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Studies on the current state of water quality in the Segamat River

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Abstract. Nowadays, pollution has become a major concern in developed and developing countries. In a study on the current state of Segamat River water quality; on-site data collection and observation and also laboratory data analysis have been implemented. Studies showed that the downstream of the Segamat River has recorded a significant reduction in quality of water during the dry season compared to the wet season. The deterioration of water quality is caused by the activities along the river such as palm oil plantation, municipal waste and waste from settlements. It was also recorded that the point sources were dominating the pollution at Segamat River during the dry season. However, during the wet season, the water quality was impaired by the non-point sources which originated from the upstream of the river.

1. Introduction

The national environment is now being threatened by various types of disruptions. The most popular threats to the environment are land, water, air, thermal, noise, and light pollutions, with examples that range from improper disposal of polystyrene, used baby diapers, and end-of-life tyres to recycled papers and many more that make up the list [1]. Land pollution often consists of garbage and industrial effluents, which are among the major pollutants to rivers. The National Resources Defense Council (NRDC) reported that food waste is also among the largest contributors to land pollution and 40% of unconsumed food becomes rotten in landfills [2]. More rotten food also means more landfills are needed and this does not only affect the environment but also increases governmental expenditures. For example, in the United States (U.S.), 10% of the energy budget was invested in food farms just to end up in these landfills [2].

In addition, water pollution also causes the lack of clean water to nearly 783 million people, improper sanitation to 2.5 billion people, and water-related diseases that annually kill 6 to 8 million people in the whole world [3]. In 2012, urbanisation and economic development were also known to be related to 14.1 million new cancer cases and 8.2 million deaths worldwide, and one of the reasons was contaminated water consumption. Breast cancer was identified as the leading cause of cancer deaths among females while prostate cancer was listed as the main cause of cancer death among men [4]. Studies showed that mortality due to breast cancer is strongly related to distance between industrial and residential areas and also the types of industry in practice. A higher mortality risk due to breast cancer was detected in residences located near mining, ceramic, and ship-building industries. On the other hand, a higher risk of prostate cancer was detected in residences located near aquaculture activities [5].



Sources of pollution can be divided into two, namely the point and non-point sources. Point sources can be defined as effluent that is being discharged through a channel such as pipe, ditch, tunnel or any other conduit to the nearest pollutant receiver such as a river, pond or even the sea [6] whereas non-point sources can be defined as effluent that is generally resulted from unknown sources which flow and carry away all surface pollutants originated from land runoff, precipitation, atmospheric deposition, drainage normally caused by rainfall and snowmelt and deposited into the rivers, lakes or oceans [7].

In managing the amount of discharged effluent into the river and at the same time keeping the river water in good quality, various methods were globally used. One of them is the total maximum daily load (TMDL) which can be described as the maximum value or amount of pollutant allowed to enter the rivers, streams, and lakes without disturbing the existing or targeted water quality [8]. The Minnesota Pollution Control Agency derives TMDL *as the maximum amount of a pollutant a body of water can receive without violating water quality standards, and an allocation of that amount to the pollutant's sources* [9]. In order to meet the standard water quality requirement, the amount of pollutant must be determined by using the TMDL analysis before being discharged into the river. There are classes to measure the river water quality based on the Department of Environment Water Quality Index Classification as shown in table 1 [10] :

Table 1. Department of Environment water classes and uses (source : EQR 2006).

Water Classes	Uses
Class I	Conservation of natural environment Water Supply I – Practically no treatment necessary Fishery I – Very sensitive aquatic species
Class II	Water Supply II – Conventional treatment Fishery II – Sensitive aquatic species Recreational use, body contact
Class III	Water Supply III – Extensive treatment required
Class IV	Irrigation
Class V	None of the above

In this study, water samples from the Segamat River were taken and sent to a laboratory to analyse for the actual situation of the existing pollution levels and determine the water quality classes. The results were then analysed by using the TMDL method by identifying its targeted parameter and determining the amount of pollutant allowed to enter the riverine system without disturbing the targeted water quality.

2. Methodology

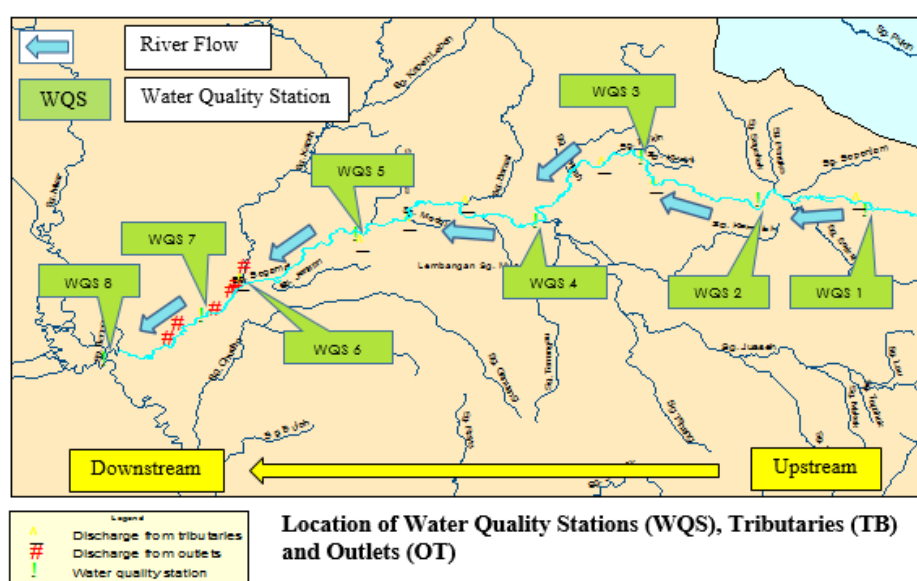
This study involved the Segamat River catchment in Segamat district. Site visits were conducted to see the real physical condition and shapes of the river and also the pollution condition along the river. Data collection on water quality was also conducted in the Segamat River catchment area. Samplings were conducted at two different seasons, namely the dry and wet season to identify the difference in water quality during these seasons. It is to enable to observe the trend of a wider data sampling for both seasons.

2.1. Sampling locations

The entire study area along the Segamat River was divided into eight water quality stations to analyse its actual water quality situation. The location for each water quality station was determined by a site inspection conducted on 4 September, 2016. The location was determined at every junction between the Segamat River main river and its tributaries. The coordinates and location of each water quality station are shown in table 2 and figure 1

Table 2. Location of water quality station.

No.	Water Quality Station	Longitude	Latitude
1.	WQS 1	103.02539	2.54136
2.	WQS 2	102.99048	2.54495
3.	WQS 3	102.95174	2.56230
4.	WQS 4	102.91724	2.53634
5.	WQS 5	102.85839	2.53094
6.	WQS 6	102.82084	2.51135
7.	WQS 7	102.80777	2.49748
No.	Water Quality Station	Longitude	Latitude
8.	WQS 8	102.77606	2.47946

**Figure 1.** Distribution of study area and location of each water quality station.

2.2. Water Quality Laboratory Analysis

After the sampling process was completed, the collected water samples were analysed in a laboratory to obtain current water quality results and index. However, of all the six parameters, only four parameters were analysed in the laboratory as the two parameters, namely DO and pH were obtained on site by using Horribar equipment. The four parameters, which were BOD, COD, TSS, and AN were analysed by using water quality test equipment in the environment laboratory.

2.3. Determination of water quality index for Segamat River

There were six parameters of water quality used in determining the levels of WQI by DOE [10]. The list of parameters is as follows:-

- Dissolved Oxygen (DO) ;
- Biochemical Oxygen Demand (BOD) ;
- Chemical Oxygen Demand (COD) ;
- Concentration of Hydrogen (pH) ;
- Total Suspended Solids (TSS) ; and
- Ammoniacal Nitrogen (AN)

Data from the parameters were analysed to get the actual WQI for the selected water samples. WQI were specified by referring to tables 1 and 3 derived from the DOE water quality index classification.

Table 3. DOE water quality index classification (source : EQR 2006).

Parameter	Unit	Class				
		I	II	III	IV	V
Ammoniacal Nitrogen	mg/l	< 0.1	0.1 – 0.3	0.3 – 0.9	0.9 – 2.7	> 2.7
Biochemical Oxygen Demand	mg/l	< 1	1 – 3	3 – 6	6 – 12	> 12
Chemical Oxygen Demand	mg/l	< 10	10 – 25	25 – 50	50 – 100	> 100
Dissolved Oxygen	mg/l	> 7	5 – 7	3 – 5	1 – 3	< 1
pH	-	> 7	6 – 7	5 – 6	< 5	> 5
Parameter	Unit	Class				
		I	II	III	IV	V
Total Suspended Solid	mg/l	< 25	25 – 50	50 – 150	150 – 300	> 300
Water Quality Index (WQI)	-	< 92.7	76.5 – 92.7	51.9 – 76.5	31.0 – 51.9	> 31.0

3. Results and Discussion

Based on data obtained from all the involved stations, the existing water quality condition for the Segamat River was calculated and the results of each water quality station in every season were summarised in table 4. Figure 2 clearly shows the changes in water quality conditions for both seasons. The darker the annotation colour, the more contaminated is the water quality.

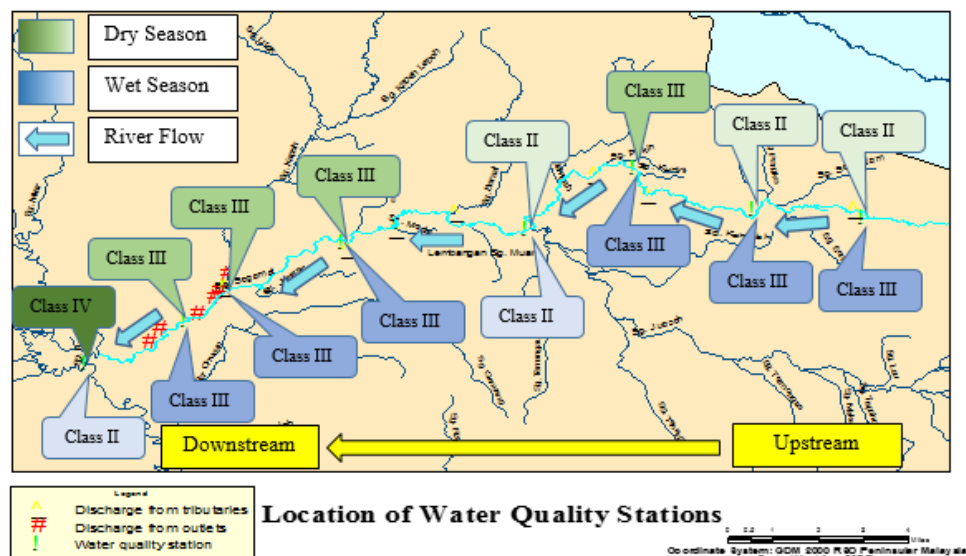
**Figure 2.** Water quality condition along Segamat River during both seasons.

Table 4. In-situ and laboratory analysis water quality data for Segamat River.

Location	Sampling	Parameter							WQI	Class
		COD (mg/l)	BOD (mg/l)	DO (mg/l)	DO (%)	TSS (mg/l)	pH	AN (mg/l)		
WQS 1	Sampling 1	20.00	5.00	5.92	76.37	10.00	7.54	0.05	85.97	II
	Sampling 2	48.00	16.00	4.85	62.07	39.00	6.02	0.02	68.47	III
WQS 2	Sampling 1	11.00	3.00	4.34	57.80	6.00	9.19	0.01	80.97	II
	Sampling 2	14.00	5.00	2.82	36.63	13.00	7.04	0.02	75.60	III
WQS 3	Sampling 1	11.00	4.00	2.80	35.23	45.00	7.19	0.06	73.40	III
	Sampling 2	17.00	5.00	5.38	70.53	78.00	7.25	0.01	66.24	III
Location	Sampling	Parameter							WQI	Class
		COD (mg/l)	BOD (mg/l)	DO (mg/l)	DO (%)	TSS (mg/l)	pH	AN (mg/l)		
WQS 4	Sampling 1	13.00	4.00	2.72	41.60	12.00	7.10	0.01	78.40	II
	Sampling 2	38.00	12.00	6.15	84.10	39.00	5.66	0.04	76.56	II
WQS 5	Sampling 1	23.00	7.00	3.29	46.43	52.00	7.75	0.02	72.38	III
	Sampling 2	25.00	8.00	4.11	53.13	201.00	6.47	0.07	69.31	III
WQS 6	Sampling 1	37.00	13.00	5.95	88.50	124.00	8.59	1.74	63.94	III
	Sampling 2	10.00	3.00	3.60	48.93	100.00	6.46	1.43	67.92	III
WQS 7	Sampling 1	40.00	13.00	6.11	83.73	163.00	8.33	0.92	66.46	III
	Sampling 2	33.00	12.00	4.05	56.93	137.00	5.51	0.08	51.77	III
WQS 8	Sampling 1	51.00	15.00	2.71	34.77	381.00	4.38	1.14	40.33	IV
	Sampling 2	11.00	3.00	4.40	58.73	124.00	6.61	0.62	75.62	II
Sampling 1 – Dry season Sampling 2 – Wet season										

3.1. Segamat River water quality condition during dry season

From table 3 and figure 2, it can be concluded that during the dry season, the Segamat River water quality was gradually reduced from upstream to downstream. The water quality at WQS 1 was recorded as a good condition of Class II with WQI of 85.97 and started to reduce to Class III quality at WQS 3, with the WQI fell to 73.40.

The TSS was recorded as increasing from WQS 1 to WQS 3. The TSS reading increased from 10.00mg/l to 45.00mg/l, respectively and caused a decrease in the water oxygen content from 5.92mg/l to 2.80mg/l. Soil erosion from agricultural activities was identified to be the sources of high concentration of TSS in rivers [11]. As shown in figure 3, WQS 3 is located near the discharge point of the Kunyit River, which was observed to carry silts from the surface water runoff from the palm oil plantation nearby Segamat River.

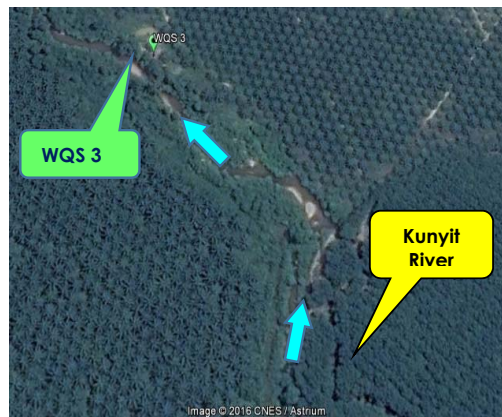


Figure 3. Location of Kunyit River.

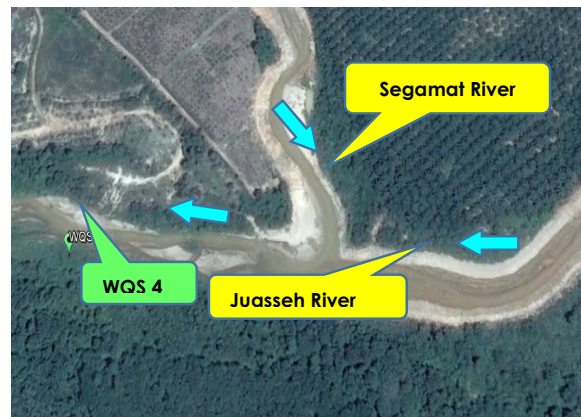


Figure 4. Meeting Point Between Segamat River and Juasseh River.

However, at WQS 4 which is further downstream, the water quality was recorded as improving from Class III to Class II with the WQI reading at 78.40. The improvement in water quality at this point was due to the WQS 4 location which is located near to the meeting point of the Segamat and Juasseh Rivers. The flow from the Juasseh River somehow had diluted the silt content in Segamat River and TSS was recorded to decrease from 45.00mg/l to 12.00 mg/l and had improved the water quality from Class III to Class II. Figure 8 shows the location of the meeting point between the Segamat River and Juasseh River.

Somehow, the water quality at WQS 5 changed back to Class III with the WQI at 72.38. During the site visit for water sampling, palm oil plantations were found to dominate the area. The water quality was observed to deteriorate from the TSS, COD, BOD, and AN increasing levels. TSS increased from 12.00mg/l to 52.00mg/l, COD from 13.00mg/l to 23.00mg/l, and BOD from 4.00mg/l to 7.00mg/l while AN recorded a very little increased value from 0.01mg/l to 0.02mg/l. Plant debris, animal and food waste, trash, gasoline and motor oil, heavy metals, fertilisers, and pesticides were identified as contributors to the high COD reading in most river systems [12].

The use of fertilizers was observed to be the reason for the increased BOD and AN levels, which were deposited into the river from surface water runoff. Ammonia, which is a nitrogen-based compound sourced from fertilisers and pesticides, is harmful to underwater living [13]. However, the increasing TSS levels are always associated with soil erosion in agricultural activities [14]. Apart from the human activities, the dry weather condition and lack of water flow rate are also the causes for the increased TSS level. Figure 5 shows the WQS 5 location.



Figure 5. Location of WQS 5.

WQS 6 and WQS 7 as shown in figures 6 and 7 somehow recorded the same Class III level with WQIs of 63.94 and 66.46, respectively. Even though both stations recorded the same water quality level, somehow the index indicated some improvements. This is due to the decreasing AN content in the water from 1.74mg/l to 0.92mg/l. Both WQS 6 and WQS 7 are located in the middle of the Segamat town and there was no contamination from AN since the land use along the river was changed from agricultural to urbanisation.

Even though the AN recorded some decreasing amount, COD and TSS had increased. Both the COD and TSS levels increased from 37.00mg/l to 40.00mg/l and from 124.00mg/l to 163.00mg/l, respectively. The increased COD and TSS levels were caused by the effluents discharged by human activities such as small industries, restaurants, food stalls, wet markets, and grocery stores.



Figure 6. Location of WQS 6.



Figure 7. Location of WQS 7.

WQS 8 as shown in figure 8 is the final water quality station along Segamat River and located at the meeting point of the Segamat and Muar Rivers. The water quality at this station was recorded as Class IV with WQI at 40.33 and classified as polluted and highly contaminated while at WQS 8, the water was recorded to be contaminated with high BOD, COD, TSS, AN levels and low DO content. TSS was tremendously increased from 163.00mg/l to 381.00mg/l, followed by COD and BOD which increased from 40.00mg/l to 51.00mg/l and 13.00mg/l to 15.00mg/l, respectively. The AN level also increased from 0.92mg/l to 1.14mg/l while DO was drastically reduced from 6.11mg/l to 2.71mg/l. Normally the DO level decreases with the increasing pollution levels.



Figure 8. Location of WQS 8.



Figure 9. Location of Settlements Area Between WQS 7 and WQS 8.

The WQS 8 water quality was badly affected due to its location at the end of the Segamat River. The upstream flow has brought together all contaminants before discharging them into the Muar River. The increasing TSS level was due to the silt accumulation from the river upstream where the surface water runoff brought along all sand and silt and deposited them in the river. Studies also proved that pollution levels, including TSS were linked to urban catchments which were strongly related to the type of land use [15]. Agricultural activities were also identified as the major contributors in worsening the situation. Apart from that, settlements located between WQS 7 and WQS 8 were also indicated as reasons for the decrease in river water quality as shown in figure 9.

3.2. Segamat River water quality condition during wet season

During the wet season, table 5 and figure 3 show that the Segamat River water quality was mostly classified as Class III at each station, except for WQS 4 and WQS 8 which were recorded to be at Class II. The WQIs for WQS 1, WQS 2, and WQS 3 were 68.47, 75.60, and 66.24, respectively. WQS 1 showed a high contamination level with BOD and COD recorded to be 16.00mg/l and 48.00mg/l, respectively. Agricultural runoff, waste from wastewater treatment plants, and failing septic systems were identified to contribute to the high BOD reading [16].

The same situation also occurred in WQS 2 and WQS 3 where BOD indicated a high contamination level with a reading of 5.00mg/l at both stations. The high BOD reading was caused by the stations' locations and on-going activities in the catchment area. Palm oil plantations are the main activity in this area, whereby during the wet season the surface water runoff brings along all the agricultural wastes and deposits them into the river. The surface water runoff from the plantation areas was categorised as the non-point sources, which normally contain pollutions from soil erosion, organic matter, manure, fertilizer, and pesticides [17].

This type of pollution is identified to be the significant sources of high BOD reading [18]. WQS 4, which is located further downstream of the Segamat River, also recorded a high BOD level of 12.00mg/l, followed by COD with a concentration of 38.00mg/l. Although WQS 4 is located at the meeting point between the Segamat River and Juasseh River, the additional flow from Juasseh River did not affect the contamination in that particular area, thus WQI for WQS 4 was recorded as 76.56.

The contamination somehow slightly changed at WQS 5. Even though it was still recorded under Class III with WQI of 69.31, this station recorded a drastic increase in TSS level from 39.00mg/l to 201.00mg/l and a slight decrease in the BOD level from 12.00mg/l to 8.00mg/l as compared to the previous station. From the on-site observation, there were palm trees re-planting activities being carried out in some areas nearby the station, which was related to the high TSS reading.

When entering the Segamat town area, water quality was still maintained at Class III with the WQI of 67.92 at WQS 6. This recorded an increased AN level from 0.07mg/l to 1.43mg/l. This is the reason why the water class level still remained the same even though there was a decrease in some of the parameters, such as BOD, COD, and TSS. From the site observation, the increased AN level in WQS 6 was due to the leachate which flows into the river through drains and culverts. During the site visit, it was observed that the Segamat town still practises an open channel system which collects wastes before transporting them into the Segamat River. This is the reason why the AN level was slightly increased at this station.

Meanwhile, WQS 7 also remained in Class III with lower WQI as compared to WQS 6. WQS 7 recorded a WQI of 51.77 as compared to 67.92 at WQS 6. The decrease in WQI at this particular station was recorded simultaneously with the increase in BOD, COD, and TSS levels as compared to the previous station. Even with the increase in certain parameters, AN recorded a slight reduction in the reading of 1.43mg/l to 0.08mg/l.

The decrease of AN contained in the Segamat River was observed because of the dilution from the Kapeh River. Kapeh River is one of the Segamat River tributaries, which meets the Segamat River near WQS 6. Despite the reduction of AN content in the Segamat River, the flow from the Kapeh River was also observed to contribute to the increased COD from 10.00mg/l to 33.00mg/l, BOD level from 3.00mg/l to 12.00mg/l, and TSS level from 100.00mg/l to 137.00mg/l. Studies also proved that highly

contaminated leachate is also one of the major contributors to the increase in COD level [19]. Apart from that, the contamination also came from effluent discharged into the river through the outlets along the Segamat River.

WQS 8, which was the last station before the water flow into the Muar River was recorded as Class II with WQI at 75.62. There was a huge difference between the water quality during the dry and wet seasons. It was observed that water from the Muar River somehow had affected water quality results since there was a process of water mixing between the Muar and Segamat Rivers near the station. The contamination was believed to be diluted by the Muar River, causing a decrease in BOD, COD, and TSS concentration. Studies by Nguyen Quang Trung in the Nhue Irrigation System proved that the mixing of water between two rivers has the capability to reduce the pollutants contained in the river [19]. The concentration of BOD decreased from 12.00mg/l to 3.00mg/l, COD from 33.00mg/l to 11.00mg/l, and TSS from 137.00mg/l to 124.00mg/l, respectively. However, there was a slight increase in AN reading from 0.08mg/l to 0.62 mg/l.

4. Conclusion

After observations were carried out in both seasons, it can be concluded that the water quality during the dry season was slightly better as compared to the wet season. However, urban activities at the Segamat town area had deteriorated the water quality from the town area until its discharge point at the Muar River. It was also observed that during dry season, the Segamat River contamination was mostly from the Segamat town effluent discharged directly from the outlets located along the river. It was also recorded that the point sources were dominating the pollution at Segamat River during dry season. Since there was only a small amount of surface runoff during the dry season, the non-point sources in the river upstream had less impact on the water quality along the Segamat River. However, due to the lack of water flow, the downstream part of the Segamat River recorded a high contamination and was considered polluted before the water was discharged to the Muar River.

However, during the wet season, the water quality was impaired from the river upstream. The non-point sources were observed to be the reason of this impairment since the major activities in the Segamat River upstream are agricultural. During the wet season, the surface water runoff capacity increased which brought along all the debris such as soil, rotting trees, fertilisers, pesticides, and rotten oil palm fruits into the river. All of these waste materials will contribute to the high BOD and TSS levels and put the Segamat River into Class III from the upstream. The situation becomes worse when the river enters the Segamat town area through the outlets that drain their effluent directly into the river. However, the water quality seemed to improve at the discharge point from the Segamat River to Muar River. Although the water quality had improved, it was observed that the mixing processes between these two rivers contributed to the dilution of the contamination in the river.

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