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Pollution of the Vardar River from Skopje's Sewerage as Problem for Urban and Agricultural Areas

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Abstract: Vardar River as the largest river in the country is the skeleton of a hydrographic system that is exposed to various types of pollution that in a long time can have unforeseeable negative consequences for the entire ecosystem in Republic of Macedonia. One of the major concentrated pollutants of Vardar river is the sewage system of the City of Skopje. The sewer of the City of Skopje is separated and is divided into fecal and atmospheric sewer. Also, as a problem of pollution that can occur are atmospheric water deposits (rainfallc) that collect whole dirt from the air over the City of Skopje and together with atmospheric waste water is transported into Vardar river. To solve this burning problem, until now three feasibility studies were made in different time periods that only confirms and justify the need for construction of central waste water treatment plant for fecal waste water. All previous measurements of the quality of waste water unequivocally indicate on completely degraded quality of fecal waste water.

Key words: Hydrological arrays of flows and rainfall, dry periods, level of self-purifying of river water, quality of measurements of fecal waste water, European standards for quality of waste water.

1. Introduction

Vardar river, as the largest river in the Republic of Macedonia, is exposed to contamination from various sources and types of pollution.

However, despite the large industrial facilities that are located all over the on flow of the Vardar river, one of the biggest polluters is the sewage system of the City of Skopje, which is separational, and is divided into two parts: fecal sewage and atmospheric sewage.

According to all previous measurements of the quality of river water, which are carried out in different time periods, there are two characteristic measuring profiles that reflect the real picture of the pollution of the Vardar river downstream through the City of Skopje. Those two-measuring profile are:

1. Most on the Vardar river at the entrance to Saraj, as a starting point of measurement.

2. Most on the Vardar river between settlements "Jurumleri" and "Dolno Lisiche", as the final point of measurement.

The measurements are mostly conducted in order of feasibility studies for the construction of a waste water treatment plant for fecal waste water of City of Skopje. So far, there are three feasibility studies, and all of them justify and confirm the need of constructing the waste water treatment plant for City of Skopje.

Those three feasibility studies are:

1. Feasibility Study prepared by the Danish company "Kruger" in April 2001.

2. Feasibility Study prepared by the Japanese government agency JICA in October 2008.

3. Feasibility Study made by the French company Egis in December 2014.

According to the feasibility studies, pollution of the Vardar river, at the entrance in Skopje, near the bridge in Saraj, measured by the parameter BOD 5 (biochemical oxygen demand for 5 days) is 2-3 mg/l, which corresponds to class II of surface waters in accordance with the legal regulation of Macedonia. Downstream, near the bridge in Jurumleri – Dolno Lisiche, amount of BOD 5 is 4 mg/l, which means that the waters of river Vardar fall into Class III, but is still within the

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legal framework of the quality of surface waters.

But, if the waste water from households and industry continue unchecked to be discharged into the Vardar river, without any treatment of purifying, then by 2020 the pollution of the Vardar river can reach a value of 18 mg/l, which means that water from the Vardar river will fall in class V, according to the legislation of Macedonia.

This prediction of the degree of pollution of the Vardar river is based on the simulation software package named "QUALK2", developed by the "JICA" expert team.

2. Material and Methods

In Table 1 are given the values of pollution of surface waters in Macedonia, according to polluting parameters.

Table 1 shows part of the Regulation on classification of waters 18/99 which is a legal framework in the area of surface water and the values it is the concentration of pollutants expressed in mg/l.

The situation with the water quality of the Vardar river really need to be seriously reflected, especially part about leaks around the city of Skopje, which is indicated in conducted hydrological analysis of the quantities of running waters in the long term.

Hydrological analysis was prepared for time of 14 years, between 1991 and 2005. With this hydrologic analysis is concluded that for the observed time period, maximum leakages occur average in 95 days, secondary leaks occur in 185 days and small leaks occur in 275 days. But the analysis also found that small leaks occur in dry years even 355 days a year.

Small leaks from 275 days have been used in the analysis for the preparation of the mathematical model of the degree of pollution of the Vardar river that gave the following results.

For leaks from average 275 days in a year, flow of Vardar river on three measuring points are:

1. On the entrance into City of Skopje:

Q = 19.6 (m3/sec).

2. Central City area, near Stone Bridge:

Q = 25.7 (m3 / sek).

3. The measuring point "Taor":

Q = 29.8 (m3 / sek).

Also, there are measured minimum input amounts of water from the tributaries of Vardar river in Skopje and those amounts are: from Treska river Q = 8.4 (m3/sec) and Lepenec river Q = 2.5 (m3/sec).

According to the leaks hygrogram on Vardar river following values can be concluded for half-year leaks: for minimum leaks Q = 25-30 (m3/sec) for the months of July, August, September and October. The maximum average leak is Q = 100 (m3/sec) in May and middle average leaks are Q = 50 (m3/sec), in January, February and March.

Hygrogram graphic on the Vardar river in Skopje, is given in Figure 1.

From hydrological analysis it can be concluded that small leaks through Vardar river adversely affect the level of pollution of river water because minimum leaks do not provide the required level of self-purifying of the river water.

Table 1 Shows part of the regulation on classification of waters 18/99 which is a legal framework [1].

Indicator	Class I	Class II	Class III	Class IV	Class V
COD	< 2.50	2.51-5.0	5.01-10.0	10.0-20.0	> 20.0
BOD 5	< 2.0	2.01-4.0	4.01-7.0	7.01-15.0	> 15.0
r-en O2	> 8.0	7.99-6.0	5.99-4.0	3.99-2.0	< 2.0
pH	6.5-8.5	6.5-6.3	6.3-6.0	6.0-5.3	< 5.3
Suspended solids	< 10	10-30	30-60	60-100	> 100
Dry residue	350	500	1000	1500	> 1500
Total Phosphorus	< 0.004	0.004-0.007	0.0071-0.01	0.01-0.05	> 0.05
Phosphates	< 0.007	0.007-0.011	0.0111-0.02	0.02-0.075	> 0.075
Total nitrogen	< 0.2	0.2-0.325	0.326-0.45	> 0.45	> 0.45

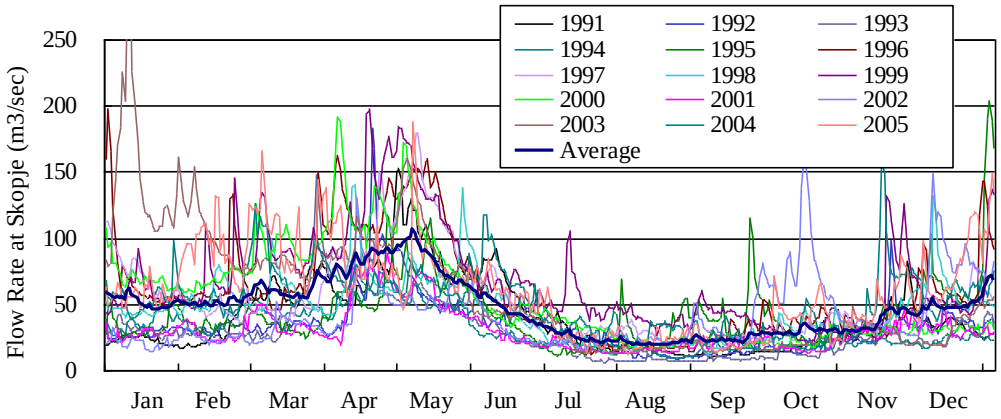

Figure 1 Hygrogram graphic on the Vardar river in Skopje [2].

Table 2 Average measured leaks of the Vardar river for a period of 275 days and leaks of the Vardar river for 355 days [2].

Leaks Q (m3/sec)	Vardar near Vlae	Vardar near City Center	Vardar near exit from Skopje	Treska river	Lepenec river
Leaks for 275 days	19.6	25.7	29.8	8.4	3.9
Leaks for 355 days	12.1	15.1	18.9	5.5	2.4

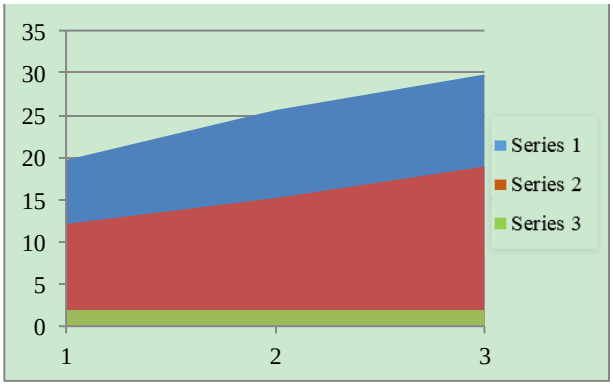

Figure 2 Graphic representation of the volumes of leaks in the Vardar river on average leaks for 275 days, 355 days and constant average daily flow of sewage into the Vardar river [1].

Table 2 gives the average measured leaks of the Vardar river for a period of 275 days and leaks of the Vardar river for 355 days.

Figure 2 give us a graphic representation of the volumes of leaks in the Vardar river on average leaks for 275 days, 355 days and constant average daily flow of sewage into the Vardar river. With a slight increase in the upcoming period as increasing numbers of people, so the amount of wastewater discharged into the Vardar river will increases too.

On the other side, leaks into the Vardar river depend on climatic factors which are more unpredictable. That means phenomenon of drought with minor leaks and the appearance of large amount of water causing floods.

With hydrological analysis, at the same time analyzed are precipitations in Skopje. This is significant if takes into consideration that the overall rainfall in the City of Skopje enter into the river Vardar and in the same time pollutants from the air and soil are entering into the river, which further contributes to the pollution of the river water.

Average amounts of precipitation are greatest in May and December and they are approximately about 50 to 60 mm of precipitation. The minimum amounts of rainfall are least in the months of February and August with 30 mm of precipitation.

In dimensioning of atmospheric sewerage in Skopje it is necessary to correct the input parameters for the intensity of the rain from the current qr = 110 (l/sec/ha) the value of qr = 120 (l/sec/ha) to qr = 140 (l/sec/ha), in order to obtain a more realistic amount of input values for dimensioning atmosphere collectors in order to avoid frequent flooding in certain parts of the city due to lack of construction of atmospheric sewers that total covers only 30% of the territory of City of Skopje.

Hydrological analysis of rainfall for the city of Skopje is prepared in a range of 26 years, from 1980 to 2006.

Figure 3 is giving a graphical representation of the intensity of precipitation for the city of Skopje.

From previous analyzes carried out concluded that the pollution of the Vardar river has reached a critical level given that the flow of fecal sewage into the river Vardar is the constant with tendency of slight increase.

Figure 4 is giving a schematic view of the fecal sewerage system of the City of Skopje together with fecal pump stations.

From Figure 4 can be seen the layout of fecal collectors in the City of Skopje and the geographical distribution of fecal system of right and lev coast, spread around the river Vardar.

Figure 5 is giving a schematic view of the existing atmospheric drains in the City.

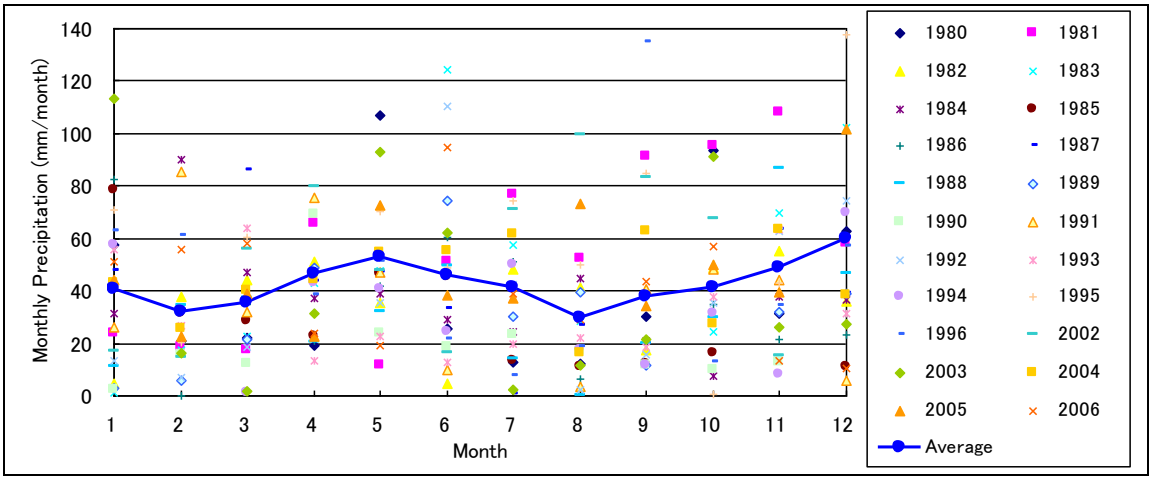

Figure 3 Graphical representation of the intensity of precipitation for the city of Skopje [2].

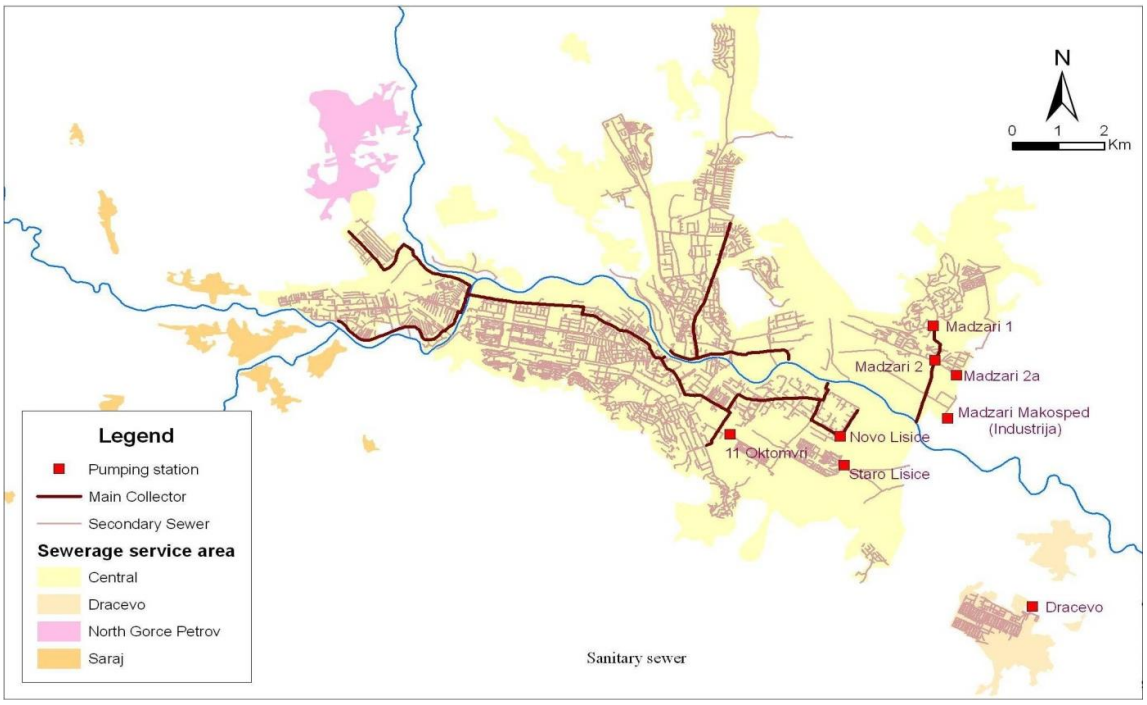

Figure 4 Schematic view of the fecal sewerage system of the city of Skopje together with fecal pump stations [3].

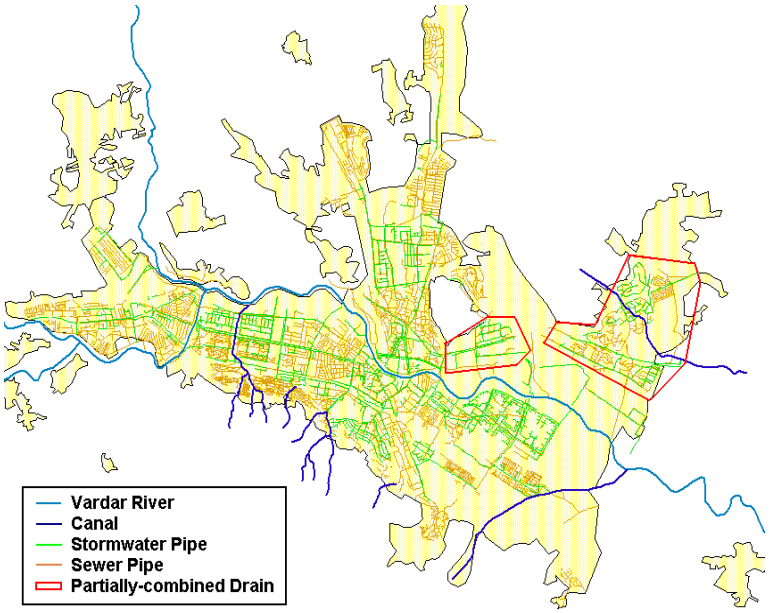

Figure 5 Schematic view of the existing atmospheric drains in the city [3].

Table 3 Produced, distributed and invoiced water from the Skopje water supply system for time period of 22 years [2].

Years from 1993 to 2014	Production of water (m3/yr)	Invoiced-household (m3/yr)	Invoiced-Industry (m3/yr)
Average value	94,138,261.00	27,448.860.00	13,575,314.00

Table 4 Average half-year values of production, billing and amount of water lost in the Skopje.

Years from 1993 to 2014	Production of water (m3/yr)	Invoiced water (m3)	Lost water (m^3)	Qo1 total (l/day/person)	Qo2 needed (l/day/person)	Losses P %
Average	94,138,261.00	41,024,174.00	53,114,087.00	509.49	223.36	56.06

Table 5 Values of the water supply rate according to four set parameters for the time of 22 years.

Years 93-14	Production of water	Invoiced-household	Invoiced-Industry	Qo1 (l/day/person)	Qo2 (l/day/person)	Qo3 (l/day/person)	Qo4 (l/day/person)
Average	93,393,723.00	27,448,860.00	13,575,314.00	509.4	223.36	148.76	74.61

Figure 5 provides a clear view of the distribution of atmosphere sewerage of the City of Skopje and accurately locates parts of town where there is no sewerage.

As a input parameters for calculation or dimensioning the size of fecal sewage that is discharged into the river Vardar, data were taken from the water supply system of the City of Skopje, which give a realistic picture of the size or leaks that pollute the river Vardar, after discharge of fecal sewage into a Vardar river.

Half-year quantities of produced, distributed and invoiced water from the Skopje water supply system for time period of 22 years are given in Table 3.

In Table 4 are given the average half-year values of production, billing and amount of water lost in the Skopje water supply system. Generally the quantities of water that are useful used can realistically be expected to occur in fecal sewage system and they are divided into the following categories:

1. Water supply rate according Q1 total produced water.

2. Water supply rate according Q2 total invoiced water.

3. Water supply rate according Q3 invoiced water - householders.

4. Water supply rate according Q4 invoiced water - Industry.

In Table 5 are given values of the water supply rate according to four set parameters for the time of 22

years.

For hydraulic dimensioning the size of fecal sewage that is discharged into the recipient - Vardar river, the following sizes are adopted for the initial sizing. Water supply norm of Qo = 250 (l/day/g) is a total rate, while the rate for households is Qo = 150 (l/day/g) and the economy rate is Q = 100 (l/day/g).

Taking into consideration population growth in Skopje which are now around 540 000 inhabitants, for the next 30 years, population growth should result in a figure of 640 000 inhabitants.

The total volume of waste water which is discharged untreated into the Vardar river is W = 166 000 (m3/day), that expressed in (m3/s) flow of waste water into the Vardar river is Q = 1.922 (m3/sec). By adding the coefficient of inequality "Ko" maximum amounts of fecal waste water is discharged Vardar are:

$$Qmax = qsr/day * Ko = 1.43 * 1.922$$
$$= 2.752(m3\ /sec)$$

Table 6 presents the parameters used in hydraulic calculations for determining the flow of waste water.

Taking into account the average minimum water flows in the Vardar river for 275 days moving within the entry and exit of Skopje Q1, 3 = 19.6-29.8 (m3/sec), then we get a percentage of the participation of 6.45% waste water on the exit from Skopje that is discharget into the Vardar river, out of total running water. Precisely, increasing the flow of the river Vardar between the second measuring point Q2 = 25.7 (m3/sec) and third measuring point Q3 = 29.8 (m3/sec), where the difference in the leak is Q = 4.1 (m3/sec). Considering the amount of discharged sewage from Q = 1.922 (m3/sec) in the Vardar river then increasing of the flow in the Vardar river only from fecal water content is 46.88%, between the second and third measuring point.

Clearly, the most critical part of the Vardar river which is most exposed to pollution is the part between the Stone Bridge in the center of Skopje with outlets in the settlement of Novo Lisice, until the exit of Skopje valley near the village of Taor. On this part has no natural tributaries only outlets of fecal and atmosphere sewers. After this part, water moving scrambled to the third measuring point to get pollution of river water from III category. Figure 6 is a schematic layout of the sewerage outfalls with the amount of waste water that is discharged into Vardar river.

Table 6 Hydraulic calculations for determining the flow of waste water [2].

Flow	m3/day	m3/hour	m3/min	m3/sec
Maximum flow by hour	237,740.00	9,906	165.1	2.752
Average daily flow (rain)	166,000.00	6,917	115.3	1.922
Average daily flow (dry)	135,000.00	5,625	93.8	1.563
Reserve frow	302,400.00	12,600	210	3.500

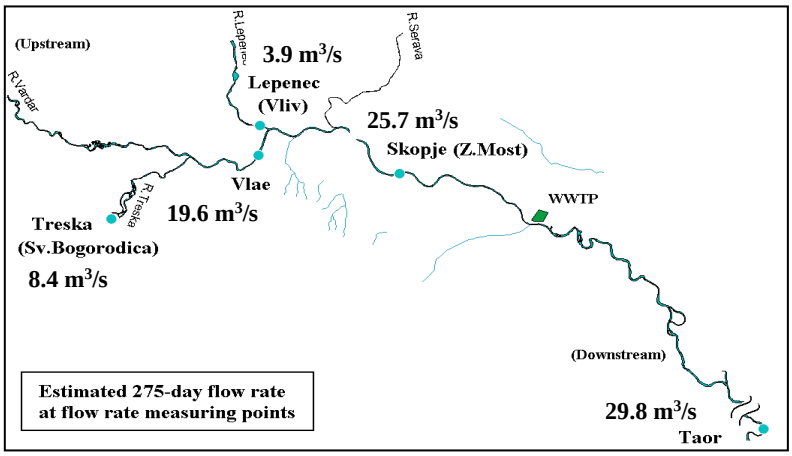

Figure 6 Schematic layout of the sewerage outfalls with the amount of waste water that is discharged into Vardar river [3].

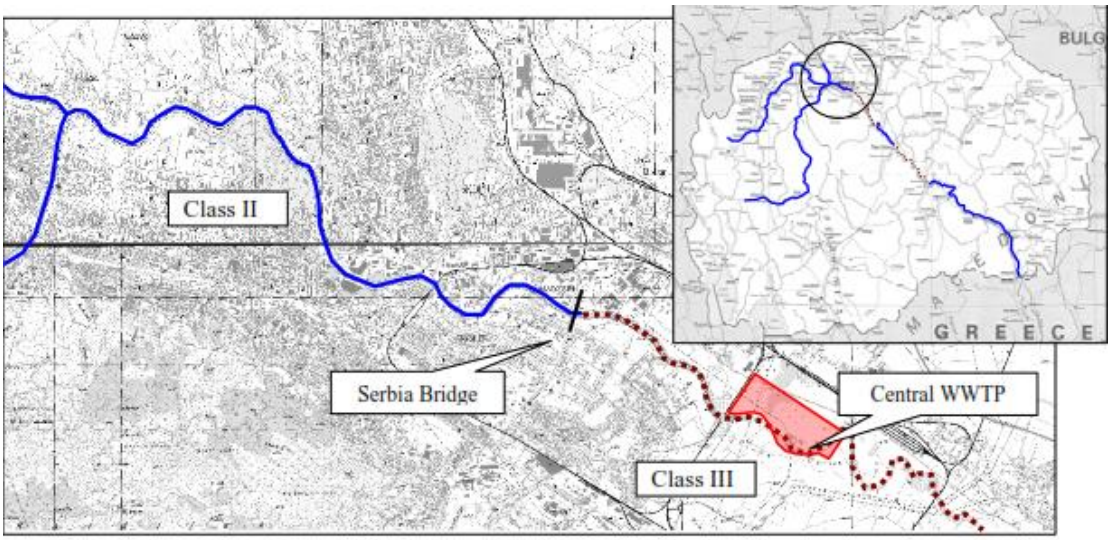

Figure 7 Schematic representation of the change in the level of contamination, and changing the class of the Vardar river water, depending on the location of fecal outlets along the river [2, 3].

Figure 7 is a schematic representation of the change in the level of contamination, and changing the class of the Vardar river water, depending on the location of fecal outlets along the river.

The quality of waste water discharged into the recipients is subject to specific physical, chemical and biochemical analyzes, which can be unify by the rules and which can be used for benchmarking.

Waste water discharged from fecal sewage according to European norms has the following levels of pollution:

1. BOD 5150-500 mg/l. (Biochemical Oxygen Demand 5 days).
2. COD 300-1000 mg/l. (Chemical oxygen demand).
3. SS 250-850 mg/l. (Suspended solids in the water).
4. TN 20-85 mg/l. (Dissolved nitrogen in the water).
5. TP 4-15 mg/l. (Dissolved phosphorus in the water).
6. Value for Ph 6-8.

Also, according to European technical standards, there is adopted expression Equivalent to the capita as a measure of critical pollution that is necessary to reduce by the waste water treatment. The values of the pollutants contained in 1 ER (equivalent capita) are:

1. BOD 5 60 g/PE/day.
2. COD 120 g/PE/day.
3. N (nitrogen), 11 g/PE/day.
4. P (phosphorus) 1.8 gEZH/day.

According to all previous measurements of fecal sewage that is discharged from Skopje sewerage and atmosphere drains has the following values given in Table 7.

Table 7 Discharged from Skopje sewerage and atmosphere drains has the following values [6].

Parameters of contamination	Unit of measurement	Concentration		
		Weak	Average	Strong
Total solid substances	mg/l	350	720	1,200
Suspended solids	mg/l	100	220	350
BOD 5 (biochemical oxygen demand in 5 days)	mg/l	110	220	400
COD (Chemical Oxygen required)	mg/l	250	500	1,000
Total nitrogen expressed as N	mg/l	20	40	85
Total phosphorus expressed as P	mg/l	4	8	15
Fats and oils	mg/l	50	100	150

Table 8 Regulated by law for the quality of wastewater discharges into the recipients [6].

No.	Parameter	Unit of measurement	Limit of the value
1	BOD_5	mg/l	25
2	COD	mg/l	125
3	Dissolution CM	mg/l	35
4	TN	mg/l	15
5	Nitrogen	mg/l	10
6	TP3	mg/l	2

The level of purification or reducing that it takes to perform, if central treatment plant for the City of Skopje is going to be build, is given in Table 8, which is regulated by law for the quality of wastewater discharges into the recipients.

By comparing the two tables immediately comes to the conclusion that the waste water that is discharged into the Vardar river has multiple pollution rate than the allowed concentrations by low.

The obtained data on the level of pollution of the Vardar river by the discharged sewage water refers to four measuring points or four outlets. These outlets are:

1. Fecal discharge "USJE" the right bank.
2. Fecal discharge "Airport" on right bank.
3. Fecal discharge "Keramidnica" the lev coast.
4. Fecal discharge "New Lisiche" the right bank.

The difference in the quality of discharged water from sewerage and required allowable concentration of waste solids is given in Table 9 where you are given deviations of waste water percent of the prescribed norms.

The percentage of contamination is given for poor concentration of pollutants. In case of larger concentrations of pollution, the percentage of contamination is increases which certainly adversely affects water quality of Vardar river.

If we started building the Central Station for treatment of fecal waste waters of Skopje, then you can expect a reduction of pollution of the recipient or the Vardar river in two-time phases. Table 10 is a table of the reduction of pollutants that will be discharged into the Vardar river, performed after complete treatment of purifying the wastewater.

Table 9 Deviations of waste water percent of the prescribed norms [6].

No.	Measurement	Parameter	Allowed concentrations	Measured values of concentrations (low)	Percentage of pollution
1	mg/l	BOD_5	25	110	77.27%
2	mg/l	COD	125	250	50.00%
3	mg/l	Dissolution CM	35	350	90%
4	mg/l	TN	15	20	25%
5	mg/l	Nitrogen	10	110	90.9%
6	mg/l	TP	2	4	50%

Table 10 Reduction of pollutants that will be discharged into the Vardar river, performed after complete treatment of purifying the wastewater [6].

Parameter	Short / medium-term objective (2030)		long-term goal (up to 2040)	
	The maximum concentration (mg / l)	Minimum rate of reduction (%)	The maximum concentration (mg / l)	Minimum rate of reduction (%)
BOD_5	25	70-90	25	70-90
COD	125	75	125	75
BSM	35	90	35	90
N total	40	-	10	70-80
P total	5	-	1	80

Conclusions from the Analysis

From the conducted hydraulic analysis between average minimum flows on the river Vardar on the one hand and the amount of discharged waste water on the other side comes to the conclusion that only minimum flows in the Vardar river, the river pollution is substantially in the constant flow of waste water sewerage.

The view of the hazard between hydrological lawfulness and hydraulic laws is gives rise to the level of the Vardar river only average daily flows for 6:45% of the entire length of the river through the city of Skopje, while between the second and third measuring point increase in flow under the same conditions was 46.88%.

In the event of peak hours of leaks the quantities of waste water increases the size of the coefficient of imbalance "Ko" for 1.43 times.

Of course, these results give a negative picture of the environmental conditions in the Vardar river in Skopje area, and represent a potential danger for the permanent pollution of the Vardar river.

Concentrations of waste products in low concentrations are also significant and pollution ranges are from 25% to 90% above permissible limits for certain types of pollutants.

Recommendations for Solving the Existing Problem

Requires construction of central wastewater treatment plant for fecal sewage with a complete wastewater treatment (mechanical, biological and chemical purification). It also should allow treatment of the dried sludge which remains after the water purification.

Construction of inflatable compartments in the central city area in order to refining the minimum flows on the Vardar river that will drastically improve the situation of self-purifying of river water in city environment in periods of low water level of the Vardar river.

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