The share of industrial wastewater is rather high, 35-40%, and this causes problems in the wastewater treatment and use of sludge /5/. The distribution of direct discharge points by district is shown in Figure 5, and the parameters of raw wastewater in Table 10.

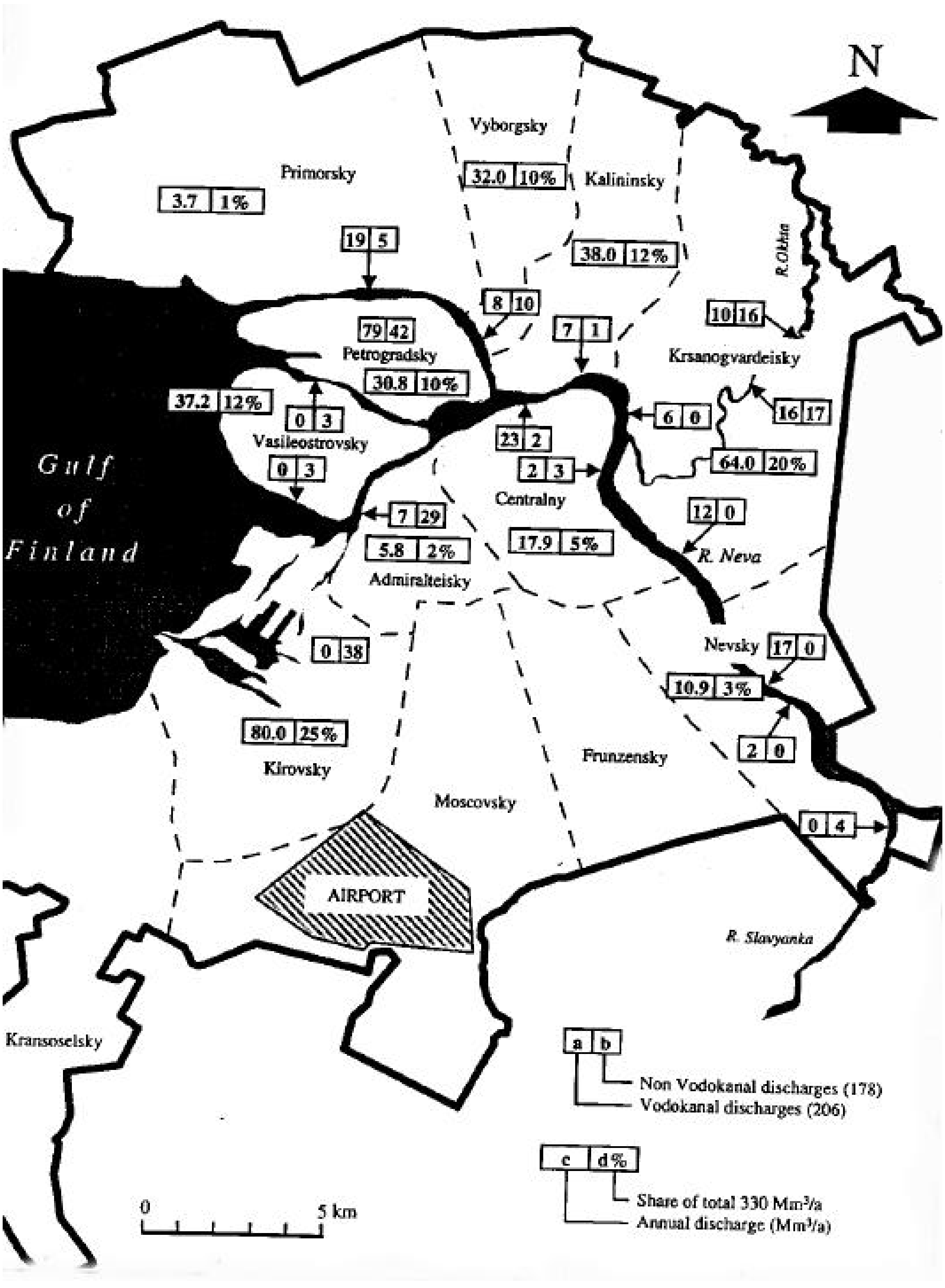

Figure 5. Distribution of untreated direct discharges into the Neva River system 1996 /1/.

Table 9. Discharges into the Gulf of Finland (1995) /1/.

Source of discharges / treated wastewater	Flow (Mld)	BOD_5 (t/a)	Total phosphorus (t/a)	Total nitrogen (t/a)
Direct discharges	831	10,390	237	6083
Pumping station Nr 1	385	11,257	590	3770
Bypasses from Krasnoselsky WWTP	50	1462	77	490
Wastewater treatment plants	2226	3064	1052	9110
Total	3492	26,173	1956	19,453

Table 10. Incoming pollution loads at the municipal wastewater treatment plants 1992 and 1995 /1/.

	Loads (t/a) and flows (Mm^3/a)		Change
Item	1992	1995	%
Flow	864	828	-4%
BOD	293,000	89,600	-69%
SS	470,300	200,600	-57%
Nitrogen	34,800	22,200	-36%
Phosphorus	20,600	3500	-83%
Ammonia	12,100	10,200	-16%
Chromium	897	361	-60%
Cadmium	19	12	-37%
Lead	209	56	-73%
Copper	414	67	-84%
Zinc	565	260	-54%

Wastewater treatment

There are seven wastewater treatment plants in the city area and 12 more in the suburbs (Figure 6.) The sizes of three of the seven city plants are from medium to large with a total designed capacity of 2820 Ml/d and the four smaller plants operate at a capacity of 2.3 Ml/d. The total quantity of wastewater in the city center sewerage area is 25% more than the designed capacity. /1/.

The lack of sufficient capacity is partly caused by the incomplete North siphon collector (the North WWTP is 50% operational) and the construction work being done in the

Southwestern WWTP. Because of this work, the Krasnoselsky WWTP is totally overloaded and Pumping Station Nr 1 has to pump wastewater directly into the Gulf of Finland; Table 9.

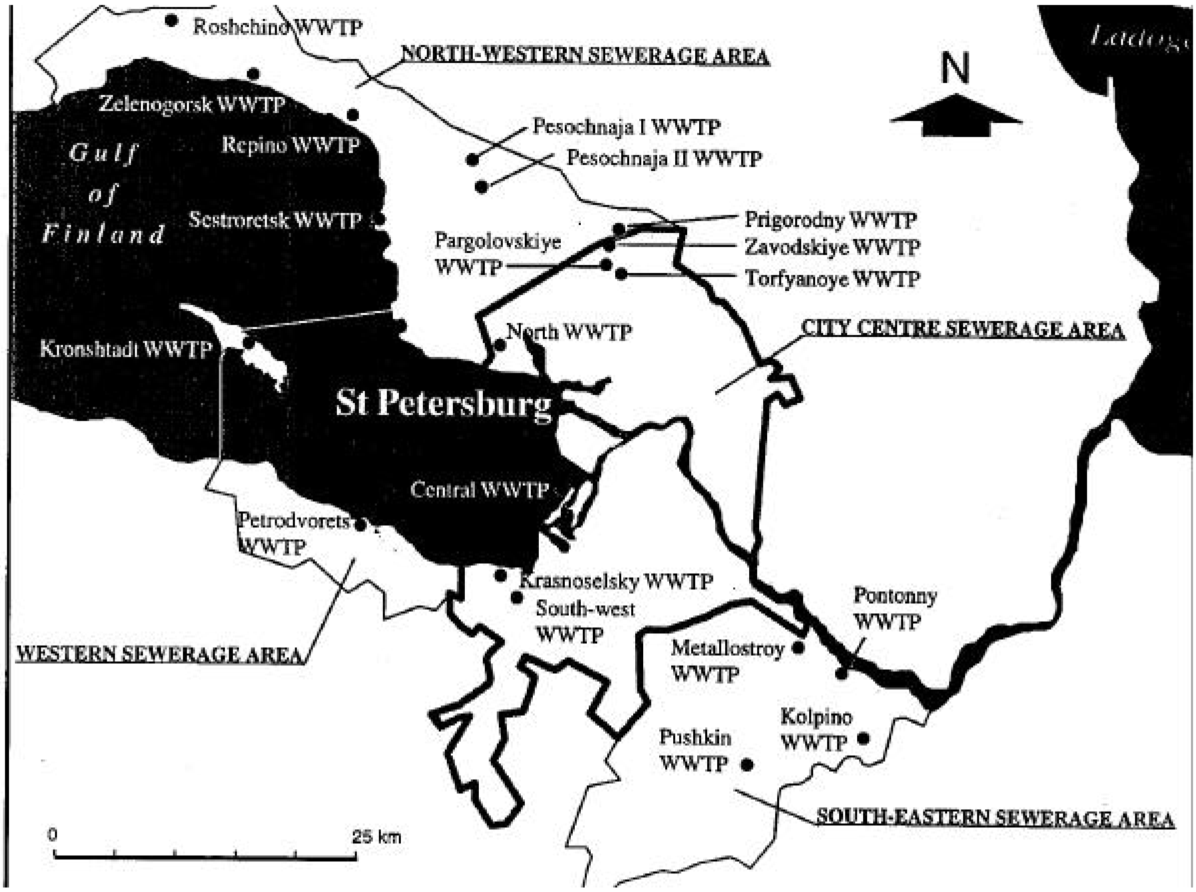

Figure 6. Wastewater treatment plants and sewerage areas in the St. Petersburg metropolitan area /1/.

With the exception of the western area, the capacity of suburban wastewater treatment plants is sufficient. The main question is whether it would be more cost-effective to reduce the numbers of such small works by interconnecting them.

The treatment process at the large- and medium-sized WWTPs follows a similar four-stage pattern: inlet pumping station – mechanical grit removal – biological treatment using activated sludge methods – and sludge treatment (Figure 6). At the smaller treatment plants, the activated sludge process is generally being replaced by trickling filters.

The water content of surplus sludge from the main city WWTP is being reduced by centrifuges before transportation to one of the two sludge deposit areas. The South area, over 51 ha large, is situated 33 km south of the Central WWTP, and it is now full, as it contains some 2.5 million m^3 of sludge. The Northern area, 20 ha large, now contains about 1 million m^3 of sludge. Volumes of sludge produced at the WWTPs vary between 1200 m^3/d and 1700 m^3/d, requiring about 300 daily lorry loads to remove it.

This kind of arrangement constitutes a serious environmental risk. Because of the industrial enterprises connected to the municipal sewer system, the sludge contains high concentrations of heavy metals, and it is not suitable for agricultural purposes. For this reason, Vodokanal's policy is to incinerate the sludge, and the first incineration plant is under construction.

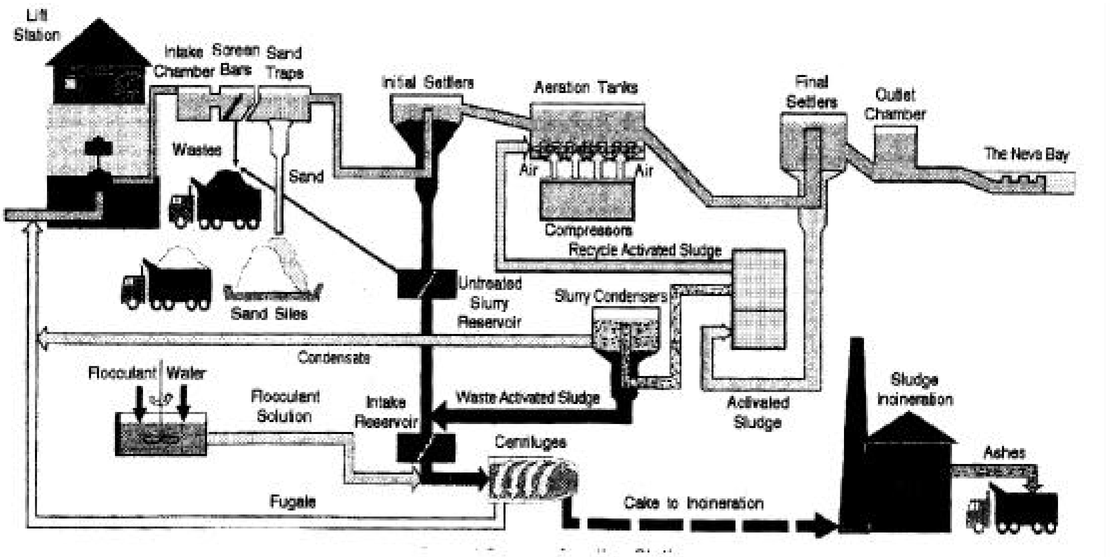

Figure 7. Wastewater treatment at the Central Sewage Aeration Station /5/.

A common problem of wastewater treatment is the insufficient hydraulic capacities of the pre-treatment units. In order to meet the future total nitrogen and phosphorus removal requirements, structural, mechanical and process changes must be made at aeration basins, sludge pumping stations and at the control centre of the whole aeration system. In addition, secondary sedimentation must be extended in order to meet those requirements. The sludge treatment at the middle-sized suburban WWTPs must be improved. Incineration is considered the only feasible solution for final disposal of the sludge at the largest WWTPs.

At the two large WWTPs (Central and North) the loading of effluents exceeds the limits of the HELCOM (Helsinki Commission) for BOD_7 and phosphorus removal, and in both cases the amount of total nitrogen is only 10% above the limit. Generally, the quality of treated effluent appears to be close to the HELCOM standard, except for the removal of nitrogen. Because of the large amount of direct discharges and the current inadequacy of WWTPs, the total effect of treatment is far below those standards.

Recipient

About 70% of the wastewater load entering into the Gulf of Finland is from St. Petersburg and the Neva. The WWTP outlets are directed straight into the river or into the Neva Bay. The enormous flow of the Neva is a positive factor for the city. The river water changes once a week, and the dilution of the nutrients is effective.

The wastewater from St. Petersburg and the river water mix in the Neva Bay, and in summer most of the pollution load stays in the bay or enters into the eastern part of the Gulf of Finland, which functions as an effective filter. In winter, the situation changes. The wastewater load from the city of St. Petersburg spreads into the Gulf of Finland, extending even to the western parts. /2/

References

1. Vodokanal of St. Petersburg, St. Petersburg Long-term Water Sector Development Programme, Synthesis Report, June 1997.

2. Heli Saavalainen, Pietarin jätevedet ruokkivat itäistä Suomenlahtea, HS 4.7.1998, B1.

3. Vodokanal of St. Petersburg, Water Sector Development Programme, Final Report of Water Sector Short-Term Development Project, December 1995.

4. Tuomo Heinonen, Asiantuntijavierailu Pietariin 27.-31.5.1996, Muistio, Helsingin kaupungin vesilaitos, 18.6.1996

5. Krasnoborodko, K.I., Alexeev, A.M., Tsvetkova, L.I. & Zhukova, L.I., The Development of water supply and sewerage systems in St. Petersburg, EWM, Volume 2, Number 4, (August 1999), pp.51-61.

6. Vodokanal of St. Petersburg, Corporate Development Plan, 17 June 1999, pp.29-52

7. Matti Iikkanen, Pietarin vesihuollon investointiohjelma, Plancenter Ltd

8. Karmazinov, F.V., Main activities of SUE Vodokanal of St. Petersburg aimed to decrease pollutant discharge to the Gulf of Finland, Report, 23.4.1998