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Evaluation of Water Quality Index (WQI) in the Estuary of Sungai Ayam, Batu Pahat, Johor

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Abstract: Water quality analysis is an essential part of environmental monitoring. When water quality was poor, it had a detrimental effect on aquatic life and the surrounding ecology. These measurements could also help restoration efforts or ensure that environmental standards were followed. The Water Quality Index (WQI) was used to determine the classification and status of a river, dependent on the value of each parameter's sub-index. The study was conducted to determine the water quality index defined by INWQS and analyse the impacts of human activities that resulted in water quality deterioration in the Estuary of Sg. Ayam, Batu Pahat, Johor. The process of this study will involve six parameters of water quality which are dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), Suspended solids (SS), ammoniacal nitrogen (NH_3-N), and pH. The result from the analysis of this study shows that human activities from the wet market, fishing and boating activities located near the estuaries had a significantly give impact on the water quality of the estuary. The result obtained shows that the water quality of the estuary has poor quality as the Water Quality Index (WQI) in all observations was Class IV at Points A (45.1), B (46.5), and C (50.5). Therefore, it concludes that the Quality of water in the estuary of Sungai Ayam was polluted according to the Water Quality Index classification.

Keywords: Water Quality Index, Estuary, Human Activities

1. Introduction

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Estuaries can be defined as a part of coastal water where the mouth of the river meets the ocean [1]. Coastal plain estuaries, or drowned river valleys, arise as rising sea levels flood existing river valleys. In estuaries, water flow transports organisms, circulates nutrients and oxygen, and transports sediment and pollutants. Because estuaries are transitional zones between land and sea and between freshwater and saltwater habitats, they may be severely influenced by various human-caused or anthropogenic activities. Kampung Sungai Ayam is a famous tourist destination due to its exceptional local food. Apart from the houses of the locals, there are also morning markets and restaurants along the estuary. The remnants of garbage from the activity can be seen in this village. For example, plastic bottles, food plastic, food waste and other similar material. Such waste materials can affect river water quality, threaten marine life, and the probability of water pollution is high.

Estuaries are precious natural resources that must be appropriately monitored to ensure the survival of the animals and plants that rely on them. Estuaries are home to thousands of birds, animals, fish, and other wildlife. They depend on them for survival, nutrition, and reproduction. It is a habitat that paradoxically provides unique ecosystem services to benefit humanity and sustain marine ecosystem health, such as retaining toxins in its sediments. It includes nursery grounds for marine fish and feeding grounds for migrating birds [2]. Numerous marine creatures, particularly those utilised for commercial fishing, are dependent on estuaries at some point in their lives. Because estuaries are biologically active, migratory birds use them as resting and refuelling areas. Numerous fish and animals rely on estuaries' protected waters and land areas as breeding grounds. Estuaries have very great commercial significance. Their resources make tourism, fishing, and recreational activities more economically beneficial. Ports and harbours, essential to the shipping and transportation industries, are supported by the protected coastal waters of estuaries.

The pollution of estuaries could have a massive impact on the local communities that make an estuary a place to make a living. Enough conversion through draining, filling, damming, or dredging threatens estuary habitats. Prior to the last few decades, many estuary habitats were drained and converted to agricultural land. Many of the world's remaining estuaries have been severely polluted by pollution. A study conducted by Mitiku [3] stated that many factors can contribute to the deterioration of water, such as domestic sewage, deforestation, flooding, toxic waste disposal, urbanisation, marine dumping, heavy metals, plastics and polythene [3].

Due to human activity, river flow, tides, and the flora and fauna that inhabit estuaries change. For example, a study conducted by Niu et al. [4] states that the release of a heavy metals has caused a disturbance in the estuary, which affect the quality of water [4]. The release of these heavy metals has increased the concentration of Cu, Zn, Pb and Cd. Pollution began to occur everywhere, posing numerous disadvantages to living things.

A healthy environment greatly influences human health, life, and other living things. A healthy environment provides clean air and water, sanitation, and new green spaces that enhance the life quality of human beings. Karnan et al. [5] proved it by studying the impact of lockdown on the environment quality along the Indian coast and the tropical estuaries (Zuari Estuary) [5]. In 2019, the outbreak of COVID-19 disease had a significant impact on all industries worldwide. This scene has forcefully stopped the industry from operating to prevent the outbreak from spreading. This action has stopped human activity (commercial and industrial activity) and positively impacted the quality of the environment.

This research aims to determine the water quality index defined by INWQS and to analyze the impacts of human activities that resulted in water quality deterioration in the Estuary of Sg. Ayam, Batu Pahat, Johor based on the observation on-site and the result obtain from the WQI

2. Materials and Methods

2.1 Study area and sampling points

The chosen study area is at Sg. Ayam, Batu Pahat, Johor with coordinates 1°45'23.2" N and 102°55'54.0" E which is located in Kampung Sungai Ayam Laut. The study was conducted near the port area of the village, where most of the fisherman's boats are tied to the dock in the area, at the three distinct places along with the Sg. Ayam estuary, water samples from four observations were collected. The sampling places were chosen upstream (Point C), in the middle stream (Point B) in the home area of the villagers, and finally the downstream (Point A) towards the open sea.

Figure 1: Sampling point location

2.2 Sample collection

One liter of water sample will be taken five times for every point. First, the sample is collected 10 cm below the surface, away from the edge, at predefined spots using telescopic sampling equipment. The water samples then were directly brought to the laboratory for some experiment.

2.3 Data analysis

Water quality analysis is essential since water is regularly used in our everyday lives. Malaysia's Department of Environment (DOE) utilizes the Water Quality Index (WQI) to assess river water quality [6]. The WQI is mainly based on six fundamental parameters, which are dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), ammoniacal nitrogen (AN) and suspended solids (SS) [7]. The analysis consists of three steps: identifying the sub-index (SI) equation based on parameter value, calculating the sub-index (SI) for each parameter, and calculating the water quality index. The formula is as follows:

$$WQI = 0.22SIDO + 0.19SIBOD + 0.16SICOD + 0.15SIAN + 0.16\,SISS + 0.12\,SIpH \quad Eq.1$$

Table 1: Best-fit equations for estimating various Sub-Index values [8]

Subindex, SI	Equation	Ranges
Dissolved oxygen, SIDO	= 0 = 100 = -0.395 + 0.030 x^2 – 0.00020 x^3	For x ≤ 8% For x ≥ 92% For 8% < x < 92%
Biochemical oxygen demand, SIBOD	= 100.4 – 4.23 x = 108$e^{-0.055x}$– 0.1	For x ≤ 5 For x > 5
Chemical oxygen demand, SICOD	= -1.33 x +99.1 = 103$e^{-0.0157x}$– 0.04x	For x ≤ 20 For x > 20
Ammoniacal nitrogen, SIAN	= 100.5 – 105 x = 94$e^{-0.537x}$– 5 abs(x-2)	For x ≤ 0.3 For 0.3 < x < 4
Suspended solids, SISS	= 97.5$e^{-0.0067x}$= 0.05x	For x ≤ 100

	$= 71e^{-0.0016x} - 0.015x$	For 100 < x < 1000
	= 0	For x ≥ 1000
pH, SIPH	$= 17.2 - 17.2x + 5.02\,x^2$	For x < 5.5
	$= -242 + 95.5x - 6.67\,x^2$	For 5.5 ≤ x < 7
	$= -181 + 82.4x - 6.05\,x^2$	For 7 ≤ x ≤ 8.75
	$= 536 - 77.0x + 2.76\,x^2$	For x ≥ 8.75

Table 2: Classification of Water Quality Index [8]

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
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

Table 3: Water Quality Classification based on Water Quality Index [8]

Sub-Index & Water Quality Index	Index Range		
	Clean	Slightly Polluted	Polluted
Biochemical Oxygen Demand (BOD)	91-100	80-90	0-79
Ammoniacal Nitrogen (NH_3-N)	92-100	71-91	0-70
Suspended Solids (SS)	76-100	70-75	0-69
Water Quality Index (WQI)	81-100	60-80	0-59

3. Results and Discussion.

3.1 pH

Figure 4.1 shows the average pH reading based on three locations in the water sampling area. The average for the first observation at Point A, Point B and Point C were 7.21, 7.12 and 7.05. Based on the second observation, the average reading calculated for Point A, Point B and Point C were 7.35, 7.21 and 7.02, respectively. While for the third observation, the pH reading for Point A, Point B and Point C were 6.99, 6.96 and 6.65, respectively. Next, the fourth observation shows the pH reading of 7.42, 7.19 and 7.0, respectively. Thus, we can see that the pH reading was more acidic during low tide compared to high tide. From the graph chart in the figure, Point A has the highest pH value in every observation. The reason could be that Point A is near the village's main dock or pier, and Point B is near the school and rows of a housing areas. The water sample at Point A is more alkaline due to a lower concentration of hydrogen ions because sea water is slightly alkaline in nature, and the high tide condition during sampling may also affect pH reading [9]. While the solvent washing activities in the residential and restaurant may have enhanced the alkalinity of the river at Point B. The fewer human activities contributed to Point C slightly in the pH reading because the activities did not really affect the amount of hydrogen ions in the river.

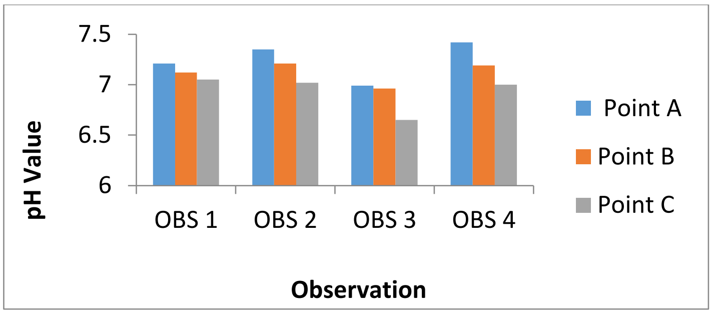

Figure 2: pH pollutant profile along the estuary of Sg. Ayam

3.2 Suspended Solids (SS)

Figure 3 shows that the third observation of SS has a higher reading value than the other observation because of the low tide condition. The SS levels were larger during low tide than during high tide. Depending on the river's flow during the tide, the concentration of organic and inorganic components in the river may rise or decrease as the river's volume fluctuates during high and low tides. This result confirmed Kamarudzaman et al. [10] observation's that SS levels were lower at high tide than at low tide. This occurred due to the river's movement from the sea upwards at high tide and back to the sea during low tide. Solids in water either exist in a real solution or are suspended. Because they are so little and light, solids in suspension remain suspended. The turbulence caused by wind and wave action in imprisoned water, or the movement of water in motion, helps to keep particles suspended. When turbulence decreases, coarse materials swiftly settle to the bottom of a body of water. However, very minute particles may exhibit colloidal qualities and can remain suspended in still water for extended durations. The SS parameter was widely used as a reference to the production of materials such as sand, silt and other domestic waste from cleansing an area and development done for various human activities [11]. SS values may result from soil erosion, runoff discharges, or agitated bottom sediments. Higher concentrations of suspended particles also could cause by the discharge of debris such as silt and decaying animal species from wet markets and food waste from restaurants that enters the surface water [12].

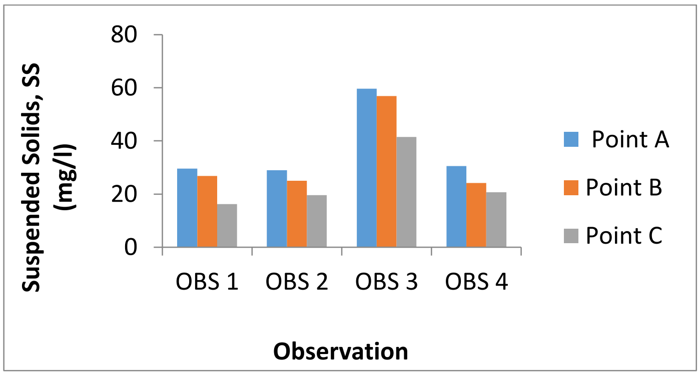

Figure 3: SS pollutant profile along the estuary of Sg. Ayam

3.3 Chemical Oxygen Demand (COD)

Figure 4 shows that the third observation of COD has a higher reading value than the other observation because of the low tide condition. The concentration of COD was larger during low tide than during high tide. As the concentration of organic material increases, so does the COD. Inorganic components susceptible to oxidation by the oxidant (usually dichromate) also increase the rate of oxidation. High COD water often contains a high concentration of decomposing plant debris, human waste, or industrial effluent. Point B has the highest concentration of COD compared to the other sampling location. It was because the wastewater discharges from the restaurant, village house and school may have increased the concentration of COD in the stream [13]. The increasing COD value may be attributable to human activities and residential growth near the river. Due to a wet market at

Point A, the COD content is lower yet more remarkable than at Point C. The wet market contributes to pollution due to the release of extra organic pollutants into the river from the wet market operations.

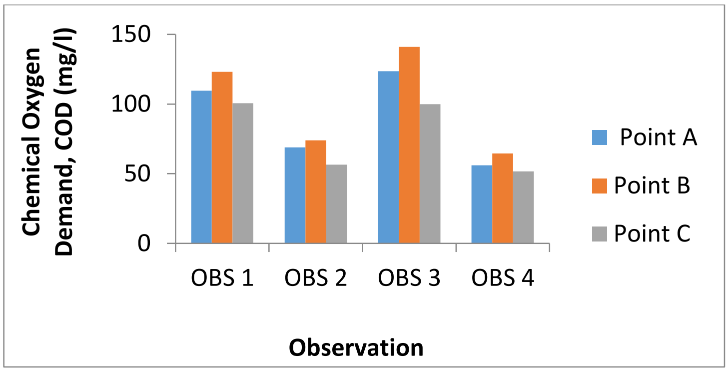

Figure 4: COD pollutant profile along the estuary of Sg. Ayam

3.4 Biochemical Oxygen Demand (BOD)

Figure 5 shows that the third observation of BOD has a higher reading value than the other observation due to the low tide condition. The concentration of Dissolved Oxygen in the water sample was more significant during low tide than during high tide. BOD has an immediate effect on the concentration of dissolved oxygen in rivers and streams. The higher the BOD, the quicker oxygen is lost from a stream. Inadequate segregation, handling, and collection of solid wastes, particularly in the chicken slaughtering, de-feathering, and fish scaling sections, exacerbates the problem, as does the spillage from garbage bins, which, in addition to the routine washing activities, discharges directly into drains carrying with it a large quantity of solids. This means less oxygen is available to aquatic life forms with a greater metabolic rate. Point A has the highest concentration of BOD compared to the other sampling location. It may be caused due to the discharge of organic materials from the wet market activities. The greater COD:BOD ratio of wet market sullage can be due to the large proportion of raw protein matter, which is less readily biodegradable [18]. Point B also shows a higher value of BOD compared to Point C, where the organic waste may also be produced from the restaurant and school cafeteria near the streams.

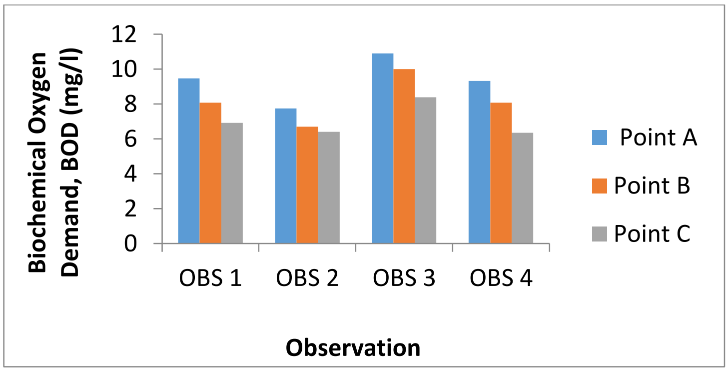

Figure 5: BOD pollutant profile along the estuary of Sg. Ayam

3.4 Dissolved Oxygen (DO)

Figure 6 shows that the third observation of DO has a lower reading value than the other observation because of the common tide condition compared to the DO level during high tide. BOD has an obvious impact on the concentration of dissolved oxygen in rivers and streams. The higher amount of organic matter to decompose, the quicker oxygen is lost from a stream. This reduces the amount of oxygen accessible to aquatic organisms. Point A has the lowest DO level compared to the other sampling location. It was because it was located downstream of the river. Point A was situated near the open sea, where the water containing large quantities of dissolved minerals, such as salt, will have a lower DO content than freshwater [14]. When dissolved oxygen levels fall too low, fish and other aquatic animals are unlikely to survive.

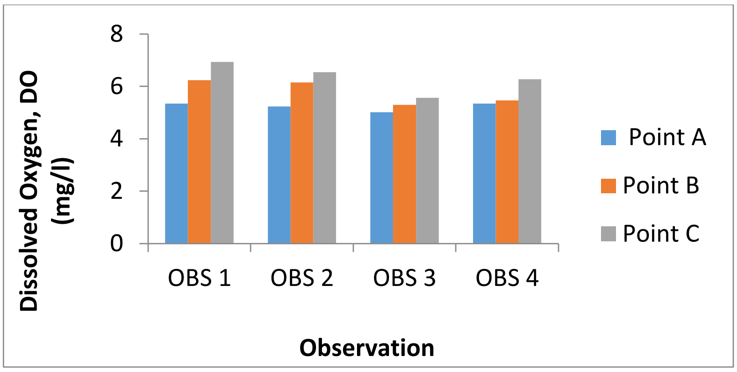

Figure 6: DO pollutant profile along the estuary of Sg. Ayam

3.5 Ammoniacal Nitrogen (NH_3-N)

Figure 7 shows that the third observation of NH_3-N has a higher reading value than the other observation because of the low tide condition. The NH_3-N value was higher during low tide than during high tide. Direct sources of ammonia include municipal effluent discharges and the excretion of nitrogenous wastes by animals while the indirect sources include nitrogen fixation, air deposition, and runoff from agricultural fields. Point A has the highest concentration of NH_3-N compared to Point B and Point C. It was because the wastewater from the wet market might enhance the concentration of ammonia in the river water [15]. The majority of seafood was processed at shore-based facilities close to ports, and the majority of marine product biowaste comes from fish. For example, during the processing of demersal fish, the viscera, frame, skin, and head are often eliminated. In addition, these effluents contain excrement, antibiotics, fish feed, and protein-rich components that can be repurposed as animal feed or manure [19]. However, fish processing effluents are frequently dumped straight into the stream, having negative effects on the aquatic ecology. As, the village's main activity was located at Point A, a higher concentration of ammonia was produced. While Point B has a higher concentration of ammonia than Point C, as wastewater from the residential and school area may contribute to the higher concentration of ammonia. The elevated concentration of ammonia in water may come from residential areas, organic debris, and faeces [16]. Thus, the components of wet market biowaste, including as moisture, organic carbon solids, and elements like potassium, was obviously have a significant impact on the river's water quality.

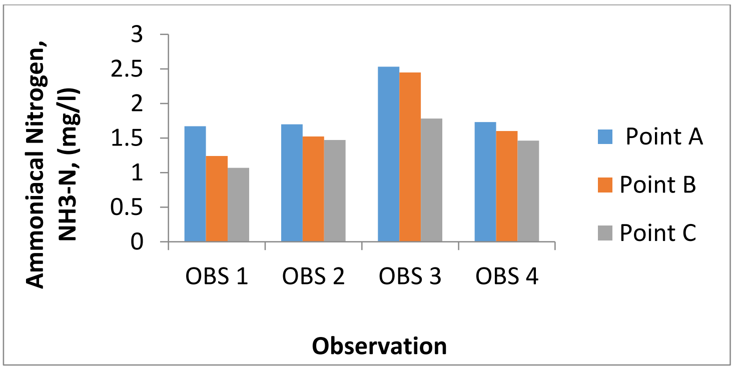

Figure 7: NH_3-N pollutant profile along the estuary of Sg. Ayam

3.6 Data Analysis

Table 4 shows the result of the WQI of Estuary of Sg. Ayam. The sub-index from the 6 parameters was used to obtain the WQI value, whereas the required sub-index were SIpH, SISS, SIAN, SIBOD, SICOD and SIDO. From the WQI value obtained, the river water quality status was classified according to the Department of Environment (DOE) Water Quality Classification shown in Table 3.

Table 4: Water Quality Index of Estuary of Sg. Ayam

Observation	Sampling Location	Sub-Index						WQI
		SIDO	SIBOD	SICOD	SIAN	SISS	SIpH	
1st	A	0.0	63.2	14.1	37.8	81.3	98.6	44.8 (Class IV)
	B	0.0	68.4	10.0	50.0	82.7	98.9	47.2 (Class IV)
	C	0.0	73.1	17.2	55.6	88.1	99.2	51.0 (Class IV)
2nd	A	0.0	69.8	32.1	37.0	81.6	97.8	48.7 (Class IV)
	B	0.0	74.0	29.3	41.7	83.6	98.6	50.2 (Class IV)
	C	0.0	75.3	40.2	43.1	86.4	99.3	52.9 (Class III)
3rd	A	0.0	58.2	9.8	19.4	68.1	99.6	38.4 (Class IV)
	B	0.0	61.3	5.62	20.8	69.2	99.6	38.7 (Class IV)
	C	0.0	67.2	17.4	35.0	75.8	98.1	44.7 (Class IV)
4th	A	0.0	63.7	40.5	36.2	80.9	97.3	48.6 (Class IV)
	B	0.0	68.4	34.8	39.6	84	98.7	50.0 (Class IV)
	C	0.0	75.5	43.7	43.4	85.8	99.4	53.5 (Class III)

The average value of WQI for the three sampling locations of Point A, Point B, and Point C in all observations were 45.1, 46.5, and 50.5, respectively, which gives Class IV in accordance with the WQI standard. The index range for these points was 0-59, indicating that the river water was polluted. Based on the observations, the primary factor that caused the estuary to be categorized as Class IV was the wet market activities carried out in the morning until noon, residential area, school cafeteria and boating activities located in the estuary area. Observations found that waste disposal from morning market activities, boating activities and restaurants contributed to the increasing concentration of ammonia and COD. Furthermore, the disposal of organic waste in water was one of the factors in increased ammonia concentration in water. In addition, a high concentration of ammonium nitrate (AN) in a river can negatively affect aquatic life, as increased levels of organic waste can lead to eutrophication issues [17]. Besides, the dumping of untreated sewage from restaurants, food stalls and other recreational activities produced by human activities located at the Estuary of Sg. Ayam will cause a high COD. According to a study by Mohmadisa et al., 2018, the emission of residential garbage from restaurants and food stalls has increased the demand for oxygen to break down waste [11]. These effects on estuaries contribute to the loss of habitats for estuarine animals and plants and detract from our coastal shoreline’s recreational value and aesthetic appeal. They also endanger the function of estuaries in sustaining the health of coastal waters.

4. Conclusion

The water quality index (WQI) evaluation in the Sungai Ayam Estuary in Batu Pahat, Johor, has met its objective. The average readings for each parameter at each of the three locations in every observation are approximately equal and belong to the same class. The average WQI class of each parameter for DO, BOD, COD, AN, SS and pH were 5.79 mg/l (Class II), 8.20 mg/l (Class IV) , 89.1 mg/l (Class IV), 1.69 mg/l (Class IV), 31.6 mg/l (Class II), 7.10 (Class V). The Water Quality Index (WQI) in all observations was Class IV at Points A (45.1), B (46.5), and C (50.5) even during the high tide and low tide conditions, with the majority of activities affecting the water quality concentrated at Points A and B. According to the Water Quality Classification, this signified that the river was polluted. The river's water quality is affected by the activities near the estuaries. Furthermore, land usage along the estuaries might impact river pollution. The discharge of effluents from residential and market zones along the estuaries into the river, from upstream to downstream, is not efficiently cleaned before being released into the river, contributing to river pollution. In addition, the tendency of trash by locals contributes to the polluting of the river. As a result, a rise in the river's water quality index should be achieved by enhancing the local community's understanding of river pollution, its origins, and how to prevent it. Local authorities must also take action to minimize pollution in the river.

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