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Waste water treatment in Lithuania from 1950 to 1990

This article presents the history of Lithuanian waste water purification, including a description of the types, construction years and numbers of different treatment plants built in Lithuania during the period 1950-1990. At present over nine hundred WWTPs operate in Lithuania, most of them biological treatment plants. Several types of waste water treatment facilities, including mechanical treatment plants, physicochemical treatment plants, biofilters, activated sludge plants, oxidation ditches, biological ponds and filtration fields, were built in Lithuania during this period according to the regulations coming to Lithuania from the State Committee on Building and Architecture of the Council of Ministers of the former USSR, located in Moscow. The regulations for the construction of WWTPs were technological standards (rules and norms), although Lithuanian engineers had to adapt them to local conditions and the construction work was done creatively. Subsequently, the first - simple - separate facilities such as mechanical and physicochemical treatment plants and other primary treatment facilities were introduced in the 1950s, including such popular solutions as settling or septic tanks. Biofilters were the first small-sized biological WWTPs, built from the 1950s onwards. Later, activated sludge and oxidation ditches were preferred and were ultimately used almost everywhere.

According to the available monitoring data on BOD5, COD, total nitrogen and total phosphorus between 1960 and 1990, the water quality in most rivers of Lithuania remained moderately polluted and only four little rivers can be classified as heavily polluted. On the other hand, due to the operation of WWTPs the pollution level has diminished in five large Lithuanian rivers.

INTRODUCTION

Waste water treatment technologies are well represented in handbooks and textbooks. Historical surveys of the introduction, development and improvement of waste water management are scarce, with only a few exceptions [1, 2, 3]. Even retrospective data regarding WWTPs are rare and just commonly available since 1980 in European environmental statistics [7, 8]. Information in English on the long-term development of waste water treatment in the Eastern European countries is especially scarce. Some of the literature concerning former Soviet republics is even misleading. For example, the European Environmental Almanac published by Earthscan (1995) states on the pollution situation of Lithuania that Lithuania's "major cities have no sewage works" [7].

The Republic of Lithuania is a small country with an area of 65,000 km^2 and a population of 3.7 million. It is relatively urbanised, as more than half of the population lives in towns. The five largest towns are the capital Vilnius, Kaunas (the former capital before World War II), Panevezys, Siauliai and Klaipeda harbour (Figure 1). Lithuania is a country characterised by rivers. According to a widely used international classification, the two largest rivers, the Nemunas and the Neris, are medium-sized rivers, and the others are little rivers. Hence pollution of rivers has been one of the most significant environmental problems in Lithuania. Most of these problems are related to insufficient waste water treatment. The worst pollution is concentrated in the catchment areas of the Nemunas River and of some rivers in North Lithuania. The problems being faced today are mostly inherited from the era of Soviet rule (1939–1990), when Lithuania was occupied. Most existing waste water treatment plants were built under Soviet waste water treatment regulations.

This article provides a historical overview of the development of waste water treatment in Lithuania. It attempts to determine whether general technological trends in the introduction of different types of WWTPs in Lithuania and in countries of Western Europe and in the former Soviet Union can be found. The number of WWTPs built, their type, capacity and general technical standards or specifications from 1950 to 1990 are presented. Data on waste water discharges and the pollution situation in Lithuanian rivers are also reviewed. The article is based mainly on original sources and literature, and it attempts to give the first systematic presentation of the history of waste water purification technology in a former Soviet republic.

DEVELOPMENT OF WASTE WATER TREATMENT IN LITHUANIA

General data on the construction of waste water treatment plants (WWTPs)

Waste water treatment facilities were introduced in Lithuania, as in all the former Soviet Union, during the 1950s. At that time, biofilters were the first biological WWTPs constructed. Since then, 928 different WWTPs have been built [4, 6]. According to the National Report issued in 1990, Lithuania had then 819 operating waste water treatment plants [6]. However, it is difficult to give precise figures to describe the historical development, because respective ministries had their own classification system for different plants and some older types of WWTPs have been omitted in the more recent statistics [4, 5, 9]. The problem is

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Figure 1. Major rivers and cities in Lithuania

of current interest because several classification systems for WWTPs still in use in the world are based on

i) biomass distribution in bioreactors
ii) rates of processes
iii) steps of treatment within a larger complex of facilities, and other factors [2, 17, 18].

The classification of WWTPs in registration documents of the Lithuanian Environmental Protection Ministry was done simply: In the 1990s the mostly aerobic WWTPs were classified, and every classified type had its own code number (Figure 2) [4, 6].

The first WWTPs installed in Lithuania, as in the whole territory of the USSR, were small. At the beginning they were constructed in rural areas, small towns, and in individual industrial enterprises as local treatment facilities. The building standards, issued by Moscow (State Committee on Building Affairs of the Council of Ministers of the USSR) in 1961, already included instructions on planning (design) of the outdoor sewerage of industrial enterprises [11]. Those standards had even detailed regulations for mechanical treatment facilities for petroleum refineries and food production and processing plants and for other types of industrial waste water treatment [11]. Only later, according to general five-year building and development plans in the USSR, waste water treatment plants of a larger capacity were built in the cities. Figure 3 provides an overview of the location of WWTPs built in Lithuania. Table 1 summarises the numbers of the different types of WWTPs built in 1950-1990. According to older statistics, 138 WWTPs for industrial and municipal waste water treatment were built in Lithuania before 1961 and 765 before 1985, so the total number of WWTPs increased fivefold [9]. Information presented in a document of the Environmental Protection Ministry in 1990 shows different numbers of WWTPs built before 1961 and 1985 (Table 1) [4]. The number of WWTPs having a capacity of over 100 cubic metres per day is 78 plants in 1950-1970 and 625 in 1970-1990. Most treatment plants were biological: Out of 928 plants built, 772 were biological.

In addition to municipal waste water treatment plants, individual industrial enterprises also have waste water treatment facilities. For example in Vilnius thirty-three factories had their own local WWTPs in 1990 (including mechanical or physicochemical treatment only and biofilters) [4]. Most of them directed treated water into the municipal sewerage system, but seven plants discharged treated waste water directly into the Vilnia River [4].

Biological treatment

In Lithuania biological treatment has been the most commonly used waste water treatment method (Figure 3). In the following section, the adoption of biofilters, filtration fields, oxidation ditches and activated sludge treatment in Lithuania is described more detailed.

Biofilters were the first waste water treatment technologies developed in Western Europe, starting since 1890 as a contact filter process [1]. They were called percolating beds (in Europe) or trickling filters (in the United States), and further development of high-rate trickling filters with recirculation of treated waste water took place about the 1930s [1]. Biofilters were the first biological WWTPs to be built in Lithuania, mostly in 1960-1970, about ten years

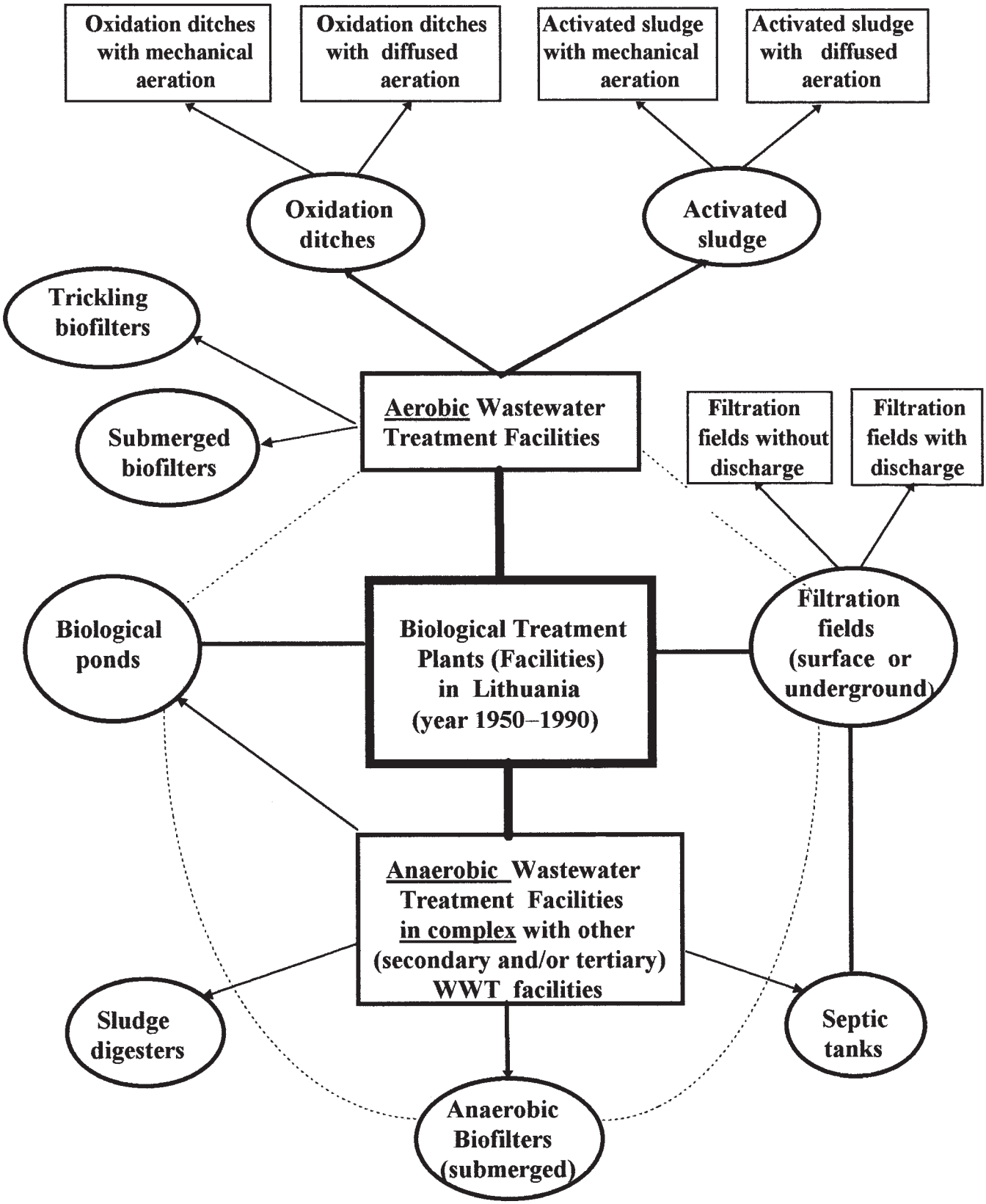

Figure 2. Types of wastewater plants (WWTPs) in Lithuania, listed in the report of Environmental Protection Ministry, and codes of WWTP registration in 1989 [4, 19]

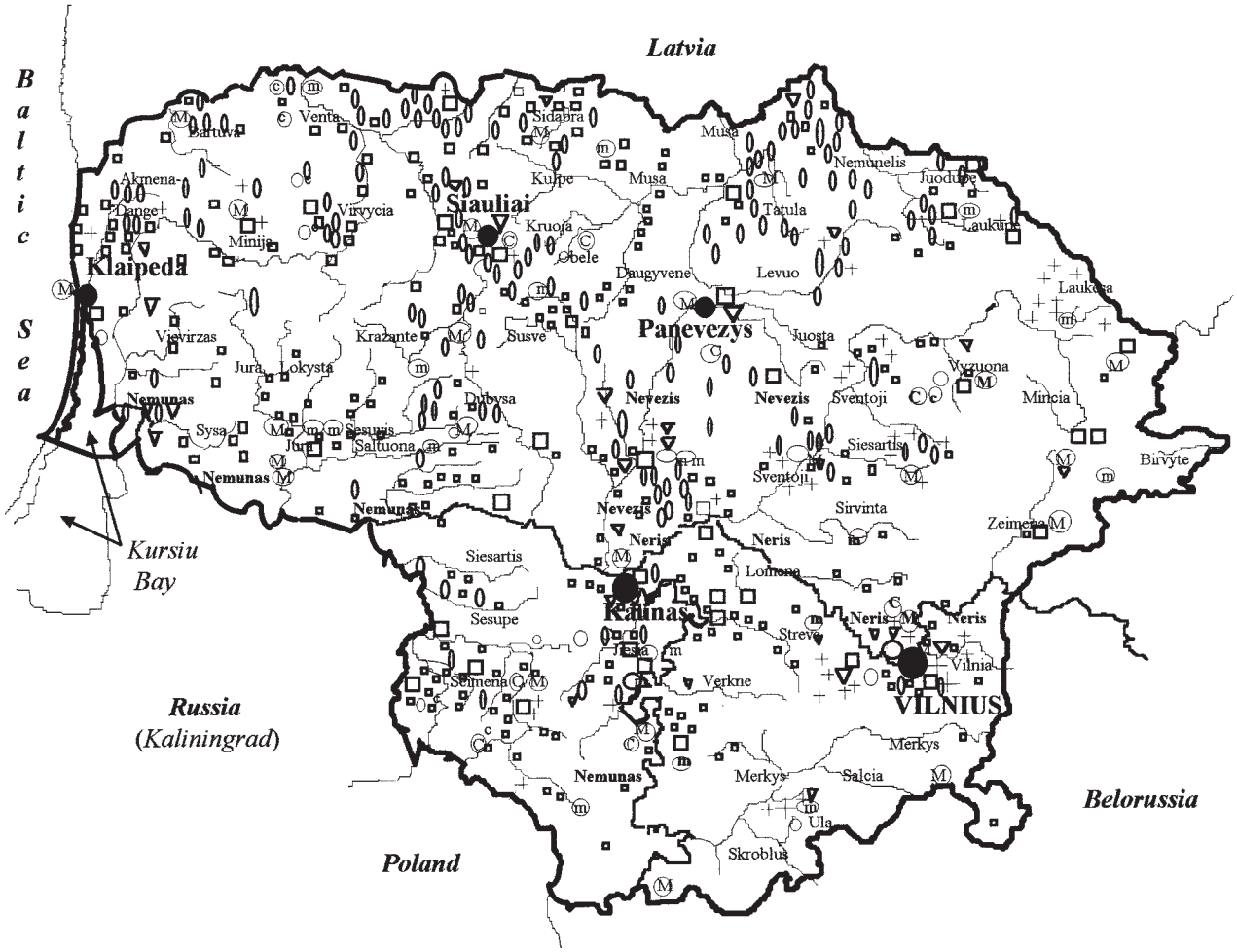

Figure 3. Location of WWTPs having capacity over 100 m³ per day built in Lithuania up to 1990

Abbreviations: □ and ▪ - Activated sludge (having capacity of 1,000 and 100 m^3 per day, respectively);
() and 0 - Oxidation ditches (capacity of 1,000 and 100 m^3 per day, respectively);
▽ and ▾ - Biofilters (capacity of 1,000 and 100 m^3 per day, respectively);
┼ and + - Filtration fields (capacity of 1,000 and 100 m^3 per day, respectively);
◯ and ○ - Biological ponds (capacity of 1,000 and 100 m^3 per day, respectively);
Ⓜ and ⓜ - Mechanical treatment (capacity of 1,000 and 100 m^3 per day, respectively);
Ⓒ and ⓒ - Physico-chemical treatment (capacity of 1,000 and 100 m^3 per day, respectively).

Remark: due to the small scale the marks of numbers of the same type of WWTPs (such as Ⓜ$_8$ or □$_4$) in separated towns are omitted.

Table 1. Chronology of wastewater treatment plant building in Lithuania during 1950–1990 [4]

Year	Number of wastewater treatment plants (WWTP) be built during the period of 1950–1990									
	Activated sludge	Oxidation ditches	Biofilters	Biological ponds	Filtration fields	Other types of biological treatment	Mechanical treatment	Physico-chemical treatment	Total numbers of WWTP	
									Biological	All types
1950*	0	0	1	0	0	0	0	0	1	1
1955*	0	1	2	0	0	0	0	0	3	3
1960*	1	0	4	0	3	0	3	3	8	14
1965*	8	2	12	0	8	0	14	5	30	49
1970*	20	23	12	0	12	6	15	7	73	95
1975*	92	28	4	0	12	6	15	7	162	206
1980	133	67	1	3	32	30	16	23	263	302
1985	94	38	0	3	18	14	11	13	170	194
1990	48	3	0	7	3	1	0	2	62	64
Total	**396**	**162**	**36**	**13**	**97**	**68**	**88**	**68**	**772**	**928**

*-In 1975 small plants as septic tanks were excluded from WWTPs general list; review on WWTPs state of year 1985 [9].

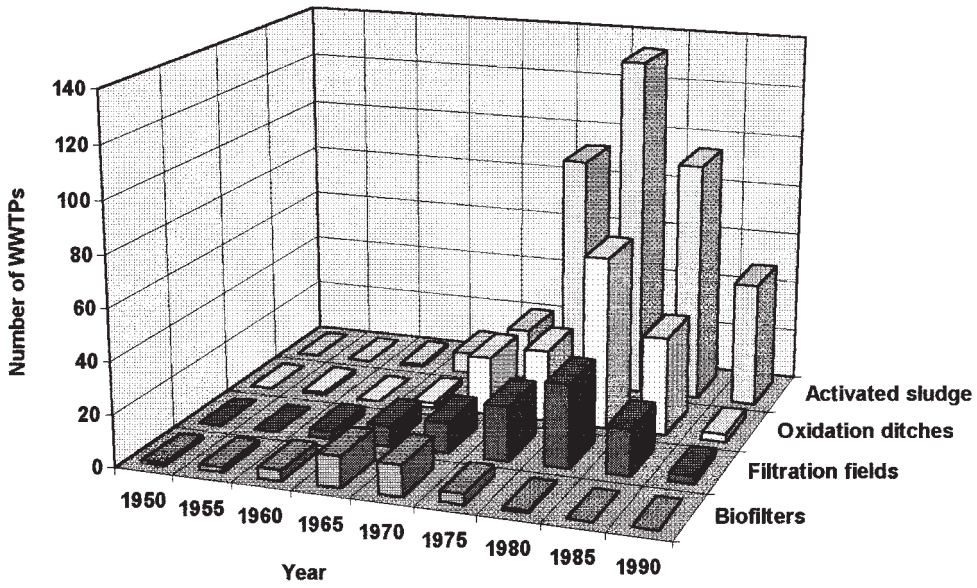

Figure 4. Number of biofilters, filtration fields, oxidation ditches and activated sludge facilities that were built in the period of 1950–1990 in Lithuania

earlier than activated sludge plants (Figure 4). Altogether thirty-six biofilters were built before 1990. They had capacity/loading rates of up to 500 m^3 per day, relatively small compared to those of activated sludge plants [4]. Such positive features of biofilters as low energy demand and low maintenance costs contributed to their early popularity. After Dow Chemical Company popularised the use of plastic media in biofilters in Europe in 1953, these improvements in biofilter technology also came to the USSR and to Lithuania [1, 11]. The first recommendations and rules on the construction of biofilters were issued in Russian in 1961 [11] and in Lithuanian in 1966 [21]. Biofilters were recommended for industrial and domestic/municipal sewage treatment. Trickling filters with stone or plastic type beds, i.e. aerobic WWTPs, were presented mainly in the technical standards literature [11].

Filtration fields were built especially in the 1970s and 1980s (Figure 4). Their total number was 97 [4]. Russian technical standards literature on filtration fields was published in 1965-1967, including a comprehensive description of an anaerobic septic tank facility [12]. Underground filtration fields were built with sand and gravity filters and usually had a capacity of up to 15 m^3 per day [12, 19]. Rarely used surface filtration fields were also described in the literature. They had a capacity of from 55 up to 250 m^3 per day, depending on the soil characteristics [19]. Usually septic tanks were connected with the use of underground filtration fields [12]. Filtration fields were recommended and used as waste water treatment facilities for local municipal sewerage as final treatment in combination with primary waste water treatment in septic tanks, biological ponds or simply primary settling tanks (two-floor settling tanks) [12, 19].

Oxidation ditches were widespread (Figure 3). A total of 162 oxidation ditches was built in 1965-1990, most of them were built in 1975-1980 (Table 1, Figure 4). The late introduction of oxidation ditches may be connected with the fact that the method was developed relatively late, in 1959, in The Netherlands by A. Pasveer [16]. The literature of technical standards for the construction of oxidation ditches was published in Russian in 1974. The oxidation ditches were used for complete biological treatment of waste water with mechanical aeration [14]. The oxidation ditches had a capacity of up to a thousand cubic metres per day. Some had also diffused aeration, despite the guidelines given [4, 6].

By 1990 396 activated sludge plants had been built in Lithuania, and 311 of them had a capacity of more than a hundred cubic metres per day [4, 6]. Hence activated sludge is today the commonest biological purification method in Lithuania (Table 1, Figure 4). Most activated sludge plants were built in 1975-1985. Ninety-four used diffused aeration (built in 1975-1980) and thirty-nine (built in 1980-1985) used mechanical aeration [4, 6]. Only four plants with a higher capacity (over 1,000 m^3/day) were built in 1950-1970 [4, 6]. The construction of larger plants (over 10,000 m^3/day) was begun after the 1970s (Table 2). Activated sludge facilities were planned and built to treat large quantities of sewage water. According to Soviet technical literature, recommendations for their capacity were up to a thousand cubic metres per day in small towns or regional centres and more than a thousand cubic metres per day in urban areas. Until 1967 the required capacity was traditionally calculated based on the number of citizens in a given area multiplied by the standard consumption of water (about 150 litres per day), and later by a population equivalent (PE) (Table 3) [12, 13]. Analysis of Russian and Western Europe technical literature on aerobic waste water treatment revealed that all conventional/traditional types of activated sludge plants came to the former Soviet Union following similar technical projects introduced already in other countries. We would like to mention a few modifications of activated sludge plant types for which the year of introduction is known:

1) Corridor type activated sludge with diffused aeration were introduced in Europe after the 1920s and later in the USA;
2) Activated sludge with secondary clarifier were built inside the same waste water treatment facility, developed by Kalinske in 1940s;
3) Series of aeration tanks of "step aeration" or "step loading" were introduced in 1942 (New York City's first WWTPs),
4) The Kraus process (complex of tanks having separate tank for prolonged aeration of digester overflow with part of return sludge) were introduced in 1945/46;
5) Anoxic reactors (for denitrification) in the whole system of

the activated sludge process were developed in the UK (1937), the USA (1960s), in South Africa (1970s) and later, after 1976, by Matsche and others [1,30,31].

According to Russian authors, WWTP leading technologists Karelin et al., in Western Europe about 1970 the building of activated sludge reached the first place compared with other types of WWTPs [10].

One of the oldest activated sludge plants in Lithuania having a relatively high capacity (40,000 m^3/day) was built in Siauliai in 1967, where expanding industry (military and tanneries) discharged waste water containing heavy metals, which caused problems for its biological purification and effluent control. In the second largest city, Kaunas, an activated sludge plant began to operate in 1978, but its capacity (20,000 m^3/day) did not meet the requirements of the growing city [9]. In the capital, Vilnius, the building of a municipal waste water treatment plant started as late as the 1980s. In 1986 a mechanical treatment facility was completed (capacity 600,000 m^3/day) while an activated sludge process was not taken into use until 1996 (capacity 420,000 m^3/day). The situation is also satisfactory in Panevezys where an activated sludge plant was built in 1989. Its capacity is 70,000 m3/day and its treatment efficiency satisfies the effluent water quality standards.

Russian technological textbooks and handbooks on activated sludge plant types and construction modifications appeared in the 1980s in the USSR and Lithuania [10, 19]. Russian literature on WWTPs technological standards up to 1974 mostly included older technical modifications, except for the latest anoxic reactor descriptions and some others [14]. Early recommendations in the literature on technical standards for activated sludge plants were to build activated sludge tanks (oxytanks) with secondary clarifiers for industrial and domestic waste waters mixture treatment and activated sludge tanks in one facility, with sludge exclusion in case of non-toxic sewage [14, 15]. The Environmental Protection Ministry (EPM) of Lithuania generally classified the activated sludge plants only according to the type of aeration, i.e. mechanical (surface) and diffused (pneumatic) aeration tanks [4].

The benefits of activated sludge, compared with other modes of purification, were as follows: The construction was simple, it had a relatively better ability to accept shock loads and a relatively better removal of helminths and viruses [2, 8].

Table 2. Activated sludge of the highest capacity (according to the projects), to be built in Lithuania up to 1990

Capacity of plant (m^3/d)	Place/city of building	Year of completion
10,000	Plunge town	1980
10,000	Rokiskis town	1982
10,000	Akmene (cement/concrete factory)	1974
18,240	Ignalina	1978
18,800	Taurage Town	1976
20,000	Kaunsa city	1978
24,000	Telsiai town	1985
25,000	Alytus town	1973
25,000	Marijampole town	1973
26,000	Utena town	1986
37,000	Kedainiai (Biochemical Plant)	1987
40,000	Siauliai city	1967
45,200	Mazeikiai (Petroleum Refinery Plant)	1979
70,000	Panevezys city	1989
600,000	Vilnius city (Only first step – mechanical, physicochemical treatment)*	1986

* Project confirmed in 1966; first biological treatment started in 1996. Real volume of city's wastewater that needs to be treated today form only 0.5 of total capacity of this WWTP. Capacity of the secondary (biological/activated sludge) treatment of Vilnius WWTP is 420,000 m^3/day.

Table 3. Permissible Concentrations (Average Annual and Maximum at the Moment) of Polluting Substances* (in mg/l) in treated wastewater discharged into surface waters

	Average Permissible Annual Concentration, *(mg/l) or [Maximum Permissible Concentration, MPC, *(mg/l)]				
	The Size of Wastewater Treatment Plant				
Parameter	<5 m^3/day	5 m^3/d –5,000 PE**	5,000 PE- 10,000 PE <10,000 PE	>10,000 PE (<100,000 PE)	≥100,000 PE
BOD7	30 [50]	25 [40]	20 [30]	15 [25]	
COD			100 [150]	75 [120]	
Total P				1.5 [2.5]	
Total N				20 [35]	15 [25]
Suspended Solids				30 [45]	25 [35]

*The norms depends on the size (capacity) of wastewater treatment plant;

**The meaning of Person Equivalent is a rational number of persons; it is calculated using norms: for 1 person per day: BOD7 - 70 g; Suspended Solids - 70 g; Total nitrogen - 12 g; Total phosphorus - 2.7 g.

In addition, at that time electricity was cheap in the USSR. From the 1970s onwards more activated sludge plants were built in Lithuania and in the USSR than plants of other types [4, 10]. As a result, the attention was so concentrated on the development of these technologies that most specialists forgot the good points of other biological treatment methods.

WATER QUALITY, WASTE WATER DISCHARGES AND ENVIRONMENTAL PROTECTION

Regulations for water quality and waste water treatment

Separate water quality standards, i.e. the maximum permissible concentrations (MPC) of chemical substances, existed in the former USSR and Lithuania SSR for

1) fishery in fresh water (a) and the sea (b)
2) household and recreational use
3) drinking water
4) waste water that needs to be treated biologically, and
5) industrial waste water of recycling (recirculation) systems having partial treatment for some industrial production types [22, 23, 24].

As a rule, water quality standards, WQS, especially for surface waters, were of the following types: general (COD, BOD_5, total nitrogen, total phosphorus, etc.), specialised (for individual inorganic and organic compounds) and bacteriological. From 1968 up to 1990 the general classification of river water quality was based on BOD_5, total phosphorus, total nitrogen and bacteriological parameters, and classified into five categories. We present here an example of a simple classification using BOD_5 as a determination parameter: [28, 29]:

I clean water (natural state): $BOD_5 \leq 2$ mg/l (xenos-aprobic and oligosaprobic zones);
II slightly polluted: $BOD_5 \leq 4$ mg/l (suitable for recreation purposes; oligosaprobic zone);
III moderately polluted: $BOD_5 \leq 8$ mg/l (β-mezosa-probic zone);
IV heavily polluted: $BOD_5 \leq 18$ mg/l (α-mezosaprobic zone);
V extremely polluted water: $BOD_5 > 18$ mg/l (polysa-probic zone).

The first regulations in the USSR containing systematic standards for waste water discharges were issued in 1957 and 1961 [11]. These compilations of technical regulations were published in Lithuanian in 1966 [21]. At that time, recommendations for activated sludge plants were given in BOD_5 values, depending on the capacity of the plant. The water treatment standard was up to BOD_5 =15 mg (or 20 - 25 mg) O_2/l [21], which corresponded to heavily or extremely polluted water, respectively, according to the conventional surface water quality classification system (i.e. using a category of the saprobic zone it would be class 6 - polysaprobic zone). Finally, quality standards (or MPC) for effluents were published in 1996 in the Environmental Normative Document LAND 10 - 96 (Table 4). The effluent standards for specific organic (anionic and non-ionic detergents, phenols, petroleum products, oils and fats) and inorganic (heavy metals, and such anions as cyanides, chlorides, sulphates, total chlorine, etc.) substances, and general regulations for waste water discharges (temperature, pH, colour, smell, transparency, mineralisation, toxicity, etc.) were also published [13]. Most of these quality standards reflected older standards of the Soviet period.

Waste water discharges and capacity of WWTPs

Water consumption data are available in a few statistical publications in Lithuania [25, 26, 27], and their analysis shows that electric power plants (EPPs) use the largest part of the total abstracted water. For example, in 1985 EPPs used 70% of the abstracted water compared to a community use of 13.08%. In 1990 the EPPs used 79% of total abstracted water. Two EPPs (the Ignalina and Kruonis plants) are the largest recirculatory systems discharging water that does not require treatment [25,26,27]. Unfortunately, in the National Report of 1992 this amount of water was included as the total amount of waste water [5]. From 1985 to 1990 the total water consumption increased. In 1990 the total water consumption was $4{,}285.5 \cdot 10^6$ m^3/year, but the water consumption by communities was only $403 \cdot 10^6$ m^3/year and by industry $179.8 \cdot 10^6$ m^3/year. The annual municipal water consumption decreased from 403 million m^3/year in 1990 to 196 million m3/year in 1995, and industrial use has diminished drastically: from 277 million m^3/year in 1989 down to 49 million m^3/year in 1995. The reasons for such changes were a) the decline of industrial production in Lithuania, b) the worsening of the economic situation of the people and c) increases in the price of drinking water throughout this period.

Official statistical data on the amount of waste water in

Table 4. Wastewater Discharges into Surface Waters from 1985 in Lithuania (10^6 m^3/year)

Type of Wastewater Discharge	1985	1986	1987	1988	1989	1990	1991	1993	1995	1996
Total amount of wastewater (WW)*	422.1	423.6	411.4	449.3	450.2	446.1	392.7	342.2	303.8	252.2
Untreated wastewater	192.2	159.1	109.2	124.8	124.4	121.7	85.1	78.1	54.1	42.1
Treated WW	229.9	264.5	302.2	324.5	325.8	324.4	307.6	264.1	249.7	210.1
as % of total WW	54.5	62.4	73.4	72.2	72.3	78.3	77.1	82.2	83.3	
Inadequately treated	142.2	169.4	186.1	201.4	211.4	226.7	194.7	174.8	171.8	110.6
Treated to Maximum Permissible Pollution Standards	87.7	95.1	116.1	123.1	114.4	97.7	112.9	89.3	77.9	99.5
as % of total WW	20.8	22.4	28.2	27.4	25.4	21.9	28.7	25.8	25.7	39.5

*-amount of water used by electrical power plants (see chapter 2.2, subchapter "Water consumption") is not included contrary to the data announced in National Report [5]; these data differ (are of higher values) from these presented in "Statistical Yearbook of Lithuania 1997" (this is due to other type of data presentation - includes amounts of water used by fisheries).

Lithuania in the period 1961-1985 are scanty, but there is a published report that the amount of waste water increased 3.3 times during this period [9]. Statistical data from 1985 are presented in a more comprehensive way (Table 4), and one can see an increase in the total amount of waste water from year 1985 to 1990. A comparison of water consumption and waste water discharges show that in the period 1985-1990 10% to 15% of all water consumed emerged as waste water [25, 26, 27]. The decrease in waste water discharges was observed after the year 1990 [25, 26, 27].

The amount of specific wastes discharged into water bodies was calculated using the BOD total, suspended solids, total phosphorus, total nitrogen and petroleum products parameters [25]. From 1987 to 1989 their amount rose constantly, but after 1990 they tended to decrease [25]. Total nitrogen and total phosphorus parameters were not presented in statistical form before 1990. The amount of total nitrogen varied from 10,600 tons per year in 1992 to 7,663 tons per year in 1995 and the amount of total phosphorus varied from 1,438 tons per year in 1992 to 1,184 tons per year in 1995. The amount of petroleum products in waste water was about 0.76 thousand tons per year in 1987 and 0.22 thousand tons per year in 1995. This change was also due to the decline of industrial production in Lithuania [25, 26, 27].

The increase in the total capacity of WWTPs (expressed in units of 10^6 m^3/year) in 1961-1990 is presented in Figure 5. The percentage of biologically treated (of total treated) waste water was 10.2% in 1961 and 58% in 1985 [9]. During this period the amount of treated waste water increased 19 times, as compared to the total amount of sewage produced, that is from 9.6% in 1961 to 54.5% in 1985 (expressed as the percentage of total waste water) [9]. Later statistical analyses also evaluated the amount of waste water that had been treated to meet water quality standards (Table 4), as not all WWTPs were able to ensure high quality treatment [25,26,27]. While the percentage of treated waste water in 1985 - 1996 increased from 54.5% to 83.3%, the amount of waste water treated according the standards (as a percentage of total polluted waste water) doubled and reached 40%; the total amount of waste water to be treated declined by approximately one half. In the 1990s the amount of untreated waste water discharges has been reduced by 50% [25,26,27].

The environmental impact

We should not forget that state policy on environmental impact problems during the Soviet period was one-sided, having the intention of preventing the disclosure of negative or even moderate information on pollution. Earlier data on the state of the environment, collected by the state laboratories of water inspection or environmental research (monitoring), were used by the Environmental Protection Department, the Hydrometeorological Board or even the Ministry of Land Reclamation and Water Economy only for official use (partly as printed manuscripts) and were acceptable for public distribution only after a careful selection. The first official publications on different aspects of the environmental situation were issued by the Environmental Protection Department (later Ministry), starting from 1989-1990, and earlier data also began to appear in these publications. Here we use the environmental data information collected in manuscripts form by environmental monitoring laboratories on the same basis as the first official issues of the EPD and scientific research works. Constant monitoring of surface water quality was performed on more than forty Lithuanian rivers from the 1960s up to 1990 at an increasing number of monitoring places (up to ninety research points) and using different water quality parameters [25,26,28,29].

In 1970 the rivers with heavy water pollution (according to BOD, total nitrogen, phosphorus parameters) were the Nevezis below the city of Pnevezys, the Dane in the territory of Klaipeda, the Daugyvene below Seduva, the Musa River below the confluence with the extremely polluted Kulpe River, the Saltuona and the Salcia. In this period there were no observations of Lithuanian rivers being constantly extremely polluted, except for the small Kulpe River, which is loaded by waste water from the city of Siauliai. The other polluted northern rivers such as the Obele, the Tatula, and the Sidabra were indicated as heavily polluted. The water of the main rivers, including the Nemunas downstream from

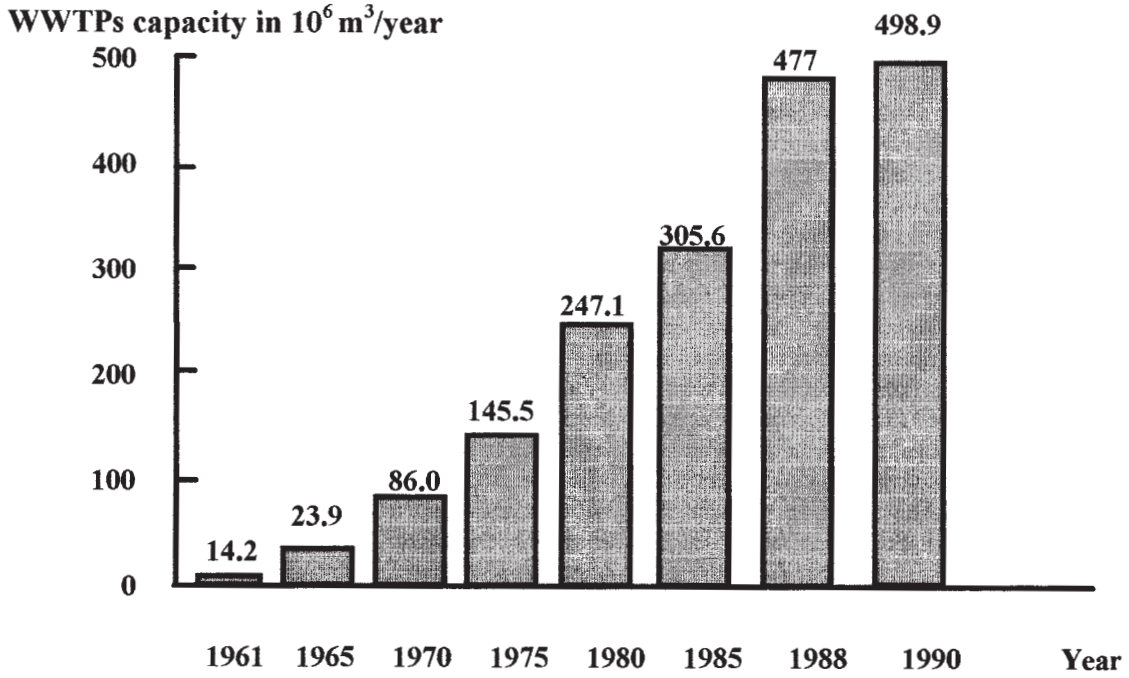

Figure 5. Capacity of Wastewater Treatment Plants be built in Lithuania in 1961–1990 [9,28]

Table 5. Main Hydrological Characteristics of Largest and Most Polluted* Rivers in Lithuania

No.	River	Water flow (m3/sec.)	River's Length, km (km)		Square of River's Basin, (km2)		Number of sampling points
			Total	in Lithuania	Total	in Lithuania	
	Largest Rivers						
1.	Nemunas	665	937	462	97928	46692	9
2.	Neris	178	510	281.5	24942	13850	6
3.	Nevezis	35.7		209		6140	5
4.	Sventoji	51.0		246	6889	6801	4
5.	Venta	38.5	343	184	11800	5140	3
6.	Jura	41.1		172		3994	2
7.	Merkys	33.7	203	190	4416	4333	2
8.	Minija	40.0		202		2942	4
9.	Sesupe	33.2	298	297.6	6105	4899	4
10.	Musa	25.4	157.3	146	5463	5297	3
11.	Zeimena	22.0		80		2793	4
12.	Dubysa	14.5		139		2033	1
13.	Demunelis	13.8	199.3	75	4047	1892	1
14.	Levuo	6.8		145		1629	4-
15.	Virvyte	9.4		99.7	5463	5297	3
	Polluted Rivers						
1.	Sidabra	0.52	79.4	33.8	185	119	2
2.	Kulpe	0.80		30.8		263	2
3.	Obele	0.85		37.6		176	2
4.	Tatula	3.05		64.7		453	3
5.	Laukupe	0.40		23.9		60.4	1

the city of Kaunas and the Neris downstream from Vilnius, was moderately and downstream (100 km) only minimally polluted, due to relatively smaller 1970 urban populations and industry in 1970 [25,28]. Water in the Nemunas and the Neris was classified as moderately polluted in 1990 [25,26,27, 28]. What has been the impact of WWTPs on Lithuanian rivers? The construction of WWTPs did not go unnoticed. Water quality improved noticeably from 1970 to 1990 in the following rivers: Nevezis, Dane, Daugyvene, Saltuona, and Sesupe. Meanwhile, Neris, the Nemunas, part of the Zeimena and the Sventoji became more polluted due to the development of rural areas, regardless of a large number of small-capacity WWTPs installed in the regions. It should be noted that the Nemunas River was classified (1990) as moderately polluted at the point where it flows into Lithuania from Belorussia. The water quality in the Musa, a smaller river, also remained the same despite the large number of small WWTPs built in the region [25,26,28].

On the other hand, the hydrological characteristics of the biggest rivers and most polluted ones in Lithuania are the most informative. They are presented in Table 5, and it can be noted that constant heavy and extreme pollution was due to the small size of the rivers. According to the international classification they are brooks (with an average water flow of 1-10 m^3/s and 100-1,000 km in length) or little brooks (with an average water flow of 0.1-1 m^3/s and 10-100 km in length) [20,25,30]. Today it is a valid question whether the data on general water quality parameters reflects the real pollution situation. Starting from 1992 the average data on specific organic pollutants are presented in the annual reports of the Environmental Protection Ministry on the Water Quality of Lithuania's Rivers. Another important question is the organic and inorganic chemical pollution concentrated in sediments and accumulated by water plants and hydrobionts. Usually these data reflect the history of pollution. Only in 1996 routine analysis of sediments in rivers was started by the EPM Joint Research Center Laboratories analysing heavy metals and organic compounds, using only a limited number of gas chromatography standards for organic compounds such as sim-triazine herbicides, hexachlorcyclohexane (HCH) and its isomers, and some chlorinated phenols [27, 30]. None of these substances was detected even in the amount of 1 ng/l in Lithuania's rivers water (more than 95 sampling places) in 1992 and later [25, 26]. Similar findings regarding these compounds were presented in the "Rivers Water Quality Chronicles" of later years [28, 30]. Exceptions to these data were the presence of prometryn and simazine in the Nemunas River (concentration 0.6 and 0.575 μg/l) upstream from Druskininkai (i.e. close to the border with Belorussia) in 1993 and of 2 μg/l of α-HCH in Neris River sediments downstream from the city of Jonava in 1996 [26, 27, 28, 30].

CONCLUSIONS

1. There were over nine hundred operating WWTPs in Lithuania in 1990, most of them biological treatment plants. Several types of treatment facilities were built in Lithuania during the period of 1950-1990 according to the regulations of the Soviet Union. The regulations for the construction of WWTPs were technological standards (rules and norms). Although Lithuanian engineers had to adopt them for local conditions, the construction work was done creatively.
2. The first waste water treatment plants were built after World War II in the industrial enterprises in rural areas and small towns. According to general five-year plans for building and development in the USSR, waste water treatment plants with a larger capacity (over 10,000 m^3/day) were introduced in the larger towns after the 1970s and in cities in the 1990s.
3. Biological treatment was a widespread and common purification method in Lithuania as well. Biofilters were the first small-sized WWTPs built from the 1950s onwards, but activated sludge and oxidation

ditches were preferred later. Due to this later trend the benefits of biofilters, low energy demand and low maintenance costs were no longer acknowledged. Other treatment plants such as surface and underground filtration fields, together with septic tanks, were also popular in Lithuania. Biological ponds were constructed only to a limited extent.

4. The improvements in waste water treatment started in the 1950s in Lithuania, but they had a notable effect on the ecological state of most rivers only after 1970, when WWTPs of a larger capacity were built. According to the available monitoring data the water quality has remained poor in four rivers, and further efforts are needed to improve the situation. On the other hand the pollution level has diminished in five rivers, and the water in the main Nemunas and Neris rivers in 1990 was characterised as moderately polluted.

Hence statements presented for example in the European Environmental Almanac (Earthscan, London, 1995 [7]) about waste water treatment in Lithuania to the effect that

i) the total capacity of the WWTPs is 1.37 million m^3/day
ii) the country's major cities had no sewage works, and
iii) over half the volume of WWTPs in 1990s depend on mechanical treatment are erroneous and misleading.

They only contribute to mystification of the situation in the former Soviet Union instead of to a rational analysis of contemporary problems and available solutions. To understand the waste water situation in Lithuania, we can compare it to that in a Western European country of the same size, for example with Denmark with an area of about 43,000 km^2 and a population of 5.16 million [7]. In 1989 Denmark had 1,039 WWTPs, and total nitrogen and phosphorous loads from municipalities were 20,900 and 4,900 tons respectively [8]. In Lithuania with an area of about 65,000 km^2 and a population of 3.7 million, there are over 900 operating WWTPs, and the total nitrogen and phosphorous loads were in 1992 10,600 and 1,438 tons, respectively [5, 6, 7, 25, 26]. There is of course a need for more comprehensive information on the state of the environmental impact of this pollution, but one can say that in general the situation in Lithuania today is almost equal to that of other European countries.

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