Assessment of water quality index (WQI) of Serlui a River, Aizawl, Mizoram

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Abstract—**Water quality of Serlui-A River was evaluated by using Water Quality Index (WQI) technique. Based on several water quality parameters, the WQI provides a single number that expresses the overall water quality at certain location. Eight important parameters such as pH, total dissolved solids (TDS), total hardness, total alkalinity, dissolved oxygen (DO), Biological Oxygen Demand (BOD), chloride, electrical conductivity (EC) and phosphate were taken for the calculation of WQI. The WQI values for the Serlui-A river ranged from 35 to 134. The water quality attributes and WQI depict that the river water at Site 1 (Control/Reference Site) is clean, and intensity of pollutants is increased from upstream to downstream of river indicated that an increase in pollution load in river (Site 2 to Site 4).**

Key words—**Serlui-A river, WQI, DO, Phosphate**

I. INTRODUCTION

River is one of the most important sources of fresh water available for our various uses even though it constitutes only 0.0002% of the earth's total water [1]. Contamination of river water with hazardous waste and wastewater is becoming a common phenomenon due to rapid development in agriculture, mining, urbanization, and industrialization activities [2]. Water quality is generally defined in terms of its physical, chemical and biological characteristics that are important with regards to a certain services [3,4] and human health is at risk if values exceed acceptable limits [5].

The WQI provides a single number that expresses the overall water quality at certain location, based on several water quality parameters [6]. The water quality index (WQI) is considered as one of the simplest methods that is used for assessing the overall water quality. Water Quality Index (WQI) is a useful and efficient method to assess the suitability of water quality. It is also serves as a useful tool for communicating the information on overall quality of water to the concerned citizens and policy makers [7,8].

II. MATERIALS AND METHOD

The study was carried out for two consecutive years (October, 2016 to September, 2018) using wide mouth plastic bottles with necessary precautions. The study area was divided into four sampling sites- Site 1 (control site) which is located near the source in Lungleng village, Site 2 which is located just before the hydroelectric power station, Site 3 which is located just after hydroelectric power station and Site 4 which is located at the point where Serlui-A river merges with the river Tlawng. Water samples were collected every month in sterilized wide mouth sampling bottles and were analysed for important physical and chemical parameters. Physico-chemical parameters like Temperature (^{0}C) and pH were performed on spot and samples were fixed at site for DO estimation. The various physico-chemical characteristics namely, ElectricalConductivity, Dissolved Oxygen, Biological Oxygen Demand, Total Hardness, Acidity, Total Alkalinity, Turbidity, Total Dissolved Solids, Chloride, Nitrogen-nitrite and Phosphate-P contents were analysed within 24 hrs of sample collection in the laboratory following the methods as outlined in 'Standard Methods for Examination of Water and Wastewater' [9] and 'Handbook of Methods in Environmental Studies, Water and Waste Water Analysis [10]. In this study, calculation of water quality index was based on nine important physico-chemical parameters. The WQI calculated using the different standards of drinking water quality recommended by USPH, BIS and ICMR

Water Quality Index Determination:

The weighted arithmetic index method [11] has been used for the calculation of water quality index of the water body in the following steps:

Calculation of Sub Index of Quality Rating (q_n): The value of q_n is calculated using the following expression.

$q_n = [(V_n-V_{id}]/S_n-V_{id})] \times 100$

Where,

q_n =Quality rating for the n^{th} water quality parameter.

V_n = Estimated value of the n^{th} parameter at a given sampling station.

S_n = Standard permissible value of the nth parameter.

V_{id}= Ideal value of the n^{th} parameter in pure water.

All the ideal values (Vid) are taken as zero for drinking water except for pH=7.0 and DO=14.6mg/L [12].

Calculation of Unit Weight (W_n): Calculation of unit weight (W_n) for various water quality parameters are inversely proportional to the recommended standards for the corresponding parameters.

$W_n=k/S_n$

Where,

W_n= unit weight for the n^{th} parameters.

S_n= standard value for the n^{th} parameters.
k=constant for proportionality and is calculated by
k = [1/(Σ1/S_n=1,2,..n)]
The overall water quality index is calculated by aggregating the quality rating with the unit weight linearly.
WQI=Σ$q_n W_n$/Σ W_n

III. RESULTS

The WQI of Serlui-A river was calculated to determine the impact of pollutants on the water quality and the suitability of the river water for drinking purpose. The recommending agencies, standard values and their corresponding ideal values, and k value of water quality parameters are presented in Table 1 and the calculation was done following Arithmetic Index method.

Table 1: Recommending agencies, Standard values and their corresponding ideal values, and k value of water quality parameters

Sl. No	Parameters	Recommending agencies	Standard Values (S_n)	Ideal value (V_{id})	k value
1	EC	ICMR	300	0	0.094
2	TDS	ICMR/BIS	500	0	0.094
3	pH	ICMR/BIS	7.5	7	0.094
4	DO	ICMR/BIS	5	14.6	0.094
5	BOD	ICMR	5	0	0.094
6	Chloride	ICMR	250	0	0.094
7	Tot. Alkalinity	ICMR	120	0	0.094
8	Tot. hardness	ICMR/BIS	300	0	0.094
9	Phosphate	USPH	0.1	0	0.094

The WQI at Site 1 was found to be 35. The calculation reveals that the water quality of Site 1 (Reference/Control site) falls within Grade B (26-50) of the water quality classification based on weighted arithmetic WQI method as given in Table 2. It therefore, indicates that the water of Site 1 is of good quality.
The WQI at Site 2, Site 3 and Site 4 were found to be 132, 132, and 133, respectively. The calculation reveals that the water quality of Site 2, Site 3 falls within Grade E (>100) of the water quality classification based on weighted arithmetic WQI method as given in Table 2, 3, 4 and 5.

Table 2: Water Quality Index (WQI) at Site 1.

Parameters	S_n	Ideal value V_{id}	k value	Weight (w_i)	Observed values(V_n)	Unit weight (W_n)	qn=(V_n-V_{id})/(S_n-V_{id})x100	$W_n q_n$
EC	300	0	0.094	5	66.683	0.00031	22.22778	0.00696
TDS	500	0	0.094	4	24.950	0.00019	4.99000	0.00094
pH	7.5	7	0.094	4	6.950	0.01253	-10.00000	-0.12533
DO	5	14.6	0.094	5	7.150	0.01880	77.60417	1.45896
BOD	5	0	0.094	5	1.650	0.01880	33.00000	0.62040
Chloride	250	0	0.094	3	1.650	0.00038	0.66000	0.00025
Tot. Alkalinity	120	0	0.094	2	65.933	0.00078	54.94444	0.04304
Tot. hardness	300	0	0.094	2	33.455	0.00031	11.15167	0.00349
Phosphate	0.1	0	0.094	2	0.035	0.94000	34.83333	32.74333
					ΣW_n=0.992107		Σ$W_n q_n$=34.75204	
							WQI=35.02851	

Table 3: Water Quality Index (WQI) at Site 2.

Parameters	S_n	ideal value V_{id}	k value	weight (w_i)	observed values (Vn)	Unit weight (Wn)	qn=(Vn-Vid)/(Sn-Vid)x100	$W_n q_n$
EC	300	0	0.094	5	200.355	0.00031	66.785	0.02093
TDS	500	0	0.094	4	114.250	0.00019	22.85	0.00430
pH	7.5	7	0.094	4	7.467	0.01253	93.33333	1.16978
DO	5	14.6	0.094	5	6.200	0.01880	87.5	1.64500
BOD	5	0	0.094	5	2.450	0.01880	49	0.92120
Chloride	250	0	0.094	3	2.450	0.00038	0.98	0.00037
Tot. Alkalinity	120	0	0.094	2	133.667	0.00078	111.38889	0.08725
Tot. hardness	300	0	0.094	2	80.722	0.00031	26.90722	0.00843
Phosphate	0.1	0	0.094	2	0.135	0.94	135	126.90
					ΣW_n=0.992107		$\Sigma W_n q_n$=130.7573	
							WQI=131.7975	

Table 4: Water Quality Index (WQI) at Site 3

Parameters	S_n	ideal value V_{id}	k value	weight (w_i)	observed values (V_n)	unit weight (W_n)	$q_n=(V_n-V_{id})/(S_n-V_{id})x100$	$W_n q_n$
EC	300	0	0.094	5	200.167	0.00031	66.72222	0.02091
TDS	500	0	0.094	4	114.383	0.00019	22.87667	0.00430
pH	7.5	7	0.094	4	7.517	0.01253	103.33333	1.29511
DO	5	14.6	0.094	5	6.267	0.01880	86.80556	1.63194
BOD	5	0	0.094	5	2.317	0.01880	46.33333	0.87107
Chloride	250	0	0.094	3	2.317	0.00038	0.92667	0.00035
Tot. Alkalinity	120	0	0.094	2	135.992	0.00078	113.32639	0.08877
Tot. hardness	300	0	0.094	2	87.300	0.00031	29.10000	0.00912
Phosphate	0.1	0	0.094	2	0.136	0.94	135.66667	127.52667
					ΣW_n=0.992107		$\Sigma W_n q_n$=131.4482	
							WQI=132.494	

Table 5: Water Quality Index (WQI) at Site 4.

Parameters	S_n	ideal value V_{id}	k value	weight (w_i)	observed values (V_n)	unit weight (W_n)	$q_n=(V_n-V_{id})/(S_n-V_{id})x100$	$W_n q_n$
EC	300	0	0.094	5	201.267	0.00031	67.08889	0.02102
TDS	500	0	0.094	4	114.717	0.00019	22.94333	0.00431
pH	7.5	7	0.094	4	7.600	0.01253	120.00000	1.50400
DO	5	14.6	0.094	5	6.350	0.01880	85.93750	1.61563
BOD	5	0	0.094	5	2.300	0.01880	46.00000	0.86480
Chloride	250	0	0.094	3	2.300	0.00038	0.92000	0.00035
Tot. Alkalinity	120	0	0.094	2	129.100	0.00078	107.58333	0.08427
Tot. hardness	300	0	0.094	2	91.767	0.00031	30.58889	0.00958
Phosphate	0.1	0	0.094	1	0.137	0.94	136.50000	128.31000
					ΣW_n=0.992107		$\Sigma W_n q_n$=132.414	
							WQI=133.4674	

Based on Water Quality Index analysis, it can be argued that the water is unfit for direct use at Site 2, Site 3 and Site 4. However, Site 1 possessed good water quality which can be recommended for use. Table 6.

Table 6: Status of Water at Selected Study Sites based on Water Quality Index (WQI)

Grade	WQI	Status	Serlui-A grade
A	0-25	Excellent water quality	
B	26-50	Good water quality	Site 1
C	51-75	Poor water quality	
D	76-100	Very poor water quality	
E	>100	Unsuitable for drinking	Site 2,3 and 4

The WQI at Site 1 (Control site) was found to be 35 and falls within Grade B (26-50) of the water quality classification based on weighted arithmetic WQI method. The WQI at Site 2, Site 3 and Site 4 were found to be 131,132 and 134 respectively, and fall within Grade E (>100) of the water quality classification (polluted) based on weighted arithmetic WQI method.

IV. DISCUSSION

The water quality attributes and WQI depict that the river water at Site 1 (Control/Reference Site) is clean, and intensity of pollutants is increased from upstream to downstream of river indicated that an increase in pollution load in river. (Site 2 to 4)

pH is an important parameter among all the physicochemical parameters selected for water quality index calculation. It determines the suitability of water for various uses. pH value was found to be higher during Post-monsoon season and lower during monsoon season. Low pH may be due to atmospheric dissolution leading to high concentration of carbon dioxide [13]. The pH range between 6.7 and 8.4 is considered to be safe for aquatic life to maintain productivity [14]. During the assessment period the range of pH was 6.1 to 7.9. The water was found to be slightly acidic in Site 1 during the year 2017-2018 and this can be attributed to the deposition of acid forming substances and high organic content which results into decrease in pH because of the carbonate chemistry [15]. DO content plays an important role in supporting aquatic life and is sensitive to slight environment changes. High community respiration results in oxygen depletion and hence DO has been extensively used as a parameter to define water quality and to evaluate the degree of freshness of a river [16]. The DO content was found to be high during Post-monsoon season and lower during Monsoon season for both the years. Higher value of DO during Post-monsoon season may be due to its greater solubility, reduced microbial decomposition of dead organic matter and low organism respiratory demand at low temperature and increased progressive growth of submerged macrophytes while lower oxygen content during monsoon season may be due to low water, high temperature and decay of macrovegetation. The value of DO during the study period range from 5 mgL^{-1} and 7.9mg L^{-1} and was found to be within the permissible limit given by different scientific agencies. Biological Oxygen Demand (BOD) is an important parameter of surface water quality which indicates the level of organic matter contamination in surface water [17]. Biological Oxygen Demand (BOD) indicates the level of organic matter contamination in surface water [18]. BOD was found to be higher during monsoon and lower during post-monsoon season. Increased BOD content during monsoon season might be due to addition of more organic matter from surface runoff which leads to acidification of water due to increase in microbial activities at elevated temperature while lower values during post-monsoon season may be due to low decomposition rate of organic matter. All the values during the study period except at Site 2 during Monsoon season (2016-2017), all lie within the acceptable range.

Chloride content in water may increase due to decomposition of organic matter. The greater source of chlorides in water bodies is disposal of sewage and industrial waste [19] and the human body release very high quantity through urine and faeces. The chloride content in water was found to be high during Pre-Monsoon season and low during Monsoon season. Low values during Monsoon season may be due to dilution by rainwater and higher values during pre-monsoon season may be attributed to the release of municipal and agricultural waste. The control site possessed lower values for all the seasons. All the values during the assessment period all lie within the prescribed limit as given by different scientific agencies. Alkalinity is a measure of the concentration of such ions in water that would react to neutralize hydrogen ions and is also regarded as a measure of productivity of natural waters [20] and it reflects carbonate, hydroxide content, phosphates, sulphates, nitrates of surface water [21]. Total alkalinity of water is primarily caused by the carbonate and bicarbonate ions [22]. Alkalinity was reported to be lower during Monsoon season and higher during Post-monsoon season. During rainy season low values of alkalinity was possibly due to dilution of river water with rain-water [23]. Higher values during Post-monsoon season may be attributed to the release of CO_2 during decomposition. The CO_2 thus released reacts with water to form bicarbonate which is limited to low level of water. All the values during the study period are within the prescribed values given by scientific agencies. Total hardness can be defined as the sum of calcium and magnesium concentrations expressed as $CaCO_3$. The hardness of water indicates water quality mainly in terms of Ca^{2+} and Mg^{2+} but is not a pollution indicator parameter. Total hardness value was found to be higher during Pre-monsoon season as compared to Monsoon and Post-monsoon season. High value during the pre-monsoon season may be due to evaporation of water, addition of calcium and magnesium salt from inflow of sewage as well as soaps and detergents used for washing and bathing whereas excessive dilution by rainwater during the monsoon can be one of the important factors responsible for lowering the hardness during monsoon [24,25]. The control site possessed lower values than all the other sites during different seasons which may be due to least anthropogenic activity. The values during assessment period all lies within the prescribed limit as given by different scientific agencies. Phosphorus is one of the limiting nutrients for floral growth in freshwater bodies which regulate the phytoplankton production [26]. Phosphate-P content was found to be high during Monsoon season and lower during Pre-monsoon and Post-monsoon season. Increase in phosphorous contents during rainy season might be possibly due to inflow of water, rich in colloidal clay particles containing various salts from extraneous sources. Phosphate-P values recorded were higher at Site 2, 3 and 4 during all seasons than the permissible limit as given by USPH. High phosphate-P content may be due to agricultural run-off containing phosphate fertilizers caused by heavy rain and inflow of sewage waste.

EC is an excellent indicator of TDS, which measures the salinity which affects the taste of potable water. EC increases with increase in TDS. EC values was found to be high during Monsoon season and low during Post-Monsoon season. Increased EC content during rainy season may be due to the high concentration of dissolved solids, decomposition and mineralization of organic matters while lower value during post-monsoon season may be attributed to the presence of low inorganic material followed by low ionic state. The control site possessed lower value as compared to all the other sites. The values fall within the permissible limit given by USPH. The high concentration of TDS leads to an increase in the nutrient status of water, resulting in eutrophication of aquatic bodies [27]. The TDS value was found to be higher during Monsoon season and lower during Post-monsoon season. Higher values during rainy season may be due to runoff of materials from the catchment areas and erosion of the river bank. The values during the assessment period lie within the prescribed limit given by ICMR and WHO.

The overall findings show that there was a seasonal fluctuation in the values of various physico-chemical characteristics in the river. All the water quality parameters lie within the permissible limit as given by different scientific agencies except phosphate values for Site 2, Site 3 and Site 4 during all the seasons.

V. CONCLUSION

The overall findings show that there was a seasonal fluctuation in the values of various physico-chemical characteristics in the river. All the water quality parameters lie within the permissible limit as given by different scientific agencies except phosphate values for Site 2, Site 3 and Site 4 during all the seasons. High phosphate-P content may be due to agricultural run-off containing phosphate fertilizers caused by heavy rain and inflow of sewage waste.

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