Research Article

Assessment of Water Quality Degradation Due to Waste Dumping and its Impacts on Ichthyo-Diversity of River Swat

Tanveer Shahzad[1], Syed Basit Rasheed[1], Zaigham Hasan[1], Muhammad Yousaf*[2], Akhtar Rasool[2], Tanzil Ur Rahman[2], Aqib Javed[2], Hina Jabeen*[3]

[1] Department of Zoology, University of Peshawar 25120, Pakistan
[2] Centre for Animal Sciences and Fisheries, University of Swat 19200, Pakistan
[3] Department of Biotechnology, Women University Mardan, KPK,

*Correspondance email: dyousaf@uswat.edu.pk (MY), Email: dr.hinajabeen@wumardan.edu.pk (HJ)

Abstract: To trace the relative change in water quality parameters of River Swat due to unplanned dumping of municipal wastes and pollutants addition as a result of various unlawful anthropogenic activities, a preliminary study was designed. Water sampling was carried out from various sites along the length of River Swat i.e. Bahrain, Mingora and Barikot from November 2017 to October 2018. Laboratory analysis of various parameters was carried out and compared with standard parameters as set by USPHS and WHO. The parameters studied at different marked sites were pH (5.69-8.90). The pH did not vary significantly among the collection points of the study area ($P < 0.05$). The total Dissolved Solids observed were (11.67-335 mg/l) and a significant increase in TDS and conductivity has been observed ($P<0.05$) as we move downstream. The dissolved Oxygen recorded was (9.3-5.7) decreasing downstream ($P>0.05$), total Hardness as $CaCO_3$ recorded was (2.05-163.11 mg/l), and showed a gradual increase downstream (33.7-172.8), the minimum value (2.05 mg/l) was observed at BH-UP while the maximum value of 222.63 mg/l was observed for BR-MP. The increase in hardness has been observed to be significant ($P<0.05$) in relation to BR-UP, the least polluted site of the study area. The increase in alkalinity among various collection points was found significant ($P<0.05$) as we move downstream and the total Alkalinity as $CaCO_3$ were (17.19-287.4 mg/l), Sodium (1.50-121.40 mg/l). The Conductivity recorded was (28-533.3 μS/cm) and a significant increase in TDS and conductivity has been observed ($P<0.05$) as we move downstream. An increase in inorganic substances like Calcium (22.3-112.1 mg/l), Sulphates (7.35-22.3), Potassium (1.59-6.59), Magnesium (11.6-47.8), Chlorides (7.85-25.1) sodium (6.04-22.18) and TSS (5.56-7.48) has been observed with the addition of effluents and solid waste to the water of the river. This increase was maximum at MN-MP and downstream. This increase has been observed to be significant ($P<0.05$) except for sodium as sampling proceeds downstream. Among all the parameters recorded, Calcium as $CaCO_3$, Total alkalinity, Potassium and Magnesium hardness showed elevation than the normal permissible limits. All these elevated parameters add hardness to the water. The breeding ground of fish has also been threatened by the uncontrolled emission of solid industrial and municipal excreta into water.

Keywords: Ichthyo diversity, Wastwater concerns, Waste dumping, Water assessment

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1. Introduction

Water is an essential component for the survival of life in the biosphere, it is also important for agriculture, goods transportation and other human needs. Being a vital part of life, water faces several challenges in the form of poor management and poor sustainability. Therefore, monitoring the water bodies' quality at regular intervals is mandatory [1-2] The current tendency of urbanisation and industrialisation might be adding to the poor water quality not only by disposal of industrial effluents and toxicants but also solid wastes, which are posing a major threat to the existence of a healthy aquatic ecosystem required not only for the survival of human race but aquatic life also. Mostly solid waste is dumped without any technical criteria or measures to minimize its harmful effect on the environment. Open dumping of solid waste along riverbanks and other water bodies is one of the major threats the aquatic life is facing for its sustainability [3] and leads to enormous pressure on water bodies in the form of pollutants, directly and indirectly, affecting the fauna and flora of aquatic ecosystem [4].

In Pakistan, the average solid waste generation is 0.4475 kg/capita/day, with a growth rate of 2.4% per year. Like other developing countries 51 to 69% of this is burned in the open, while the remaining are discarded in open space or added directly to water bodies like ponds, stagnant water bodies or even rivers. Such an addition of contaminants directly destroys the breeding ground of fish and acts as a hotspot for various arthropod-borne diseases [5-6]. Municipal authorities hardly manage to collect only 60% of the total waste being dumped while the rest goes untreated [7]. This management of solid wastes is an issue of greater concern since waterborne diseases result in the deaths of an estimated 2.5 million people each year in Pakistan [8].

The Indus Riverine System covers an area of about 1.12 million km^2 area, of which 47% lies in Pakistan and River Swat is one of the main tributaries of this riverine system [9]. River Swat originated from the Hindu Kush mountains of Swat Kohistan and moved across different Districts of the Malakand Division including Swat, Dir Lower and Malakand before joining River Panjkora. The river has great volume during summer due to melting glaciers and snow, which are the main water source of River Swat. The development of tourism and commercial businesses along the length of River Swat has resulted in the increase of pollutants in the form of effluents and solid waste. These anthropogenic activities are affecting the water quality of River Swat, which may pose a threat to aquatic life and human health. Along with solid waste deposited by tourists and hotels located on the bank of River Swat, the Tehsil Municipal Administration (TMA) of Babuzai (Mingora) along with other Tehsil municipalities are also using the riverbank for dumping municipal solid waste materials. Moreover, the presence of heavy metals has been reported in the fish of River Swat [10-12].

This study aimed to estimate the impact of pollutants on the water quality of River Swat and to compare the distortion in water quality among different areas/sections/segments of River Swat. By taking the water, parameter data all year around this study has also tried to evaluate the effect of water flow on the mixing of contaminants in the river as the river has maximum volume during rainy season, which decreases during winters.

2. Materials and Methods

Study Area

For the current study water samples were collected from River Swat during 2017 and 2018 for a year (November to October). Three different collection locations were selected across District Swat including Bahrain, Mingora and Barikot. Three collection points for each location were selected i.e. upstream (US), midpoint (MP) and downstream (DS), 2-3 kilometres apart (Table 1) to check the pollution impact and its dilution. These sampling points were chosen based on maximum public use and high pollutant dumping. Among these locations, Bahrain is a famous tourist attraction site and is part of the upper part of River Swat with less pollution issues. However, Minogra is an administrative centre of swat with a huge population and industrial structure. The Mingora collection site on the River Swat (Takhta Band) is the main dumping point for municipal solid waste and sewage water. The third location Barikot has the same situation as Mingora

Table 1: Collection sites with catchment population, sampling points and their GPS coordinates used for water quality analysis in District Swat

S. No.	Collection Site	Sampling points	GPS Coordinates	
		Upstream (BH-US)	35° 12' 44.064'' N	72° 33' 6.336'' E
1.	Bahrain	Midpoint (BH-MP)	35° 12' 21.240'' N	72° 32' 52.26'' E
	(332,908)	Downstream (BH-DS)	35° 11' 24.252'' N	72° 32' 20.29'' E
		Upstream (MN-US)	34° 47' 43.620'' N	72° 23' 49.92'' E
2.	Mingora	Midpoint (MN-MP)	34° 47' 30.768'' N	72° 20' 49.056'' E
	(2,210004)	Downstream (MN-DS)	34° 47' 12.084'' N	72° 18' 32.508'' E
		Upstream (BR-US)	34° 40' 43.233'' N	72° 11' 52.904'' E
3.	Barikot	Midpoint (BR-MP)	34° 40' 59.052'' N	72° 12' 51.3'' E
	(2,394004)	Downstream (BR-DS)	34° 42' 3.5172'' N	72° 15' 6.948'' E

SAMPLING METHOD AND ANALYSIS

The samples were collected in sterilized 1500 ml labelled (Collection site, date of the collection etc.) plastic bottles every month. A total of 108 samples were collected from all nine points during the study duration. To avoid microbial degradation affecting water quality parameters, the samples were transported in cold boxes to the Pakistan Council of Scientific and Industrial Research (PCSIR) laboratory in Peshawar, Pakistan for analysis. The biochemical properties of water samples were tested for dissolved oxygen (do), ph, calcium as caco3, sodium, magnesium, potassium, sulphates as SO4, Chloride as Cl, P- Alkalinity and Total Alkalinity, Total Hardness, Conductivity, and Total Dissolved Solids. The mean and standard deviation of each parameter for each sampling site were calculated and a graph for each parameter's monthly data was plotted by taking the mean and standard deviation of all three collection points of each sampling site to see the effect of season (summer and winter) on the water quality parameters. The means for each parameter at each sampling site were statistically analyzed by using a student t-test to see the difference between various sampling sites by taking the null hypothesis that the samples were not significantly different (α=0.05).

3. Results

River Swat is the main river of the Swat valley and huge population of the District Swat live across this river. Due to the urbanization in this valley, there is a serious threat to the freshwater biology of the River Swat. The range of values of water quality analysis reported for various sampling sites along river Swat are shown in Table 2 while the mean (±SD) of each collection point (Table 3). The study area lies in a subtropical area with a cold winter and hot humid summer. The river is fed by melting glaciers in summer, so water volume rises in summer thus river flow varies between the two seasons. By comparing the recorded data with the standard limits as set by WHO and USPH (Table 3) majority of the parameters are still within permissible limits, however, in Bahrain all parameters except total alkalinity were within the limits prescribed by WHO. At Mingora pH, TDS, sodium, sulphates, chlorides, TSS and conductivity were within the WHO permissible limits while the values of total hardness, potassium, calcium and magnesium were found to be more than the limits described by WHO. At Barikot total alkalinity, sodium, potassium, calcium and magnesium were more than the permissible limits while the remaining were within the permissible limits of WHO.

The pH of the collection points in the present study ranged from slightly basic to slightly acidic (Table 2). The lowest mean pH value was observed at BH-UP while the highest was observed at MN-US (Table 3). The highest and lowest pH values were recorded at Mingora. The pH did not vary significantly among the collection points of the study area (P < 0.05). However, Mingora was observed to be the most variable site while Bahrain was found to be the least variable site in pH fluctuation (Table 1). An acidic pH of 5.69 was observed at MN-MP where most of the effluents from the population fall into the river. MN-MP and MN-DS had the most variable pH of 5.69 to 8.9 due to the addition of effluents as well as municipal solid waste. pH among various collection points across the year varied more at Mingora as compared to Bahrain and Barikot. This was due to the mixing of municipal waste dumped on the banks of the river at Mingora. The lowest mean total alkalinity as $CaCO_3$ was observed at BH-DS while the highest total alkalinity was observed at BR-MP (Table 2). Total alkalinity varied a lot at Barikot ranging from 23.97 mg/l to 287.4 mg/l followed by Mingora (26.8 – 210 mg/l) while the least fluctuation was observed at Bahrain (17.19 – 53.72mg/l). The total alkalinity was within the range of USPH and WHO permissible limits. The increase in alkalinity among various collection points was found significant (P<0.05) as we moved downstream from Bahrain toward Barikot thus showing a decrease in water quality along the river due to the addition of sewage and solid waste to the river.

Table 2: Comparison of recorded parameters with standard limits

Parameters	Bahrain	Mingora	Barikot	USPH Limits	WHO Limits
pH	6.10-7.90	5.69-8.90	6.21-8.70	6.5-9.0	6.5-9.2
TDS	29.11-72.0	11.67-291.0	30-335.0	<400	500
DO	9.3	5.7	6.0	4.00	6.5 to 8.00
Total Hardness	2.05-68.54	20.34-163.11	11.79-222.63	10-400	150
Total Alkalinity as $CaCO_3$	17.19-53.72	26.80-210.0	23.97-287.4	10-400	0-40
Sodium	1.50-20.67	2.28-121.40	2.10-26.80	>5	0-200
Potassium	0.87-3.80	1.61-15.30	1.02-7.07	<5	10
Sulphates	2.01-29.21	7.18-40.11	7.04-56.10	250	100
Calcium as $CaCO_3$	10.01-37.81	11.23-188.0	7.86-172.57	4-160	75
Mg	4.14-30.73	5.86-118.20	1.96-72.72	<15	50
Chlorides	6.18-12.90	3.97-23.82	3.97-63.70	350	200
TSS	2.0-9.11	3.32-10.12	3.67-11.21	<80	NS*
Conductivity	40-110	50-210	28-533.3	3000	1000

*NS: No Standard

Dissolved oxygen concentration decreased gradually downstream from Bahrain reaching a minimum at Mingora, however, a constant increase in DO has been observed at all three collection points of Barikot (6.0 mg/l). Higher DO concentration has been observed at all collection points during winter months as compared to summer months. The DO concentration was affected by the amount of effluents and solid waste that enters the river. A decrease in DO has been observed with an increase in the addition of pollutants to the river.

An increase in inorganic substances like Calcium (22.3-112.1 mg/l), Sulphates (7.35-22.3), Potassium (1.59-6.59), Magnesium (11.6-47.8), Chlorides (7.85-25.1) sodium (6.04-22.18) and TSS (5.56-7.48) has been observed with the addition of effluents and solid waste to the water of the river (Table 3). This increase was maximum at MN-MP and downstream. This increase has been observed to be significant (P<0.05) except for sodium as sampling proceeds downstream. The values of these inorganic substances showed a maximum increase among the collection points of Mingora. The addition of these inorganic substances has been observed to be maximum during the summer months when the rain and glacier melting increase the volume of water in the river.

Total dissolved solid is the measure of all the organic and inorganic content present in water. The lowest mean TDS was observed for BH-US while the Highest was for BR-MP. A gradual increase in mean TDS has been observed as we moved from Bahrain towards Barikot (Table 2). A TDS fluctuation across the year was maximum for Barikot followed by Mingora, while the least fluctuation was observed for Bahrain (Table 3). The TDS values across months were more variable at Mingora as compared to Barikot and Bahrain. Conductivity is the index of the total ionic content of water bodies and is taken as an indicator to determine the freshness of water bodies [19]. The highest mean value among all the sites was observed for BR-MP while the lowest was for BH-US (Table 2). Conductivity values across various months fluctuated more in Mingora than in Barikot and Bahrain. A significant increase in TDS and conductivity has been observed ($P<0.05$) as we move downstream from Bhrain to Barikot.

The values of mean total hardness as $CaCO_3$ showed a gradual increase from Bahrain to Barikot (33.7 – 172.8). A minimum value (2.05 mg/l) was observed at BH-UP while a maximum value of 222.63 mg/l was observed for BR-MP. The increase in hardness has been observed to be significant ($P<0.05$) in comparison to BR-UP, the least polluted site of the study area. Total hardness was observed to be higher in river Swat water during the winter months as compared to the summer months.

Table 3: Recorded data during the study from all sites

Site	Sulphates as SO_4 [mg/l]	Calcium as Ca [mg/l]	TSS [mg/l]	TDS [mg/l]	Potassium as K [mg/l]	pH	TA as $CaCO_3$ [mg/l]	Conductivity [µs/cm]	Sodium as Na [mg/l]	TH as $CaCO_3$ [mg/l)	Magnesium [mg/l]	Chlorides as Cl [mg/l]	Dissolved Oxygen [mg/l]
BH-US	7.35±2.71	22.3±8.50	5.56±2.03	46.6±15	1.59±0.5	7.38± 0.27	34.5±14.8	66.7±18.8	6.04± 5.95	37.41 ±14	11.6 ±8.22	8.59±1.8	9.3±0.19
BH-MP	12.2±5	24.9±8.01	6.38±1.51	51.5±11.9	2.0±0.77	7.25± 0.41	33.9±11.5	67.9±19	7.69 ± 6.6	33.7 ±15.8	13.1 ±6.50	8.52±1.7	8.9±0.17
BH-DS	12.7±7.1	27.08±6.08	6.19±1.55	57.1±7.65	2.18 ± 0.85	7.42± 0.49	33.8±10.7	77.6±21	7.08 ± 6.1	38.45±10.8	12.7±5.7	7.85±1.6	8.6±0.34
MN-US	14.2±3.63	38.5±17.8	6.25±1.72	93±32.9	1.99 ± 0.34	7.64± 0.30	65.1±22.7	106.4±44.2	8.44±5.5	74.36±32	21.4±16.4	13.2±5.2	7.2±0.45
MN-MP	12±4.28	51±45.6	6.51±1.91	93.4±23.8	2.58 ± 0.91	7.58±0.87	62.1±15	118.8±20.3	12.98± 6.7	78.94±29.4	32.4±17.5	9.70±2.9	6.3±0.79
MN-DS	16±8.78	50.4±30	7.25±1.78	120.5±73.8	6.59±4.14	7.58± 0.62	76.9±53.3	160.9±63	22.18± 33.	82.67±49.8	33.8±33.1	11.5±3.6	5.7±0.83
BR-US	14±3.71	72±36	6.93±1.74	144.9±39.3	2.92±0.95	7.45± 0.45	76.1±28.1	177.6±30.6	11.75± 4.6	77.10±31	24.8±9.40	25.1±17.3	6.1±2.1
BR-MP	22.3±12.4	112.1±47.6	7.48±2.02	276.8±61.7	4.08±1.93	7.29± 0.34	143.1±44.7	372.3±140	19.61± 8.3	172.8±40.5	47.8 ±13.31	17±7.9	6±1.86
BR-DS	17.9±6.45	72.3±39.4	7.27±1.83	161.9±65.9	2.91±1.46	7.47± 0.61	139.6±23.8	219.5±92.6	10.18± 6.5	93.56±42.5	33.4± 12.84	10.7±6.8	6±1.67

1= BH-UP; 2= BH-MP; 3= BH-DS; 4= MN-UP; 5= MN-MP; 6= MN-DS; 7= BR-US; 8= BR-MP; 9= BR-DS; TSS = Total Suspended Solids; TDS = Total Dissolved Solids; Cl= Chlorides as Cl; TA= Total Alkalinity as $CaCO_3$; TH = Total Hardness; TA= Total Alkalinity; units; µs/cm = microsiemens per centimeter; mg/l = milligrams per liter.

4. Discussion

The current study was aim to analyze the biochemical parameters of the River at different sampling sites along river Swat. The study area lies in a subtropical area with a cold winter and hot humid summer. The river is fed by melting glaciers in summer so water volume rises in summer thus river flow varies between the two seasons. By comparing the recorded data with the standard limits as set by WHO and USPH (Table 3) majority of the parameters are still within permissible limits. The pH indicates the degree of alkalinity and a pH less than 7 indicates the acidity of the water. Aquatic organisms like fish require a pH of 6.5 – 8 for better growth [13] and a lower pH negatively affects their growth and reproduction. It has been observed that a pH of less than 5 can badly affect the growth of carp fish. In the current study, acidic pH has been observed at sites where the city effluents and municipal solid waste join the river i.e. at midpoint and downstream collection points of all three sampling sites. These slightly acidic pH values indicate the corrosiveness of water, which could be due to waste dumping as observed in the Brahmani River and Nambul River, India [14]. Previously a mean pH value of 6.7 was recorded for River Swat at Mingora [15] compared to the current mean of 7.6 for the same location.

Dissolved oxygen can act as an indicator of the environmental health of watersheds and is frequently used to evaluate water quality degradation due to industrial and municipal effluents [16]. DO and temperature are inversely proportional to each other due to which high DO values have been reported in winter as compared to summer at all sites of River Swat. DO is necessary for living organisms both plants and animals. Cold and semi-cold-water fishes are more sensitive to oxygen concentration and depletion of oxygen due to pollutants may badly affect the distribution and diversity of these fishes. DO levels below 4 mg/l may cause stress in fish and even lead to death in semi-cold-water fish. The present study reports oxygen levels within the permissible limit at all sampling sites for sustaining aquatic life in river Swat but a comparatively low level of DO has been observed at Mingora. The addition of sewage and municipal solid waste at MN-MP and downstream could be the reason for a decrease in DO concentration as also observed in Turag River, Bangladesh [17] and Sembilang River, Malaysia [16], where a reduction in DO concentration has been reported due to addition of pollutants from industrial areas. A little improvement in DO has been observed at the tail end of river Swat in Barikot (6.1 mg/l). The flow of water causes dilution of pollutants in water resulting in improvement of health of the water. This has been shown by the increase in DO at Barikot, which agrees with the observations reported by Chima and his coworkers for Asata River, Nigeria, where an increase in DO has been reported downstream due to a decrease in effluents and solid waste added to the river water [18].

An increase in inorganic substances was observed with the addition of effluents and solid waste to the water of the river. The values of these inorganic substances showed a maximum increase among the collection points of Mingora. The addition of these inorganic substances has been observed to be maximum during the summer months when the rain and glacier melting increase the volume of water in the river. The high value of these inorganic substances is an indication of pollution from solid waste [14].

The increase in TDS and conductivity could be attributed to the addition of pollutants in the form of effluents and solid waste. The increase in TDS along River Swat was observed downstream from Bahrain, which could be attributed to the mixing of solid waste as observed in River Nambul [14] and Cauvery River, Tamil Nadu [20] in India. The increase was marked at the waste dumping sites (MN-DS, BR-MP), indicating the presence of more salts in water due to the discharge of effluents and solid waste dumped along the river [21]. A similar observation has been reported from River Karnafuli [22], Turag River in Bangladesh [17] and River Asata in Nigeria (18). High concentration of TDS in water harms the flora and fauna of the aquatic environment. TDS affect the gills of fish and decreases the photosynthetic activity thus increasing the turbidity of the water [23]. The concentration of dissolved oxygen varies between various collection points. Maximum concentration was observed at BH-UP which was receiving the least pollutants due to low population while minimum concentration was observed at MN-DS which was the main municipal solid waste dumping site of the TMA.

The values of mean total hardness as $CaCO_3$ showed a gradual increase from Bahrain to Barikot (33.7 – 172.8). A minimum value (2.05 mg/l) was observed at BH-UP while a maximum value of 222.63 mg/l was observed for BR-MP. The increase in hardness has been observed to be significant ($P<0.05$) in comparison to BR-UP, the least polluted site of the study area. Total hardness was observed to be higher in river Swat water during the winter months as compared to the summer months. Previously a value of 21.6 mg/l has been recorded at Mingora [15], much lower than observed in our study. This shows that the health of River Swat has declined during the past couple of decades. Yousafzai *et al.*, recorded a water mean hardness of 118.75 mg/L of River Swat in the Charsadda District [24], while a mean hardness of 95 mg/L was reported by Muhammad *et al.*, (2016) at Batkhela, Malakand District [25]. The current study recorded water hardness of 222.63 in Barikot which is beyond the normal limits as prescribed by WHO and USPH. The increase in total hardness, calcium and magnesium values at Mingora and Barikot cannot be attributed to the dumping of solid waste along the riverbank but could be due to the direct influx of slurry produced by stone-crushing plants located in abundance at the bank of River Swat. Although the direct effect of water hardness on fish diversity is unknown however hardness contributes to mineral deficiencies in water bodies. However, such hardness causes gastrointestinal and kidney problems that may arise if used for domestic purposes [26-27]. Various pathways like runoff from agriculture fields, discharge from the groundwater and stormwater may result in the entry of various pollutants into the river system, the dumping of solid waste by TMA has shown a considerable physiochemical effect on the water quality of river Swat. The dumping of solid waste and the discharge of sewage water in the river has increased the inorganic concentrations of the river although it remains within the permissible limits prescribed by USPH and WHO.

The result of the current study highlights a gradual deterioration in water quality as we move downstream along the length of the river. Similarly worsening of these parameters is also linked with population increase along the progression of the river, specifically at sites where Tehsil Municipal Administration (TMA) load their waste products which not only affects the water quality but also destroys the breeding grounds of fish and act as nurseries for insect-borne diseases. The increase in contamination may also be linked to an increase in population along the riverbank. A gradual increase in population was recorded in Bahrain and Barikot. The population of Swat has increased by almost 100% as recorded during the 2017 census (2,309,570) which was previously recorded as 1,257,602 during the 1998 census, by the Statistical Bureau of Pakistan. Three tehsils, understudy, add contaminants directly to water bodies as they have their headquarters on the bank of River Swat. However, Kalam is the tehsil with the least population, lying upstream of Bahrain, and having the origin of River Swat. Due to this least population, all water quality parameters lie within permissible limits, though a little fluctuation was observed due to tourist influx during the summer. This impact on the population is also been observed by Liyanage and Yamada who described the population density and its impact on water quality parameters in Kelani River, Sri Lanka and reported a spike in pollution in thickly populated areas along the riverside while comparatively very low pollution in an area with least population [28].

Solid waste from various tehsils i.e. Kabal, Khwazakheila, Charbagh and Matta are accumulated towards Mingora (Tehsil Babozai), which is the reason for an increase in the concentration of pollutants. This increase is also attributed to the commercial status of Mingora, direct seepage of industrial and commercial wastes and dumping of municipal wastes by TMA. The same effect has been revealed by Camara *et al*, 2019 who reviewed certain studies to find the impact of commercial activities on water pollution and found that urban land usage contributes to 87% of the total contamination to the freshwater in Malaysia [29]. This continuous addition of contaminants to River Swat is the major cause of inflation in water quality parameters and will make the water unfit for human and aquatic fauna if remains unchecked in the coming years. Graph 1 shows a comparison of all parameters recorded during the study at all the sampling sites. The effect of all the pollutants is obvious in Barikot (the last tehsil of Swat) and showed elevation despite its smaller population. The reason for this elevation observed is due to the assimilation and dilution of impurities that are added to River Swat on its way from Kalam to Barikot.

Among all the parameters recorded, Calcium as $CaCO_3$, Total alkalinity, Potassium and Magnesium hardness showed elevation than the normal permissible limits. All these elevated parameters add to the water's hardness. Magnesium hardness was recorded in Mingora due to the excessive accumulation of municipal wastes by TMA which is the cause of the surge in results.

5. Conclusions

The majority of water quality parameters fall within desirable limits however such uncontrolled anthropogenic activities will deteriorate the water quality if remain unchecked for a longer time and will make water unfit for fish fauna as well as human use. The breeding ground of fishes are also been threatened by the uncontrolled emission of solid industrial and municipal excreta into water. Therefore, a proper recycling system for municipal wastes is strongly recommended and a pilot study must be carried out after regular intervals to check the changing status of water quality focusing on community mobilisation and awareness.

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References

1. Legler, J., Leonards, P., Spenkelink, A. and Murk, A.J. (2003). In-vitro, biomonitoring in polar extracts of solid phase matrices reveals the presence of unknown compounds with estrogenic activity. Ecotoxicology, 12, 239-250.
2. Phiri, O., Mumba, P., Moyo, B.H.Z. and Kadewa, W. (2005). Assessment of the impact of industrial effluents on water quality of receiving rivers in urban areas of Malawi. International Journal of Environmental Science & Technology, 2, 237-244.
3. Sahu, A.K., (2007). September. Present scenario of municipal solid waste (MSW) dumping grounds in India. In Proceedings of the international conference on sustainable solid waste management (pp. 5-7). National Solid Water Association of India, Mumbai, India.
4. Zeinalzadeh, K. and Rezaei, E. (2017). Determining Spatial and Temporal Changes of Surface Water Quality Using Principal Component Analysis. *EJRH,* 13, 1-10.
5. Masood, M.; Barlow, C. Y.; Wilson, D. C. (2014). An Assessment of the Current Municipal Solid Waste Management System in Lahore, Pakistan. Waste Management and Research, 32 (9), 834-847.
6. Tariq, M. and Rashid, M. (2014). Solid Waste Management and its Willingness to Pay in Mingora, Swat. *IISTE,* 6 (8), 102-109.
7. Javied, S.; Hanan, F.; Munawar, S.; Qasim, M.; Anees, M. M.; Ghani, M. U.; Azad, A.; Khlaid, M.; Ullah, I.; Ansar, Awais. (2014). Management of Municipal Solid Waste Generated in Eight Cities of Pakistan. International Journal of Scientific Engineering and Research., 5 (12), 1186-1192.
8. Daud MK, Muhammad N, Shafaqat A, Muhammad R, Raees AB, Muhammad BS, Muhammad UA, Shahzad ASC, Deeba F, Murad W, Malook I, Zhu SJ. (2017). Drinking water quality status and contamination in Pakistan. Bio-Medical Research International. 2017:7908183.
9. Ojeh, E. (2006). Hydrology of the Indus Basin (Pakistan). GIS in water resources term project–CE K, 394.
10. Shah, M., Kausar, S., Mian, J.A., Jabeen, H., Ullah, N., Rasool, A., Akbar, F., Israr, M., Mehmood, S.A., Ahmad, S. and Khan, M.A.A. (2021). Bioaccumulation of heavy metals in the tissues of *Schizothorax plagiostomus* at River Swat. Brazilian Journal of Biology, 82, p.e243633.
11. Ullah, N., Said, A., Israr, M., Rasool, A., Akbar, F., Ahmad, S., Mehmood, S.A., Jabeen, H., Islam, M., Muhammad, S. and Noureenh, S., 2021. Effect of different protein-based feed on the growth of mahseer. *Brazilian Journal of Biology*, *82*, p.e243670.

12. Ullah, N., Ullah, I., Israr, M., Rasool, A., Akbar, F., Ahmad, M.S., Ahmad, S., Mehmood, S.A., Jabeen, H., Saeed, K. and Khan, W., 2021. Comparative brain analysis of wild and hatchery reared Mahseer (Tor putitora) relative to their body weight and length. *Brazilian Journal of Biology*, *82*, p.e231509.
13. Meade, J.W. (1989). Water and health management. In Aquaculture Management Boston, MA: Springer US. (pp. 59-69).
14. Singh, C.R. and Dey, M. (2014). Surface water quality with respect to municipal solid waste disposal within the Imphal Municipality Area, Manipur. Magnesium, 3(2.15), pp.0-7.
15. Muhammad, A., Shah, M.F., Bangash, N.G. and Zeb, H. (1998). A limnological survey of the river Swat at Mingora, NWFP Pakistan. Sarhad Journal of Agriculture (Pakistan), 14(3).
16. Ibrahim, T.T., Othman, F. and Mahmood, N.Z. (2017). Assessment of water quality of Sembilang River receiving effluent from controlled municipal solid waste (MSW) landfill in Selangor. In IOP conference series: materials science and engineering (Vol. 210, No. 1, p. 012019). IOP Publishing
17. Islam, M.S., Tusher, T.R., Mustafa, M. and Mahmud, S. (2012). Effects of solid waste and industrial effluents on water quality of Turag River at Konabari industrial area, Gazipur, Bangladesh. Journal of environmental science and natural resources, 5(2), 213-218.
18. Chima, G.N., Ogbonna, C.E. and Nwankwo, I. (2009). Effects of urban wastes on the quality of Asata River in Enugu, South Eastern Nigeria. Global Journal of Environmental Sciences, 8(1)
19. Rajbongshi, M.K., Das, J. and Dutta, R.K. (2016). Water quality assessment of capture and culture fishery in Barpeta district, Assam, India. International Journal of Fisheries and Aquatic Studies, 4(5), pp.516-520.
20. Hema, S. and Subramani, T., (2013). Study of physicochemical characteristics of surface water using regression analysis of Cauvery River and its tributaries in Tamilnadu, India. Asian Journal of Chemistry, 25(6), pp.3199-3203.
21. Khan, T., Irshad, M. And Malik, N. (2011). Effect of solid waste on the heavy metal composition of soil and water at Nathiagali-Abbottabad. Journal of the Chemical Society of Pakistan, 33(6), p.830.
22. Chowdhury, N.K. (1994). Study on the effects of effluents discharged from the KPRC on the water quality with the preview of pollution status of the Karnafuli River, Chittagong(Doctoral dissertation, M. Sc Dissertation, Institute of Marine Science, University of Chittagong, Bangladesh, 1-87.
23. Meade, J.W. (1989) Aquaculture Management. Chapman & Hall, London, 175 p. https://doi.org/10.1007/978-1-4615-6470-6
24. Yousafzai, A.M., Khan, W., Hasan, Z. (2013). Fresh Records on Water Quality and Ichthyodiversity of River Swat at Charsadda, Khyber Pakhtunkhwa. Pakistan Journal of Zoology, 45(6), 1727-1734.
25. Muhammad, I.; Muhammad, A.; Niaz, S.; Shams, S.; Khan, A.; Khan, I.; Ullah, A. (2016). Physico-chemical Analysis of River Swat at Batkheila District Malakand, KPK Pakistan. International Journal of Pure and Applied Zoology, 4 (1), 70-76.
26. Mulk, S.; Azizullah, A.; Korai, A. L.; Khattak, M. N. K. (2015). Impact of Marble Industry on Water and Sediment Quality of Barandu River in Buner District, Pakistan. Environmental Monitoring and Assessment, 187 (8), 1-23.
27. Sengupta, P. (2013). Potential Health Impacts of Hard Water. *Int J Prev Med*, 4 (8), 866-875.
28. Liyanage, C. P and Yamada, K. (2017). Impact of Population Growth on the Water Quality of Natural Water Bodies. *Sustainability*, 9 (1405).
29. Camara M.; Jamil, N. R.; Abdullah, A. F. B. (2019). Impact of Land Uses on Water Quality in Malaysia: A Review. Ecological Processes, 8 (10).