Surface water pollution of major rivers in the Republic of Macedonia

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Abstract

In this paper an analysis of the concentrations of BOD$_5$, total ammonium, nitrates, nitrites and orthophosphates in the major rivers (Vardar, Bregalnica and Crna River) in Republic Macedonia for the period 2000-2008 will be conducted. In our country the pollution of rivers is particularly serious in the urban areas due to the growing amount of wastewater that is often discharged without treatment. The regression analysis indicates that there hasn't been a record of a downward trend with the parameters and in certain periods an increased average annual value is recorded. These results reflect the status of the inefficient treatment of urban and industrial wastewater and inadequate protection of river basins. This paper aims to show the situation in Republic of Macedonia regarding this issue and to indicate the measures taken to reduce and prevent water pollution and thus achieving good ecological status or potential of the waters.

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1. Introduction

As a result of the development of the urbanization and industrialization, negative consequences are arising on the natural resources and the environment [1]. As main sources of water pollution in Republic of Macedonia occur: wastewater from industry, mining and households [2]. The pollution is especially serious in the urban settlements with greater number of inhabitants and with developed industry [3]. The
inadequate sanitary urban infrastructure and the lack of control of the pollution where the majority of the urban and industrial waters are not treated, both lead to worsening of the condition [3]. But even though the condition of the quality of the surface waters in certain regions is substandard, in the Republic of Macedonia appropriate measures are being undertaken to lower or even stop the pollution of the waters with which a better ecological status or potential could be achieved. So far in the Republic of Macedonia certain researches and analysis of the quality of the waters of the river Vardar [4, 5, 6] of the Crna River [7, 8] and the river Bregalnica [9] are being done.

These analysis are mostly from biological aspect, are referring to a shorter period, and most of them are with an older period of research. This article has two objectives: a) analysis of the water quality of the major rivers in the Republic of Macedonia (Vardar, Bregalnica, Crna River), and b) pollution sources for these rivers for the period from 2000-2008.

2. Data and methods

The Republic of Macedonia is located in South – East Europe, in the centre of the Balkan Peninsula. According to the geographical position it is a central Balkan country that borders with four countries: Bulgaria to the east, Serbia to the north, Albania to the west and Greece to the south. The Republic of Macedonia has an area of 25,713 km². The land relief is mainly hilly and mountainous.

According to the 2002 Census, the total population is 2,022,547 people [2]. The surface waters cover 477 km², which represents 1.88% of its territory. There are about 35 rivers, 53 natural and artificial lakes. The rivers flow in three different areas of river basins: Aegean river basin (87% from the overall territory of the Republic of Macedonia), Adriatic river basin and Black Sea basin. The biggest river is Vardar, 388 km (from which 301 in RM) where its flow gathers the major part of the area of the country (80%) and is a part of the Aegean flow area. Larger confluents of Vardar are: Treska, Pcinja, Bregalnica and Crna River [3]. Most represented industries are food processing and tobacco industry, also the production of iron and steel.

This paper is mainly based on analysis of the data and information collected primarily from the government institutions and their publications. Because this paper has a need for additional data, the authors visited parts from the analyzed areas for detailed preparation of the work materials and also registered the problems in relation with the pollution of the surface waters in the analyzed area. The main source of data for the quantity of used water for technological applications also the quantities of wastewaters from industry and mining is the State statistical office in the Republic of Macedonia. Further, the data for wastewaters from the households are received from the Ministry of environment and physical planning of the Republic of Macedonia. The data for the concentrations of the previously defined parameters in terms of the pollution of the major water flows are received from the State statistical office and the Ministry of environment and physical planning in the Republic of Macedonia. Because this paper is directed toward presenting the condition and trend of pollution of the major water flows, many different statistical methods have been used for its processing, such as: method of analysis, method of synthesis, comparative method, and the method of field observation has been used.

3. Results and Discussion

3.1. Wastewaters from industry and mining

The industry and mining in the Republic of Macedonia for its own needs are supplying with water form the watercourses, artificial accumulations and lakes, and rarely from spring and underground waters. The used waters for technological applications from the industry and mining are quantities of water used
or spent during the technological processes for example during production and cooling. Regarding the
used waters for technological applications, an oscillatory trend can be noticed in the period 2000-2008
where a particular spike is noticed in 2004 [Figure 2(a)]. This variability of data above all is a result of
the discontinuity in the industrial processes. In the period 2000-2008, for technological applications fresh
waters (99%) were mostly used. The wastewaters from the industry and mining are result of their usage in
the technological processes for production, cooling systems (most often are being discharged without
previously being cooled), from sanitary facilities and other sources. Major quantities of wastewaters in
2008 were created during the production processes (77.5%), form cooling (13.1%) and about 6.3% form
sanitary waters [2].

![River basin and river basin districts in the Republic of Macedonia](image)

**Fig. 1.** River basin and river basin

![Graphs showing water usage](image)

**Fig. 2.** (a) Water used for production purpose, (b) Discharging of untreated waste water from industry and mining by recipient
districts in the Republic of Macedonia
In the Republic of Macedonia a big problem appears from the discharging of untreated wastewaters from the industry and mining in certain recipients (soil, sewer, watercourses, accumulations and lakes). In the analyzed period certain changes regarding the recipients of these wastewaters can be noticed [Fig. 2(b)]. In 2000, from the overall discharged untreated wastewaters 97.9% were discharged in the watercourses, 1% in the accumulations and the rest in the public sewer systems and in the soil. In 2008, from the overall discharged untreated wastewaters 60.2% were discharged in the watercourses, 30.4% in the accumulations and 8.9% in the public sewer systems and the rest in the soil. In the period 2003 – 2008 there is no discharging of untreated wastewaters from industry and mining in the lakes. This slight change is a result of the changes in the industrial production and in the mining where in the given period, a part of the industrial objects and mines were not operational, and the newly built smaller industrial objects are connected to the public sewer systems.

Fig. 3. Industrial pollution in the Republic of Macedonia

In the Republic of Macedonia only about 3-4% from the whole quantity of wastewaters from the industry and mining are being treated [2]. Before they are discharged in the recipient, they are being treated on a certain manner (mechanical, chemical, biological or combined treatment). In the analyzed period 2000-2008 certain changes were noticed in respect of the recipient that receives these treated
waters [Fig. 4]. In 2000 the largest percentage (48.7%) were discharged in the accumulations, 36.6% in the rivers and the rest in public sewer systems, lakes and soil.

In 2008, from the total discharged treated waters, already 68% were released in the public sewer systems, 25% in the accumulations, and 6% in the watercourses, the rest in the soil.

We need to emphasize that the percentage of treatment of the wastewaters is quite small and unsatisfactory and there is a problem with the technical correctness of the treatment facilities which in great part are obsolete. Given the fact that most of the wastewater that comes from the industry and mining is being discharged without treatment, it is necessary major efforts to be made for improvement of the condition in terms of building new facilities that currently show no tendency to rise.

![Graph showing wastewater discharge by recipient](image)

**Fig. 4. Discharging of treated waste water from industry and mining by recipient**

### 3.2. Wastewater from households

The wastewaters from the households in the Republic of Macedonia, if not being treated, present a major impact on the quality of the surface waters, mainly because of the deposits of organic materials and nutrients, as well as dangerous substances. The wastewaters from the settlements should be treated in appropriate treatment stations before being discharged [10].

The types of treatment according to the Directive for treatment of the urban wastewaters are taken as representative indicators for the level of treating and the potential improvement of the aquatic environment. With the primary (mechanical) treatment parts of the suspended solid particles are removed, while the secondary (biological) treatment uses aerobic and anaerobic microorganisms for decomposition of most organic matter and preserving parts of the nutrients (about 20 – 30%). The tertiary (advanced) treatment more efficiently removes the organic matter. Generally, this includes preserving of the phosphorous, and in some cases removing of the nitrogen. The primary treatment on its own does not remove the ammonium, while the secondary (biological) treatment removes up to 75% [10].

Under the Urban Wastewater Treatment Directive, the EU Member States are required to provide connection to wastewater collection systems in all agglomerations exceeding 2000 population equivalent. The secondary treatment – the biological treatment must be provided for all agglomerations that are larger than 2000 equivalent residents which discharge wastewaters directly in the fresh waters-recipient. Special
requests with different terms or deadlines for fulfilling in dependence on the sensitivity of the recipient waters are being established for agglomerations with more than 10,000 equivalent residents [11].

However, a small progress has been made in the treatment of the wastewaters from the households in the past few years in the Republic of Macedonia. There is a secondary treatment for wastewaters from just a few cities in Macedonia, and that in Kumanovo, Prespa, Prilep, Struga, Sveti Nikole, Makedonski Brod and Dojran, and recently in Berovo. The current treatment facilities satisfy only 10-12% of the need for treatment. All the other settlements discharge its own wastewaters without treatment in the rivers causing possible pollution of the watercourses in the densely populated areas, resulting with a bad quality of the watercourses [12].

Next table shows the situation in the Republic of Macedonia regarding the percentage of population connected to stations with primary, secondary and tertiary wastewater treatment.

Table 1. Percentage of population with and without public sewerage system

|                          | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
|--------------------------|------|------|------|------|------|------|------|------|------|
| Total public sewerage    |      |      |      |      |      |      |      |      |      |
| % of popul.              | 49.0 | 43.0 | 51.0 | 52.0 | 53.0 | 54.0 | 55.0 | 55.0 | 55.0 |
| Mechanical treatment only| 5.0  | 5.0  | 5.5  | 5.5  | 6.5  | 7.0  | 8.0  | 8.0  | 8.0  |
| Biological treatment     | 4.5  | 4.5  | 6.0  | 6.0  | 6.0  | 6.5  | 7.0  | 7.0  | 7.0  |
| Other sewage treatment   | 0.5  | 0.5  | 0.5  | 0.5  | 0.5  | 0.5  | 0.5  | 0.5  | 0.5  |
| Public sewerage without treatment | 39.0 | 33.0 | 39.0 | 40.0 | 40.0 | 40.0 | 39.5 | 39.5 | 39.5 |
| No public sewerage or independent sewerage | 51.0 | 57.0 | 49.0 | 48.0 | 47.0 | 46.0 | 45.0 | 45.0 | 45.0 |
| Of which with independent treatment | -    | -    | 24.0 | 23.0 | 22.0 | 21.0 | 20.0 | 20.0 | 20.0 |

According to results on the distribution of the population in the Republic of Macedonia in relation to treated municipal wastewaters involving only mechanical treatment, biological, treatment and latest treatment technology, it can be concluded that there is no conformity with the Urban Wastewater Treatment Directive [10]. Namely, although the percentage of population covered by the public sewer system is rising, this number is still low (55.0% of the total population) and does not meet the European standards. Significance of the problem of wastewater must be set to the right place, and it means to be a top priority for local and national authorities.

3.3. Quality of surface waters

The monitoring of the quality of the surface waters is being done by the Hydro Meteorological administration of the Republic of Macedonia. The monitoring comprises of 20 measuring stations located on the rivers, lakes and accumulations [Fig. 5]. The classification of the surface waters is performed in accordance with the bylaws: Regulation on water classification (Official Gazette of RM, No.18/99) and a Regulation for categorization of watercourses, lakes, accumulations and underground waters (Official Gazette of RM, No.18/99). According to this classification, today there are five classes of waters, where the quality of the first (I) class is the best and the quality of the fifth (V) class is the worst [3].

The pollution of the surface water flows in the Republic of Macedonia is being monitored through $\text{BOD}_5$, the content of total ammonium, nitrates and nitrites in the rivers. The analysis will be taking into
account the average annual concentrations of the mentioned parameters for the major rivers Vardar, Bregalnica and Crna River, for the period 2000-2008.

From the Figure 6(a), can be noticed that in the analyzed period there is a high concentration of BOD$_5$ in certain measurement points in the rivers Vardar and Crna River that for the period 2000-2008 mostly correspond to water quality for III and IV class (maximum allowed values for BOD$_5$: I class <2.00; II class (2.01-4.00); III class (4.01-7.00); IV class (7.01-15.0); V class>15.0 mg/l).

![Fig. 5. RIMSYS monitoring stations in the Republic of Macedonia](image)

On some monitoring stations located on the rivers Vardar and Crna River is recorded eutrophic status of the waters with high levels of BOD$_5$. Higher concentrations of BOD$_5$ in the river Vardar are registered in 2001 and 2002 and in the Crna River in 2001. In the river Bregalnica there is a trend for increasing of the amounts of BOD$_5$ starting from 2003 where for the period 2005-2008 the concentrations correspond to a water quality for III and IV class. As to the concentrations of total ammonium [Figure 6(b)] in the rivers in the analyzed period there is a trend of decline from 2001 to 2008. Higher concentrations of ammonium are registered in Crna River and Vardar in 2001 corresponding to water quality of III and IV class (maximum allowed values for ammonium: I-II class <1.0; III-IV class 1.0-10.0; V class>10.0 mg/l).
These results most likely represent the condition with inefficient treatment of the industrial wastewaters, the wastewaters from the households as the inappropriate protection of the river basins.

Fig. 6. (a) BOD₅ concentration in rivers, (b) Total ammonium in rivers (in mg/l)

The average annual concentrations of nitrates for the whole analyzed period of the major watercourses are relatively stable [Figure 7(a)]. Only in 2003 higher concentrations are registered in the river Bregalnica (maximum allowed values for nitrates: I-II class <10.0; III-IV class 10.0-15.0; V class>15.0 mg/l). The concentration of this parameter with higher values appears in the river Vardar in regard to other rivers, but still the concentrations of nitrates in all the rivers are in accordance with the Regulation for categorization of the waters in the Republic of Macedonia. The average annual concentrations of nitrites [Fig. 7(b)] in the whole analyzed period have high values in all the rivers and correspond to water quality for III and IV class (maximum allowed values for nitrites: I- II class <0.01; III-IV class 0.01-0.5; V class>0.5 mg/l). The highest concentrations are noticed in the river Vardar in 2000. The concentrations of nitrites have a trend of decline in 2003-2008, but still correspond to water quality for III and IV class.

Fig. 7. (a) Nitrates in rivers , (b) Nitrites in rivers (in mg/l)

The trend of lowering of the pollution which is shown for the major watercourses is positive in regard to the water quality, but unfortunately, this trend is a result of the lowered intensity of industrial activity, and not as a result of the undertaken measurements for protection of the surface waters. In addition to this we can add the fact that certain smaller confluents are being turned into collectors of wastewaters that
emanate from the discharges of the major polluters. The quality of the surface water is better in areas with low population density and areas without industry.

4. Conclusion

The surface waters in the Republic of Macedonia are seriously endangered by different sources of pollution, but as major sources are the urban wastewaters and the wastewaters from the industry and mining. Most urban settlements and industrial capacities directly discharge their wastewaters in the rivers without treatment, which leads to their pollution especially in the densely populated areas. Some rivers are turned into collectors for wastewater that emanates from the discharges of the major pollutants. The quality of the water in the rivers Vardar, Crna River and Bregalnica, after the collection of the wastewater from the households and the industries from the bigger cities through which they flow is below the stipulated national standards. The trend for lowering of the pollution in recent years is positive, but unfortunately this trend is a result of the lowered intensity of industrial activity in our country. A small advance has been made in the treatment of the urban wastewaters in the past few years in the Republic of Macedonia. There is a secondary treatment for the urban wastewaters in just a few cities in Macedonia, but the current treatment facilities cover only 10-12% of the need for treatment. A small amount of treatment facilities have been built for treating the industrial wastewaters, and most of them have technologies only for a mechanical treatment. A small number of these treatment facilities have technologies for mechanical and chemical (or biological) treatment of the industrial wastewaters. Some of these facilities are out of order because of defects, lack of spare parts, or just because their regular maintenance is very expensive. Although the condition with the quality of the surface waters in some regions is substandard, in the Republic of Macedonia appropriate measures are being undertaken to reduce and even prevent the pollution of the waters, with which a better ecological status or potential of the waters would be achieved.

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