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# The development of waste water treatment systems in Gdansk in 1871–1998

*This paper describes the development of waste water purification systems in Gdansk from the beginning of the 19th century up to now. The operating conditions of the sewage plants are also presented and illustrated with flowsheets. From the beginning the sewerage system in Gdansk was decentralised. Each of the three sewerage subsystems existing at the beginning of the 20th century had its own local treatment plant.*

*The first waste water treatment plant "Stogi," using filtration fields, was built in 1872 and it fulfilled its role efficiently for almost 120 years before it was closed in 1991. In 1932 an activated sludge plant "Zaspa" was built in order to replace two smaller local plants using the technology of filtration fields and biofilters. Later developments of the sewerage system aimed at centralisation just as much as they do today. The central mechanical treatment plant "Wschod" with a total flow of 180,000 $m^3/d$ was constructed in 1976. Chemical treatment to remove pollutants more effectively was not introduced until 1993. By the middle of 1999 the plant will treat all waste water using the modified UCT[2] system for biological nutrient removal.*

## INTRODUCTION

Gdansk is a thousand-year-old city with a rich mercantile tradition that can be traced back to the Middle Ages. Thanks to its geographical location the city has been an important land and sea port for centuries. Today it is Poland's biggest sea port and an important communication centre.

Gdansk is situated on the coast of Gdansk Bay at the mouths of the Vistula River and occupies an area of 262 $km^2$ with 460,000 inhabitants. Gdansk is a part of a large metropolitan area called "Tri-city," which includes Gdynia and Sopot. This metropolitan area has a population of 760,000 and it covers an area of 415 $km^2$. Each city has a separate water supply system. Gdansk and Gdynia have their own sewerage systems. Waste water from Sopot is directed to Gdansk. Such a high concentration of people and industry has a significant impact on the sea, above all on the Bay of Gdansk.

The Vistula River carries about 30 $km^3$ of water per year from a vast catchment area of 194,424 $km^2$, which covers most of Poland. There are about 50,000 sources of waste water that pollute directly or indirectly the river. Approximately 34% of the total amount of municipal sewage produced in the Vistula catchment area, where twenty-six million people live, gets to the rivers without any purification [13].

Gdansk Bay is a shallow water basin, which is separated from the sea by the Hel Peninsula. This limits the refreshing of sea water in Gdansk Bay, i.e. the exchange of water with the Baltic Sea.

In the 19th century Gdansk (Danzig) was an important military harbour in the Kingdom of Prussia. In 1875 it had 98,000 inhabitants [16]. The population grew rapidly, but according to the statistics in 1851-1855 the death rate was very high, 4.5 per cent. Until the 1870s the death rate exceeded the birth rate, primarily as a result of deficiencies in the water supply system [1, 4, 16].

Small amounts of clear spring water were delivered to the city with the help of horse carts. However, it was very expensive and could be bought only by the rich. Most citizens used water from wells or simply from the Radunia River, which flows through the city. Water from the river was delivered to some parts of the city by means of wooden pipes dating even from the Middle Ages [1]. The very same river also played the role of sewage receiving body. Waste water from households was collected in buckets and dumped into ditches constructed along the main streets. It flowed by gravity outside the city or to the rivers within the city. Hence epidemics were common and threatened the visitors of the city [1].

Obviously, one of the most important issues for the citizens of Gdansk was the supplying of clear drinkable water. In 1869 the first groundwater intake "Pregowo" was built. Raw groundwater was taken from high morainic hills at 110 m above sea level and fourteen kilometres from the city. It was transported to the city by a pressure pipe with a diameter of 418 mm. The average water production was 10,400 $m^3/d$ and no treatment was needed [1, 2, 6]. Supplied water was not bacteriologically contaminated.

There was an obvious need for developing the sewerage system as well. The first steps in developing waste water purification were also taken early at about the same time the water supply system was begun [16, 4].

## THE DEVELOPMENT OF WASTE WATER MANAGEMENT IN GDANSK

The sewerage system of Gdansk, including a sewage treatment plant, a pumping station and collecting sewers, was designed by the German engineer Fredrich Wiebe in 1865. It is worth stressing that the problems of collecting, transporting and treating waste water were solved simultaneously. From the very beginning the storm water system and the sewerage system were separated. The first interceptors and a pumping station were built in 1871 and the sewage treatment plant "Stogi" was in operation in 1872. The plant consisted of settling tanks, filtration and irrigation

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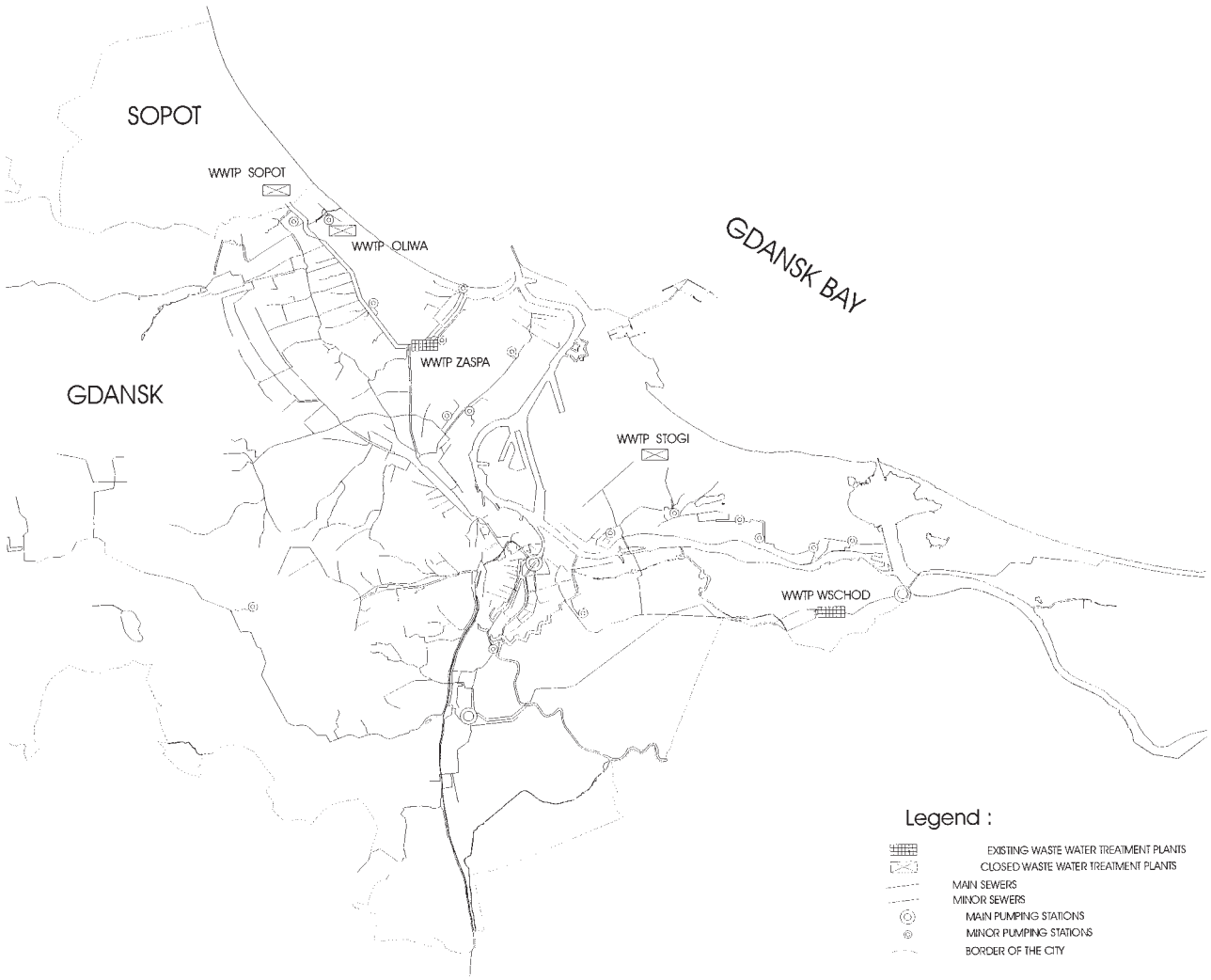



Figure 1. The sewerage system of Gdansk

fields [8]. Because waste water treatment plants and sewerage network were treated as indispensable elements of one system, their realisation and launch were co-ordinated with the construction of sewage collecting pipes to ensure purification of all the collected waste water.

The issues of waste water purification were tackled at the turn of the 19th and the 20th century when three local treatment plants were built: in Sopot, a plant using the technology of filtration fields, in Oliwa, a plant using the technology of biofilters and in Zaspa, a mechanical plant with primary settling tanks [8].

As the sewage networks of these plants were developed and the amount of inflowing waste water grew considerably, it was resolved to enlarge the "Zaspa" plant and to close the local plants in Sopot and Oliwa. The waste water from Sopot and Gdansk was to be treated only in the "Zaspa" and "Stogi" plants. In 1930 the "Zaspa" plant started to operate, which made it possible to close two existing small local plants.

Already after World War II, waste water discharges made it necessary to expand the capacity of the "Zaspa" plant. This stage was completed in 1958-1964. There was also a plan to enlarge the "Stogi" plant, which meant the extension of the filtration fields, but eventually this plan was dropped.

The expanding of the "Zaspa" plant did not improve the situation and both "Zaspa" and "Stogi" were considerably overloaded. Therefore, the decision was taken to build a new central mechanical plant, "Wschod," and close the old plants. The first stage of the construction of "Wschod", was completed in December 1976 and at present it purifies about 80% of all waste water collected in the sewerage system of Gdansk [8]. The "Stogi" plant was closed in 1991 and the "Zaspa" plant will operate until 2005. Since 1945 the sewerage system in Gdansk has functioned on the basis of the sewage networks of three plants: "Stogi", "Zaspa" and "Wschod" [3] [8]. The changes in the amounts of waste water flowing to Gdansk plants are shown in Figure 2.

## THE FIRST WWTP "STOGI"

The first plant "Stogi" with filtration fields was constructed in 1872 in an uninhabited area about 4 km away from the city. The plant was launched in connection with the construction of the first sewerage system in Gdansk. It was an experimental treatment plant, which made use of sand filters with a bacterial film. The original area of the fields was 160 ha, which was systematically expanded to 320 ha, due to an increasing waste water inflow [4]. Sewage flowed through settling tanks and later was spread on filtration fields whose area determined the flow rate, 22,000 $m^3/d$.

These high-loaded filtration fields ensured high phosphorus and nitrogen removal. The loading of the fields equalled to 3,000 mm per year in 1907 [11, 4]. The results of treatment were similar to those obtained with full biological treatment, during winter time the results were a little lower. Tables 1 and 2 show the operating conditions of the plant at the beginning of the 20th century [4. 11].

Since the 1960s the plant "Stogi" has been overloaded

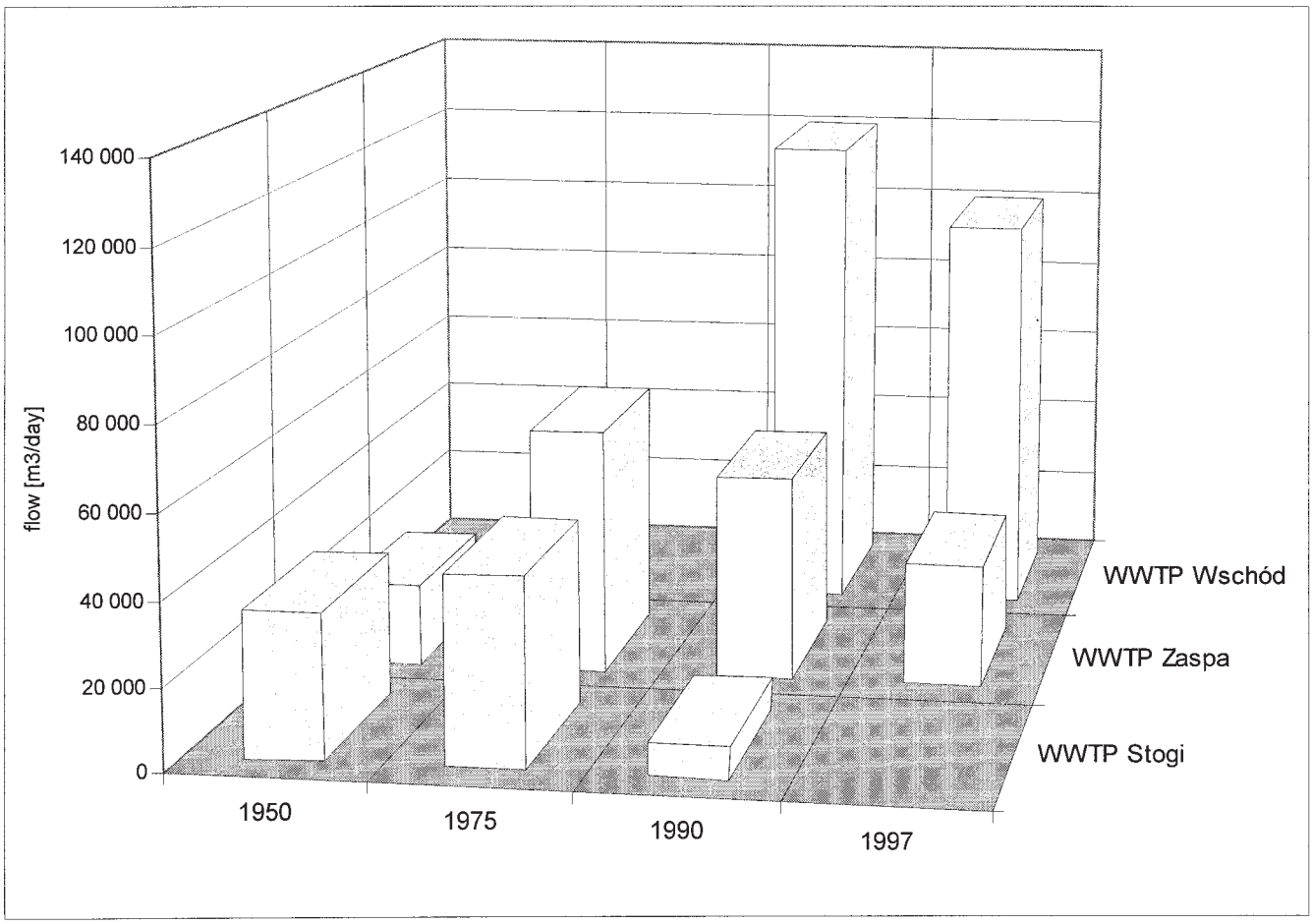



Figure 2. Changes in the flow rates of wastewater treatment plants

and the sewage inflow has reached 45,000 $m^3/d$ [8]. In the 1970s the filtration fields ceased to work properly because of the construction works of a new port and devastation caused by illegal collection of amber in this area. Most of the sewage flowing to the plant was directed in 1977 to the "Wschod" plant. Consequently, the area of the filtration fields was limited to 30 ha relative to the diminished waste water inflow, that is 8,000 $m^3/d$.

Negligence and deterioration of the filtration fields in the 1980s reduced purification, resulting in 1991 in the closing of the plant and the redirection of all the sewage to the plant "Wschod". For about a hundred years the plant "Stogi" fulfilled its tasks efficiently. However, at present it is unrealistic to have such a plant in a city because it takes up too large an area and, in consequence, has a negative impact on the city.

[3]The facilities "Stogi", "Zaspa", "Oliwa", and "Sopot" are named after city districts.

Table 1. The efficiency of sewage treatment during the summer in the WWTP "Stogi"

| Parameter | Raw sewage [mg/l] | Treated sewage [mg/l] | Removal [%] |
|---|---|---|---|
| Organic nitrogen | 7.10 | – | – |
| Ammonia | 61.88 | 4.48 | 93% |
| Total nitrogen | 64.80 | 9.40 | 85% |
| Nitrate | – | 23.51 | – |
| Phosphorus | 24.50 | Residual | 100% |

Table 2. The efficiency of sewage treatment during the winter time in the WWTP "Stogi"

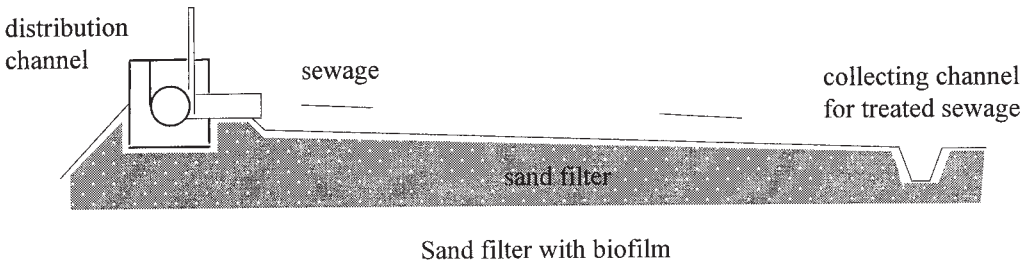
| Parameter | Raw sewage [mg/l] | Treated sewage [mg/l] | Removal [%] |
|---|---|---|---|
| Organic nitrogen | 7.10 | – | – |
| Ammonia | 61.88 | 12.00 | 42% |
| Total nitrogen | 58.06 | – | – |
| Nitrate | – | – | – |
| Phosphorus | 24.50 | 1.30 | 95% |

## WASTE WATER TREATMENT PLANT "ZASPA"

The construction of the "Zaspa" plant started in 1930. At the very beginning the sewage treatment was based only on settling tanks. In 1932 biological treatment was introduced. The plant employed a combined technology based on biological filters and activated sludge, which guaranteed full biological sewage treatment and high pollutants removal. In the 1930s the flow rate of the "Zaspa" plant increased to 12,500 $m^3$/d [3, 8]. In the 1950s the flow rate increased to 30,000 $m^3$/d and as a result about 50-70% of waste water was directed to the outlet after only mechanical treatment, omitting biological treatment. In 1958-1964 the plant was enlarged to a total capacity of 35,000 m3/d [8]. The first step of the biological treatment was changed by introducing a highly loaded activated sludge process. In spite of this improvement in the 1960s the plant was still overloaded. Consequently, the results of treatment deteriorated significantly.

In 1991 a new pumping station and a sewer were built to direct some of the influent to the "Wschod" plant. This investment made it possible to relieve the "Zaspa" plant and improve the results of treatment. Today the total flow of the plant equals 25,000 m3/d. The recipient of purified waste water is Gdansk Bay. Table 3 shows the present operating conditions of the plant [14].

It is assumed that the "Zaspa" plant will be closed about 2005. However, this would require further extension of the central plant "Wschod" and building new sewer systems to direct the flow of sewage to that plant.




Sand filter with biofilm

Figure 3. The filtration fields built in Gdansk in 1872 (by Imhoff, 1957) [19]

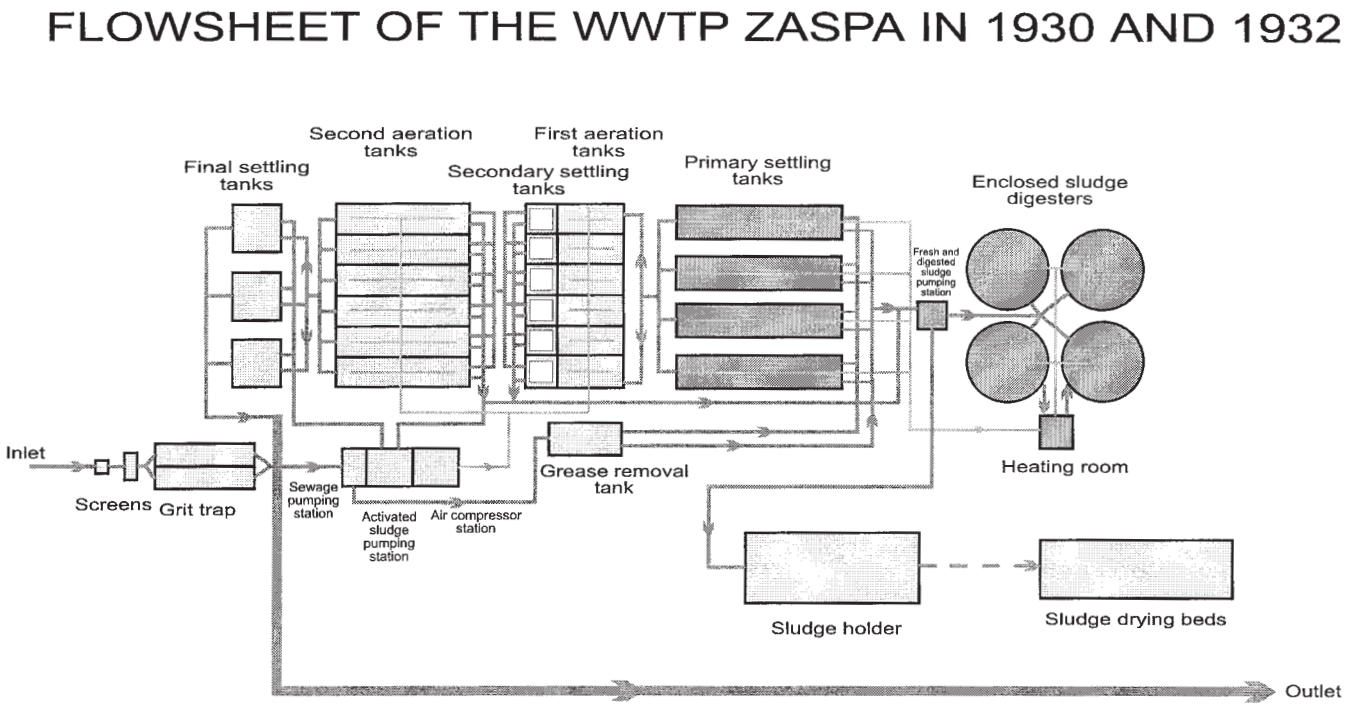



Figure 4. Flowsheet of the WWTP Zaspa in 1930 and 1932. Black grey colour indicates parts of the plant built in 1930

Table 3. Average efficiency of sewage treatment in the WWTP "Zaspa" in 1998 for the total mean flow of 25,100 $m^3$/d

| Parameter | Raw sewage | Treated sewage | Removal [%] |
|---|---|---|---|
| $BOD_5$ | 271 | 11 | 96% |
| COD | 560 | 51 | 91% |
| TSS | 213 | 23 | 89% |
| TN | 60.2 | 43.8 | 27% |
| TP | 9.7 | 6.3 | 36% |

Table 4. The results of treatment in the mechanical-chemical WWTP "Wschod" in 1997 for the total mean flow 98,540 $m^3$/d [14]

| Parameter | Raw sewage | Treated sewage | Removal [%] |
|---|---|---|---|
| $BOD_5$ | 293 | 115 | 61% |
| COD | 652 | 249 | 62% |
| TSS | 277 | 52 | 81% |
| TN | 56.4 | 49.8 | 12% |
| TP | 9.8 | 2.4 | 76% |

## WASTE WATER TREATMENT PLANT "WSCHOD"

The construction of this mechanical purification facilities plant was completed in 1976 and the capacity was 94,000 $m^3$/d. In 1985 the plant was expanded to the capacity of 180,000 $m^3$/d. In 1996-2001 the biological stage of treatment will be introduced.

Originally, a typical mechanical-biological plant was foreseen. However, the ideas for the plant's completion changed very often. The construction of the plant was to be completed in 1985, but it is not yet finished. It is noteworthy that chlorination of waste water was planned. Eventually a relatively big and inefficient chlorination unit and open sludge digesters were built [9]. From the beginning several problems were evident: an insufficiently worked out concept, excessively large capacity, technological limitations in the mechanical treatment and defects in project completion as well as difficulties in ensuring the continuity of the enterprise financing. The alternative chosen was mechanical purification, which could produce only mediocre treatment results.

At the end of the 1980s the plant sewage flow rate was about 120,000 $m^3$/d. The efficiency of $BOD_5$ removal was about 30%. After chemical treatment with the coagulating agent PIX, which was introduced in 1993, the removal of BOD5 increased to 60%.

Today the flow is about 100,000 $m^3$/d. The effluent is directed into the Vistula River. It is still assumed, however, that in the future all waste water from the city of Gdansk will flow to the "Wschod" sewage treatment plant.

Table 4 shows the operating conditions of "Wschod" plant in 1997 [14].

A plan is foreseen to complete the plant development, the construction of the biological step of treatment and sludge utilisation line in two stages. The first stage (1996-1998) concerns the construction of waste water treatment equipment itself. The second (1999-2001) involves the final solution of the sludge utilisation problem and the modernisation of a sewer for treated waste water. Plans have been made to build a pipeline that will transport the treated waste water into Gdansk Bay, 2.4 km away from the shore [9]. The plant will operate according to the modified UCT system, which ensures biological nutrient removal. The concentration of pollutants in the effluent will not exceed the limits that will be in force after the year 2000 in Poland:

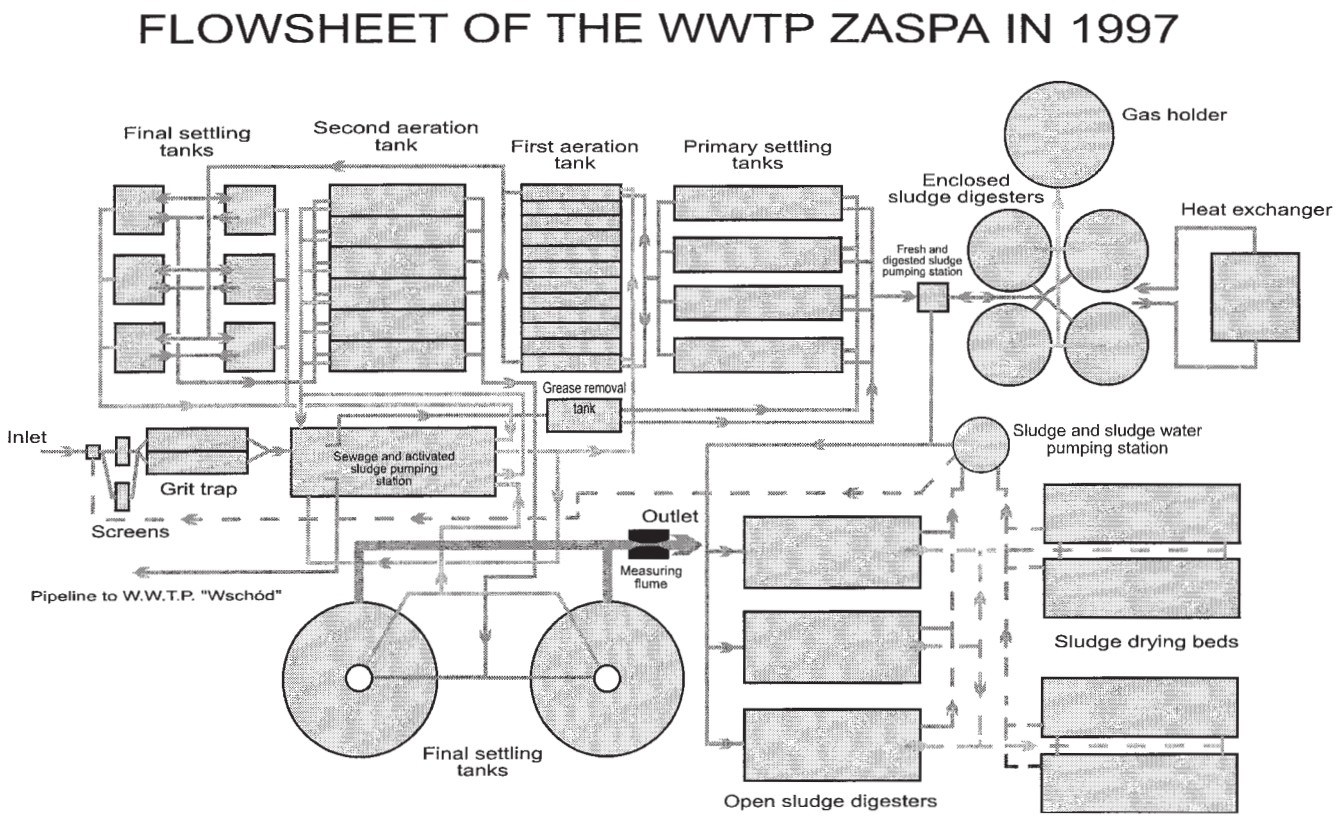



Figure 5. Flowsheet of the WWTP Zaspa in 1997

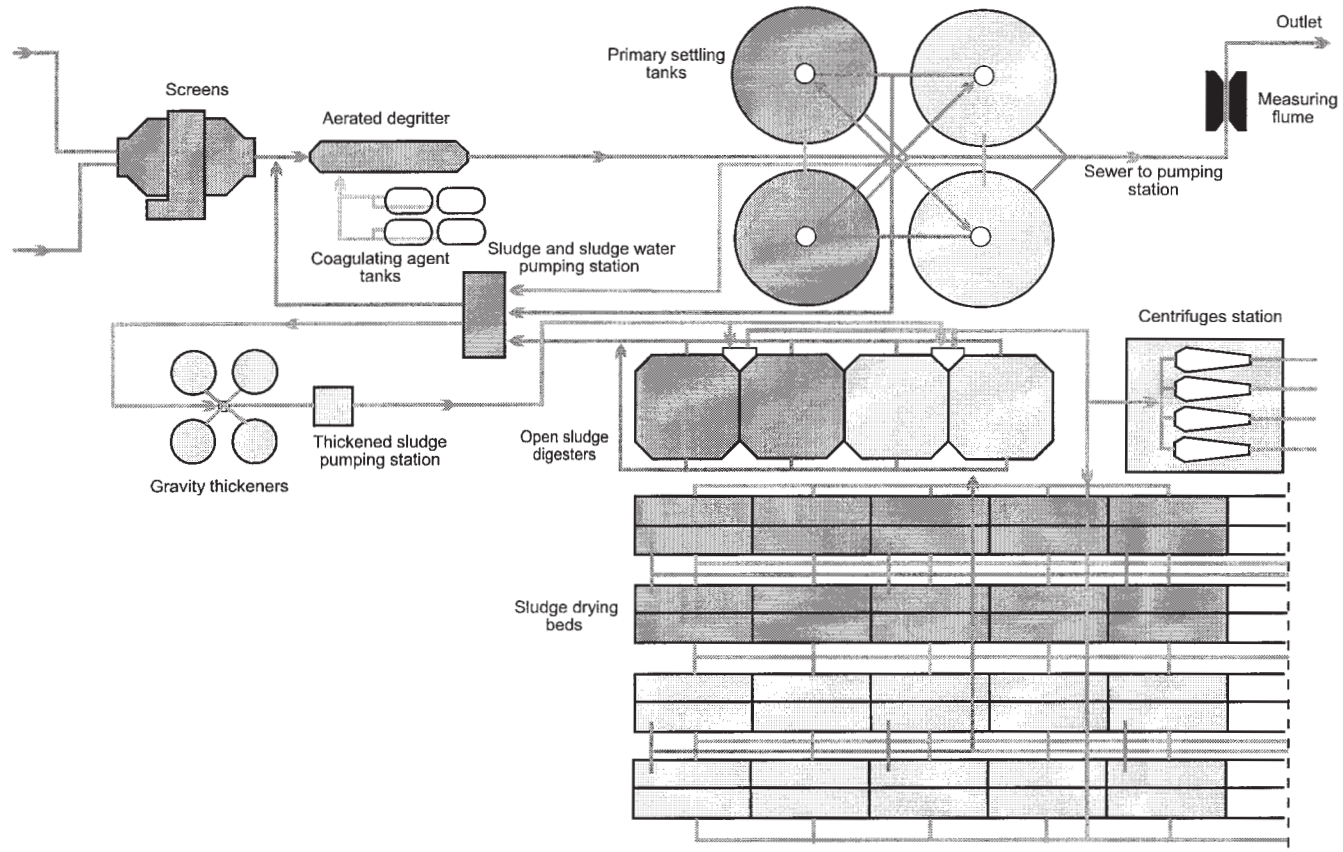



Figure 6. The WWTP Wschód in 1976 and in 1997 before development and retrofitting. Black grey colour indicates parts of the plant built in 1976

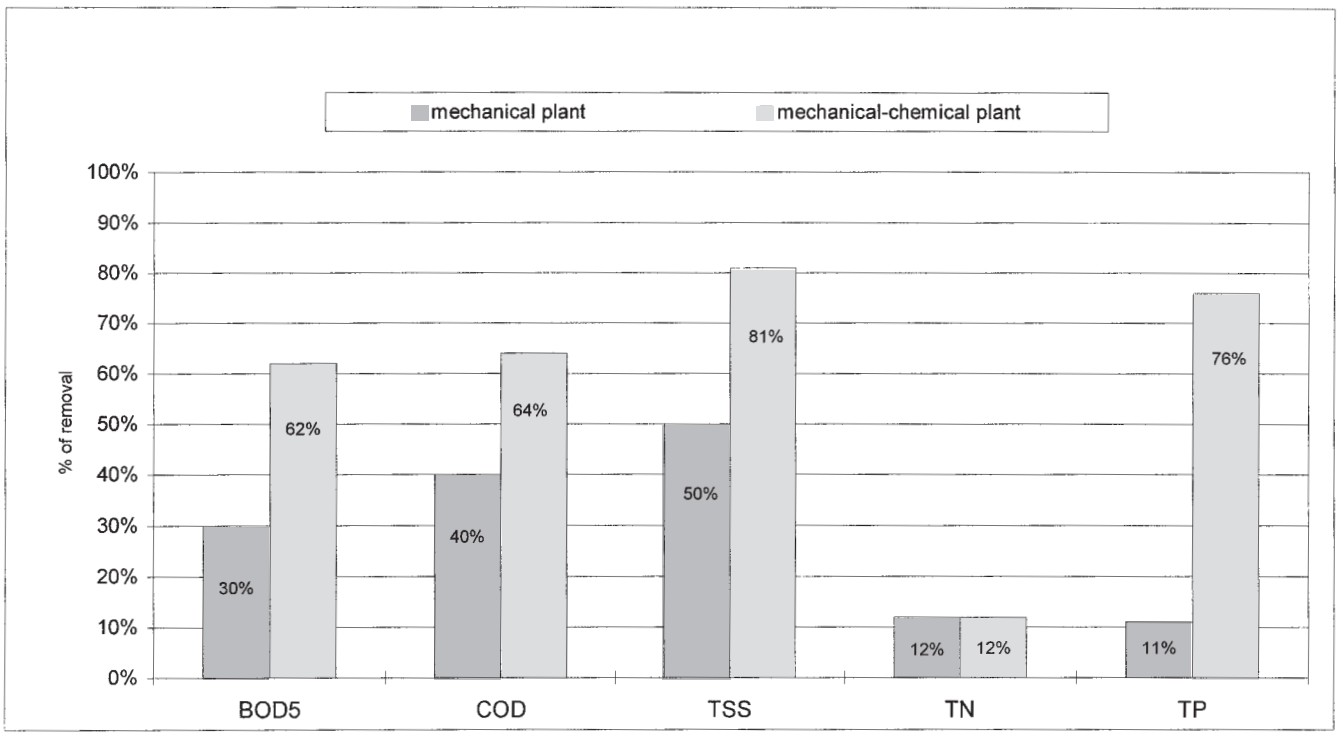



Figure 7. The comparison of results of treatment in mechanical and mechanical-chemical WWTP Wschod in 1997 for the total mean flow 98,540 $m^3/d$ [14]

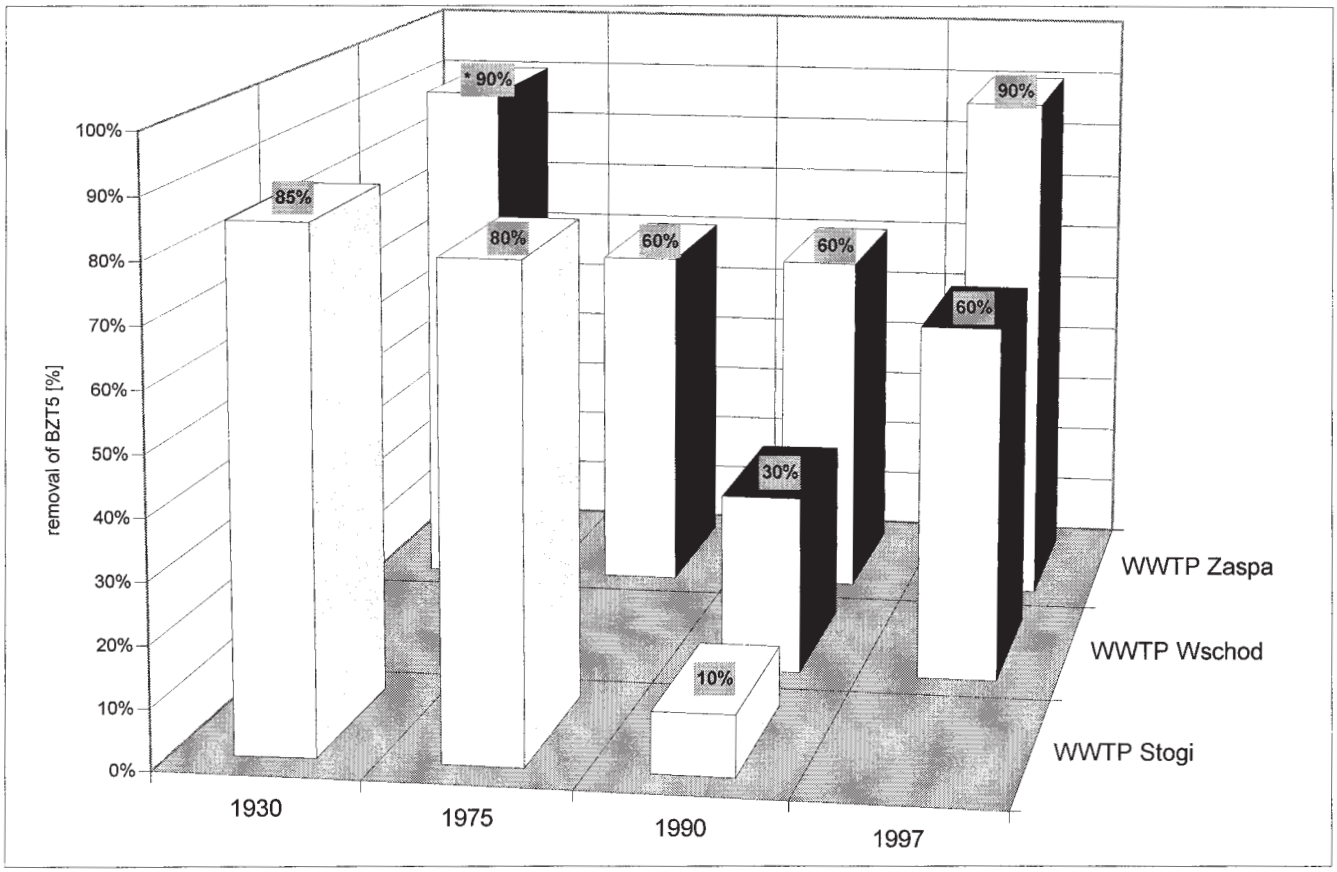



Figure 8. The removal of $BOD_5$ in wastewater treatment plants of Gdansk during the last seventy years

COD - 150 mg/l
$BOD_5$ - 15 mg/l
TSS - 30 mg/l
TN - 15 mg/l
TP - 1.5 mg/l.

## CONCLUSIONS

The prosperity of the city of Gdansk in the second half of the 19th century and, on the other hand, the bad sanitary conditions of the city were the main reasons for large-scale investments in the construction of sewerage systems. The first sewerage system used the most innovative solutions of that time. Gradually, districts of the city were linked to the system. The local sewerage systems were designed in such a way that all collected waste water was directed to sewage treatment plants. The plants functioned effectively, which ensured a high degree of sewage pollution removal.

Clearly the waste water management in Gdansk has developed from dispersed systems with local plants to the construction of one central plant for one integrated system. This evolution was influenced by the following factors:
- Geographically Gdansk is dispersed, which has promoted decentralisation,
- The constraints associated with the location of the treatment plants,
- The problems connected with the water quality recipient of treated waste water in the context of tourism in the Gdansk region [8].

Until 1970 the sewerage system of Gdansk built before World War II mainly remained in its original form. The existing system was modernised only to enlarge its capacity. Due to the lack of money, treatment plants were not developed and modernised in the 1970s and 1980s, though the need was urgent. As a consequence, the results of treatment deteriorated significantly. Most of the increasing amounts of sewage collected in Gdansk was treated only mechanically, which caused increasing pollution of Gdansk Bay.

In the 1990s the financing connected with modernisation and development of the sewerage system in Gdansk was undertaken again. However, the incomplete and long-neglected system has needs which greatly exceed the financial resources of the city. In 1997 government subsidies made it possible to begin modernisation and further development of the waste water treatment plant "Wschod", which will contribute greatly both to the improvement of the sanitary condition of the Gdansk coast and to sea water pollution control.

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