IMPACT OF MUNICIPAL WASTEWATER ON THE QUALITY OF THE RIVER SAVA

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ABSTRACT

The River Sava is very polluted in certain sections. At times, the dissolved oxygen is completely exhausted (1.0 to 3.0 mg O₂/l) resulting in frequent massive fish kills. The water quality has significantly deteriorated during the past few decades, due to the industry developed in the watershed and the increased population in the area. Especially heavy pollution loads come from the greater Zagreb area (153 t BOD₅/day). Treating the wastewater from Zagreb could upgrade the water quality of the Sava, and 68 to 72% oxygen saturation could be achieved even under the most unfavourable conditions. Particular attention should be given to the choice of the treatment process, due to the planned construction of multi-purpose reservoirs along the Sava.

KEYWORDS

Water quality; River Sava; oxygen saturation; COD; wastewater; reservoirs; eutrophication.

INTRODUCTION

The Sava is the largest tributary of the Danube in Yugoslavia, and the watershed of the river and its tributaries covers 95,132 km². Several large industrial centres are located in the watershed, over a million hectares are used for agriculture, and 8.5 million people live in the area. The middle and lower reaches of the river are used for navigation.

Along the riverbed, there are significant quantities of groundwater, dependent on the water level of the river. Water from the Sava penetrates into the ground, feeding the groundwater which is used as the water supply for communities along the river.

Many cities, communities, and industries discharge their wastewaters into the river and its tributaries, mostly untreated or only partially treated. Owing to the intensive pollution of the river, only in its upper reaches does the water quality comply with the standards for water supply or recreation and swimming.

Due to the wastewater discharged by the communities and, especially, from industry (e.g., the metal, leather, textile, chemical, pharmaceutical, cellulose, and coal separation industries), the water quality of the Sava deteriorates as it passes through Slovenia and, on entering Croatia, it is in the lowest category. After the discharge of the untreated wastewater from the city of Zagreb and its industries, the River Sava is completely degraded.
According to saprobiological research, the Sava up-river of Zagreb is beta-mesosaprobic, with a high organic load but also a significant self-purification capacity. Down-river of Zagreb, alpha-mesosaprobic and, occasionally, polysaprobic conditions are found, as well as a marked decrease in the self-purification processes (Matanićkin et al., 1979). Massive fish mortalities have been observed in the Sava since 1965, which continue to the present. This is almost a normal occurrence during low summer water levels.

Significant quantities of wastewater are discharged into the river from the greater Zagreb area. The total pollution load which enters the river from the mouth of the River Krapina to the city of Sisak is estimated to be \(2.197 \times 10^6\) population equivalents (p.e.), which exceeds the self-purification capacity of the river by 8.2 times (Anon., 1986).

The area of the city of Zagreb is the largest urban and industrial conglomeration in the Sava watershed. Therefore, the impact of wastewater from this area on the water quality of the Sava will be considered.

WATER QUALITY OF THE RIVER SAVA

From 1933 to 1936, the first extensive examinations were made of the water quality of the River Sava. A total of 155 samples were taken at a sampling station near Savski Most (Dančević, 1937). According to the results of this research, at that time the river was sufficiently clean to be used for swimming and water sports. The goal of the research was to investigate the water quality from the sanitary viewpoint, i.e., its suitability for swimming. At that time, Zagreb had a population of 200,000 and there were no larger sources of pollution in Slovenia. The next large community (6000 inhabitants) was 45 km away. The research showed that the pollution of the Sava by wastewater from a coal separation works in Trbovlje was a special problem. However, it should be noted that, as early as 1911, complaints from firms and individuals in the municipality of Zagreb concerning the pollution of the river by wastewater from the coal mines in Trbovlje were received by the authorities (Kopić, 1986).

The next significant examinations of the water of the Sava in the Zagreb area were carried out between 1960 and 1964. During this period, samples were taken at 6 stations in the area. A total of 47 samples were analysed, taken from all the stations, mostly during the summer, when the water levels were lower and water temperatures were higher. Sampling at the 6 stations thus did not correspond with the times of high flow rates of the river (Petrik et al., 1965). The water qualities of the major tributaries of the Sava, including the main wastewater receiver in Zagreb, were also investigated at that time.

In the period between the two investigations mentioned above, significant changes in the watershed took place. The number of inhabitants in the urban areas doubled and the population of Zagreb reached over 450,000. A large number of industrial facilities developed in the watershed and development of the chemical industry also commenced.

The water quality research results indicate a significant increase in pollution. The River Sava transports large quantities of organic matter from Slovenia, expressed as BOD5. Due to the additional load from the wastewater of Zagreb, the level of dissolved oxygen decreases, with the lowest recorded levels from Zagreb to Belgrade being recorded in the section between Dubrovčak and Galdovo. The pollution load entering the river from the Zagreb area is estimated as from 593,130 to 889,690 p.e., depending on the water inflow (Petrik et al., 1965). Assessing the quality of the water according to the standards of that time, the water of the Sava was determined as unsuitable for the water supply of the population and industry, as well as for swimming, water sports, and fisheries. At that time, particularly at low flows, the Sava could only be used as a source of cooling water in industrial processes, for navigation, and as a wastewater recipient.

In the 1970s, regular monitoring of the Sava commenced. In the Zagreb area, water was sampled at 5 stations (Fig. 1). In the period from 1971 to 1977, the number of samples per year ranged from 25 to 130, and since 1977 the water has been sampled once a week, i.e., 52 times a year. Data on the water analyses are
collected and statistically processed by the Water Management Organization in Zagreb. Besides data obtained from regular monitoring, data from numerous studies carried out for a variety of projects are also available.

Recently, an increase in the pollution load in the Sava watershed has been observed. The benefits of certain significant measures and procedures for the reduction of pollution have still not become apparent, and at certain times, the Sava downstream from Zagreb takes on the characteristics of a sewer. A dissolved oxygen concentration of only 0.4 mg/l has been recorded at the Galdovo station (1973), and at the same station the 95 percentile oxygen values are estimated as less than 1.0 to 3.0 mg/l (1980-1987).

Due to the heavy pollution load coming from Slovenia, the Sava can be categorized as alpha-mesosaprobic when it enters the Zagreb area. The municipal and industrial wastewaters from Zagreb (which has a current population of over 800 000) places an additional load on the river. According to the population equivalents (p.e.) of the wastewaters, it is estimated that more than 153 t of pollution as BOD$_5$ is discharged daily into the Sava in the Zagreb area, on the basis of a BOD$_5$ of 70g per capita per day.

The increase in the pollution load in the Zagreb area for the period from 1933 to 1985 can be seen in Fig. 2.
The COD concentration (KMnO₄) increased in this period by one order of magnitude. A significant increase in the COD concentration could be observed after the 1960s. The measurements recorded at the Savski Most (1933-1936) and Jankomir (1960-1985) stations are compared, since these stations are very close to one another, and the results are, therefore, comparable.

A pronounced decrease in the oxygen saturation of the Sava in the Zagreb area is due to the location of the outfall sewer mouth (Fig. 3).

Although the oxygen saturation of the Sava significantly decreased in the 1960s, it was still within allowable limits. However, since the 1970s, it has decreased further, and the impact of the wastewater of Zagreb has become even more pronounced.

The total number of coliform bacteria can be used to assess the changes in the water quality during the past 50 years. According to the research carried out from 1933 to 1936, the number of coliform bacteria in 100 ml was 10⁴ to 10⁵ (according to the Coliform Index). Thirty years later, the number of coliform organisms had increased by one order of magnitude, i.e., to 10⁵ to 10⁶ (according to the most probable number, MPN), and only ten years later, it had increased by yet another order of magnitude, reaching values of 10⁷ to 10⁸ bc/100 ml. These results were for the stations upstream of the main wastewater conduit in Zagreb. Downstream of this conduit, the minimum recorded values of total coliform organisms were higher by another order of magnitude, at 10⁷, with the maximum values reaching 10⁹ bc/100 ml.

The levels of ammonium, according to the data from continuous monitoring, have always been very low. However, since 1985, a slight increase in ammonium values has been observed at the Galdovo station, with a maximum value of 16 mg N/l being recorded.

An increase in nitrites by one order of magnitude has been recorded at the Galdovo station, as well as at Obarovo. A maximum value of 0.304 mg N/l was recorded at Galdovo in 1987. Since 1986, however, concentrations of nitrates have decreased at the Galdovo station by one order of magnitude. It can therefore be assumed from this that there has been a decrease in the decomposition of organic matter along the Sava, and, in particular, a slowing down in the nitrification process.
A high suspended matter load is characteristic of the Sava in the Zagreb area. Maximum values of 2996.0 mg/l at the Jesenice station (1979) and 1407 mg/l at the Petruševec station (1980) have been recorded. During the past 5 years, 95-percentile values of suspended matter at all the testing stations had levels of over 100 mg/l, and even up to 400 mg/l.

Other water quality parameters could also be analysed and discussed, however, all the results indicate a high pollution load.

POSSIBILITIES FOR FUTURE USE OF THE RIVER SAVA

The present state of the water quality of the River Sava limits its use. However, a wide-ranging programme for the exploitation of the river exists in the development plans of the watershed regions. In the Zagreb area, the construction of three consecutive reservoirs and five sunk thresholds (weirs) is planned. These plans have a multi-purpose character, and should result in the production of energy from the river, increased aquifer recharge and consequently improved pumping sites for Zagreb, and the possible use of the upgraded water area for recreation.

Upstream from Zagreb, in Slovenia, the construction of a series of reservoirs (for hydro-electric power generation) is planned. A further reservoir is planned downstream, and the lake will reach all the way down to the lowest dam in the Zagreb area. However, on the basis of the ecological studies undertaken for these projects, it was concluded that the reservoirs could not be constructed under the present water quality conditions of the Sava. In addition to other protection measures, one of the most basic prerequisites for the construction of the reservoirs is the construction and maintenance of wastewater treatment plants.

The wastewater treatment facility at Zagreb will be one of the principal water quality control structures on the Sava downstream from the mouth of the wastewater conduit. It is assumed that, with the completion of this treatment facility, and in conjunction with adequate measures to be taken downstream from Zagreb, the water quality of the River Sava will improve.

With the design effect of treatment of the wastewater of Zagreb being a 90% reduction in the BOD₅, i.e., an effluent concentration of 20 mg O₂/l, the oxygen saturation level would be 70% at Galdovo. At this point, it is assumed that there would be a minimum flow of 86 m³/s and a temperature of 26°C, as a consequence of the discharge of cooling water from the nuclear power station in the area (Tedeschi, 1988).

The construction of weirs in water-courses causes changes in the existing ecosystem, especially morphological changes in the water-course and flow regime. The hydroelectric dams to be constructed on the Sava will change the flow velocities and water depth. Increased decomposition of organic matter will occur, together with increased consumption of oxygen, because of the slower flow in the reservoir downstream from the Zagreb sewage outfall. Due to the lower re-aeration effect and slower flow, decreased dissolved oxygen concentrations may be expected at the Galdovo station. With the same flow rate of 86 m³/s at the Galdovo station, an oxygen saturation level of 68% and a water temperature of 26.5°C may be expected (Tedeschi, 1988).

The construction of the reservoirs would not directly affect the oxygen balance in the River Sava, assuming that, upstream, the wastewaters are treated before being discharged. However, higher concentrations of nutrients (nitrates and phosphates) may be expected if special processes are not installed to reduce their levels. Assuming that conventional biological processes will be used, the first phases of mineralization of organic matter will occur. The weirs and reservoirs, in which organic matter will deposit, will have the same effect.

The present concentrations of phosphates recorded (0.734 mg P/l at the Oborovo station and 0.679 mg P/l at the Galdovo station) greatly exceed the permitted values. Under certain circumstances, eutrophication may be expected in these conditions. For illustration purposes, the impact of the city of Zagreb with respect to the level of phosphorus in the Sava is discussed below.
The wastewater treatment facility at Zagreb has a design capacity of 2,100,000 p.e. At an influent phosphorus level of 0.7 kg P per capita per year, and with a 35% decrease in phosphorus being achieved by the biological treatment process, the mass inflow of phosphorus into the River Sava would be 30.3 g P/s. Assuming mixing of the treatment plant effluent (8 m³/s) with the whole of the river water volume, the concentration in the reservoir would be 0.322 g P/m³, not including the concentration of phosphorus from upstream sources.

Due to the very diverse morphology of the reservoirs, and because of the possibility of longer water retention times in the shallower parts, eutrophication would be expected to occur at an even lower P load than that estimated. Eutrophication, and all processes related to it, may seriously threaten the quality of the water, and also the multi-purpose use of the river.

CONCLUSIONS

Owing to the increased amounts of untreated wastewater discharged from cities and industry over the last 50 years, the water quality of the River Sava has significantly deteriorated.

The decreased water quality in certain sections of the river, such as downstream from Zagreb to Sisak, has meant that the river can only be used for navigation and as a wastewater recipient.

The construction of a series of reservoirs is planned for energy production and other uses.

This will require the implementation of protective measures, in particular the treatment of municipal and industrial wastewaters before their discharge into the river.

It will be particularly important to monitor the progress of eutrophication in the reservoirs, because this will indicate whether it is necessary to increase the degree of treatment of the wastewaters.

REFERENCES


