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STUDY ON WATER QUALITY OF HINDON RIVER (TRIBUTARY OF YAMUNA RIVER)

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ABSTRACT

Hindon River has become a destination for a dump of untreated industrial and domestic waste that attributes to the deterioration of water quality. In this study, Samples were collected from five sites between Muzaffarnagar and Meerut along the Hindon River during July 2016-June 2017 to evaluate the seasonal variation of water quality. These water samples were analyzed for pH, Electrical conductivity (EC), Dissolved oxygen (DO), Chemical oxygen demand (COD), Biological oxygen demand (BOD),Total dissolved solids (TDS), Total suspended solids (TSS), Total hardness (TH), Total Alkalinity (TA), Nitrate (NO_3^-), Sulphate (SO_4^{-2}), Sodium (Na^+), Calcium (Ca^{2+}) and Magnesium (Mg^{2+}) and the status of water quality was determined by using water quality index (WQI).The results revealed that all physicochemical parameters were beyond the prescribed limit by BIS standard (IS 10500) and the water quality was most deteriorated during pre-monsoon season as compared to monsoon and post-monsoon season. Therefore, based on this study, it can be believed that Hindon river water is not acceptable drinking, fish farming and irrigation activities at all the sampling sites along the Hindon River.

Keywords: WQI, Drinking Water Quality Index, Hindon River, Physicochemical parameters.

INTRODUCTION

A river comprises of both the main course and the tributaries, brings substantial contents in form of dissolved and minute separate particles from both natural and anthropogenic sources. It is the foundations of many civilizations and is responsible for supporting and maintaining various forms of life. Unfortunately, rivers play a major role in accommodation or transportation of industrial wastewater, municipal waste and runoff from agricultural land and most of the times, rivers are considered as places for disposal of the sewage[1]. Municipal and industrial wastewater discharge constitutes a constant polluting source, whereas surface runoff is a seasonal phenomenon, largely affected by climate within the basin[2]. However, urbanization has a direct influence on water resources through the settlement around the locality of water bodies by encroachment[3]and associated industrial development which has exerted tremendous burden on this vital resource leading to the deterioration of water quality[4]. Hindon River is the main tributary of Yamuna River, one of the major rivers of India, is confronted with the serious threat for its existence mainly because of various anthropogenic activities including disposal of untreated and partially treated industrial effluents and sewage containing toxic metals[5]. This highly polluted river covers an extensive area and is being widely used for various purposes in domestic, agricultural and industrial activities. Besides this, lack of common policy for effluent discharge in the river and lack of approach by the government toward the restoration of rivers have made the river water unsuitable for ecological use[6]. Since the quality of water is directly and indirectly associated with human health and another living being, therefore, it is an essential concern for human beings. In addition to urbanization, different materials like flowers, incense sticks, food, sweets, clothes etc. used in religious rituals activities spread out in rivers which results in pollution and deterioration of river water quality and is supplied as potable water for urban population[7].

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The polluted water can cause an adverse effect on plant growth and human health, therefore, the water pollution has become an imperative subject to be prevented and controlled worldwide[8]. Water quality index (WQI) which is a mathematical model, transforms several physicochemical parameters of waters into a single number and represents the level of water quality. The concept of water quality to categorize water according to its degree of purity or pollution pertains to 1848 in Germany[9].

EXPERIMENTAL

Study Area and Sample Collection

Water samples were collected during periods July 2016 to June 2017 from five sampling locations viz. Atali village (S-1), Baparsi village (S-2), Shekhpura village (S-3), Kalina village (S-4), Kinauni village (S-5) of which details are shown in Table 1, These were collected into new polyethylene bottles that had been rinsed two to three times with the water to be analyzed. The bottles were filled until overflowing and closed underwater to minimize aeration. All bottles were carefully labeled and numbered prior to transport and kept at low temperature 4 °C and then received samples were analyzed for different physicochemical parameters (as described in Table 5) by following the standard methods of APHA (2012).

Most commonly used water quality parameters namely pH (by pH meter), EC (by electrical conductivity meter), TDS and TSS (by gravimetric method), TA, TH, DO, COD, BOD, $Ca^{2+}$and Mg^{2+}(by titrimetric method),SO_4^{2-}andNO_3^- (by UV/VIS spectrophotometer), and Na^+ (Atomic absorption spectroscopy), together, reflect the overall water quality of the Hindon River and were selected for generating the water quality index (WQI).

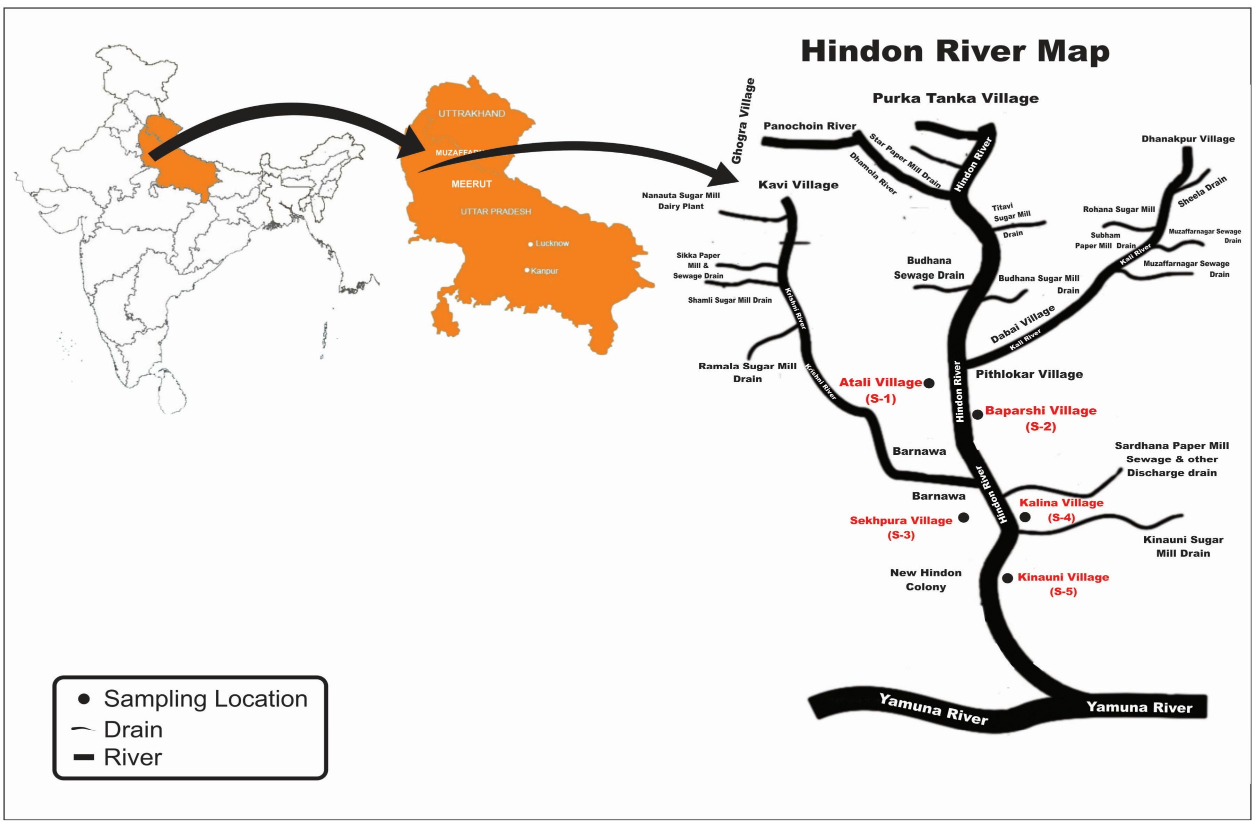


Fig.-1: Sampling Locations in Map of Hindon River

Water Quality Index Determination

Water quality index (WQI) is defined as a technique of rating that provides the composite influence of individual water quality parameter on the overall quality of water[10]. WQI has been calculated to evaluate the suitability of water quality of Hindon River using the weighted arithmetic water quality index method, which classifies the water quality according to the degree of purity by using the most commonly, measured water quality variables. Calculation of WQI was carried out by following the 'weighted arithmetic index method as stated below[11]:

$$WQI=\sum Q_nW_n/\sum W_n$$

Where, Q_n is the quality rating of the n^{th} water quality parameter, W_n is the unit weight of n^{th} water quality parameter.
The quality rating Q_n is calculated using the equation:

$$Q_n=100[(V_n-V_i)/(V_s-V_i)]$$

Where, V_n is the actual amount of n^{th} parameter present, V_i is the ideal value of the parameter [$V_i = 0$, except for pH ($V_i = 7$) and DO ($V_i = 14.6$ mg/l)], V_s is the standard permissible value for the n^{th} water quality parameter.
Unit weight (W_n) is calculated using the formula:

$$W_n=k/V_s$$

Where, k is the constant of proportionality and it is calculated using the equation:

$$k=[1/\sum 1/V_s=1,2,\ldots,n]$$

The water quality status (WQS) according to WQI is shown in Table-2.

Table-1: Sampling Location along Hindon River

S. No.	Sampling Location Code	Names of Area	Location	Description
1	S-1	Atali Village	29°12'43.4"N 77°31'18.4"E	This site is the confluence of Kali River and Hindon River, near to Budhhana 4 km away
2	S-2	Baparsi Village	29°11'07.2"N 77°29'42.6"E	This site brings a load of agriculture run off and small industrial effluents.
3	S-3	ShekhpuraVillage	29°05'34.4"N 77°25'21.1"E	This site is the merging point of Krishna River
4	S-4	Kalina Village	29°04'27.1"N 77°27'43.6"E	It has the major polluting drain from Sardhana.
5	S-5	Kinauni Village	29°03'05.2"N 77°27'15.9"E	It is the point of having a high amount of pollution from industries.

RESULTS AND DISCUSSION

Physico-Chemical Properties

pH ranged from 6.44 to 7.91. Each sampling location has almost the same pH. Sampling location (S-4) denoted low pH (6.4).IS 10500 recommended the pH value from 6.5 to 8.5 for drinking purpose, therefore, pH of five sampling location reached the criteria of quality standard.

Electrical conductivity, which measures the capacity of a water sample to carry the electric current, is directly associated with the dissolved ions existing in the water and was analyzed using a digital conductivity meter as microsiemen/centimeter. Observed EC values for the water samples of the Hindon River ranged between 1076–2122 µS/cm.

Total suspended solids (TSS), varied from78 to 223 mg/l. It relies on the weight of the residue (after the water evaporated) from materials contained in the water as a suspension. Overall water quality data of Hindon River at 5 locations is presented in **Table-3**. High **TDS and TSS** can boost the water temperature because solid materials absorb heat from sunlight. Since when the rain falls, dilution occurs in river water and decreases the TSS, but it can also increase TSS depending on the watershed. CPCB standard prescribes TSS <100 mg/l, therefore TSS of five sampling location did not meet the quality standard. The range of TDS falls between **923-1342** mg/l. IS 10500 recommends the TDS <500 mg/l, hence TDS of all five locations was found out of the standard permissible value. TDS is determined for measuring the amount of solid materials dissolved in the water (surface, ground). High TDS value causes harmful effect to the public health such as the central nervous system, irritability, dizziness, provoking paralysis of the tongue, lips andface[13].

Table-2: WQI Range, Status and possible usage of the Water Sample[12]

WQI	Water quality status (WQS)	Possible usage
0–25	Excellent	Drinking, irrigation and industrial
26–50	Good	Drinking, irrigation and industrial
51–75	Poor	Irrigation and industrial
76–100	Very poor	Irrigation
Above 100	Unsuitable for drinking and fish culture	Proper treatment required before use

Total Alkalinity (TA) and Total Hardness (TH)
The alkalinity of the water body is a measure of its capacity to neutralize acid to a designated pH. The maximum value i.e. 432 mg/l was found at sampling location S-1 during the pre-monsoon. The high alkalinity may be due to the concentration of domestic sewage and consumption of fertilizers in agriculture. For drinking use, desirable alkalinity is less than 200 ppm as per IS 10500. At all sampling locations, alkalinity crossed the standard permissible value. **Total hardness** of water increases the boiling point and reduces the formation of lather. During the study period, total hardness was found between 273-551 mg/l**,** which was out of prescribed limit i.e. 200 mg/l as per IS 10500.

Dissolved Oxygen (DO)
DO is the concentration of oxygen dissolved in the water. Its presence is essential to maintain a variety of biological life forms in water and the effect of a waste discharge in a water body is largely determined by the oxygen balance of the system[14]. Natural water bodies have high levels of oxygen which varies depending on temperature, salinity, water turbulence, and atmospheric pressure[13]. DO values ranged between 0.8-5.1 mg/l. All five sampling locations had almost the same DO and still not in good criteria. DO is necessary for the survival of aquatic organisms. The low DO indicates high demand for oxygen by the microorganisms. The more organic materials that pollute the water body, the more amount of oxygen consumed to decompose these materials, therefore, the content of dissolved oxygen in the water decreases so low. As per CPCB (class A), DO must be less than 6 mg/l, hence the DO of the all sampling location was out of the standard permissible value.

Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD)
Biochemical Oxygen Demand (BOD) is a measure of the amount of oxygen used by microorganisms to decompose organic materials in water within five days period. The high BOD value indicates the high organic pollution[13]. The BOD in Hindon river ranging 74-141 mg/l was relatively high. This might be due to the decomposition process of organic matter by microorganisms consuming oxygen. High BOD in water is undesirable because it will reduce the DO. As per CPCB (class A), BOD must be <3 mg/l, therefore BOD of all five sampling locations did not meet the criteria of the standard permissible value. The **COD** ranged between 232-532 mg/l. COD in each sampling location was not much different,but exceeded the standard permissible value. This was likely caused by decomposition of organic matter in the form of leaves, trunks etc. that consumed much oxygen. High oxygen consumption in the chemical process shows increased pollution in water bodies.

Calcium, Magnesium, Sodium, Sulphate and Nitrate

Both **calcium and magnesium** are essential minerals and beneficial to human health in several aspects. Inadequate intake of either nutrient can result in adverse health consequences (WHO standard). As per IS 10500, limits for calcium and magnesium content are ≤75 mg/l and ≤30 mg/l respectively, where the concentration of Ca and Mg at five sampling locations ranged from 94-136 mg/l and 16-52 mg/l respectively which were found out of standard permissible value for drinking purpose. **Nitrate** concentration on five sampling locations ranging from 2.9–5.1 mg/l was relatively low. This is highly related to the small number of human activities nearby[15-17]. A major source of river water pollution comes from domestic sewage, small industries, animal waste, agricultural waste, soil erosion and runoff from the settlement. As per IS 10500, nitrate content has to be ≤45 mg/l, therefore nitrate at five sampling location was within the quality standard. The sulphate concentration ranged between 39-59 mg/l which is under the permissible limit of 200 mg/l as per IS 10500. The concentration of sodium was found between 10-32 mg/l, there is no as such specification for sodium, but a high concentration of sodium could cause an unpleasant taste.

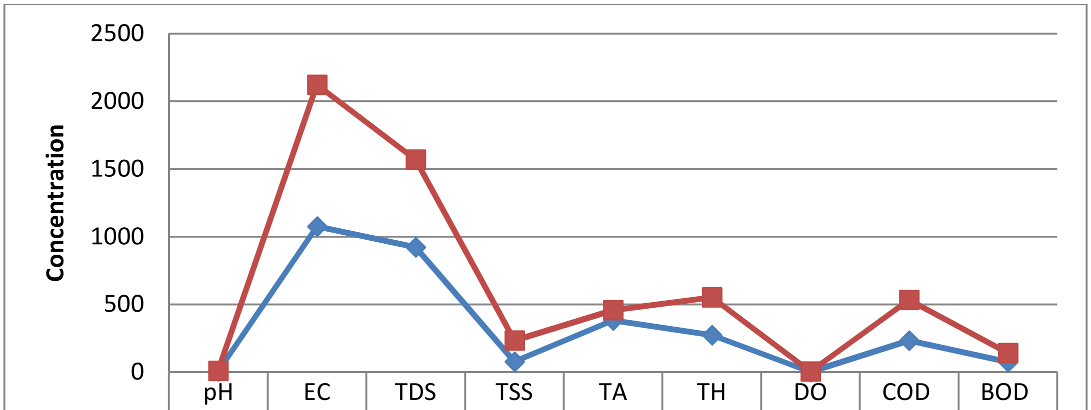
Table-3: Analytical Results of Physico-Chemical Parameters in the River Water from July 2016 to June 2017

Sampling location		pH	EC (µS/cm)	TDS (mg/l)	TSS (mg/l)	TA (mg/l)	TH (mg/l)	DO (mg/l)	COD (mg/l)	BOD (mg/l)
S-1	PEM	7.12	1583	1342	234	432	448	0.8	532	132
	M	7.16	1343	1175	162	382	360	3.1	344	96
	POM	7.34	1632	1254	138	408	461	1.2	357	105
S-2	PEM	7.15	1193	984	124	399	387	0.9	311	110
	M	6.61	1762	1029	88	416	436	3.2	311	85
	POM	7.19	1319	1156	96	432	468	1.8	287	98
S-3	PEM	7.57	1863	1143	216	457	390	1.1	289	108
	M	6.92	1935	1570	98	398	393	3.3	254	103
	POM	7.74	1238	1167	126	410	467	2.2	274	141
S-4	PEM	7.26	1351	1073	134	406	403	1.1	301	138
	M	7.32	1402	1148	77	397	273	2.8	276	98
	POM	6.44	1076	923	96	426	404	1.1	285	117
S-5	PEM	7.86	1748	1414	84	387	483	1.6	243	111
	M	7.52	1452	1189	78	399	551	5.1	232	74
	POM	7.91	2122	1352	92	405	441	3.8	264	107

PEM (Pre-Monsoon), M (Monsoon) and POM (Post-Monsoon)

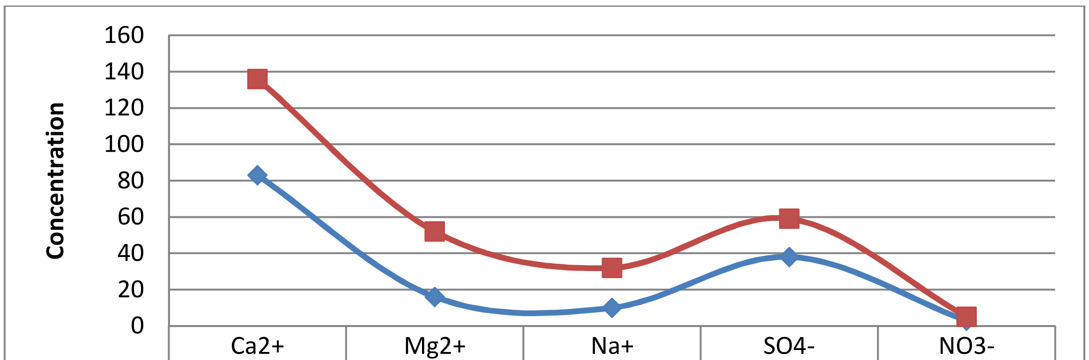
Table-4: Analytical Results of Ion Concentration in the River Water from July 2016 to June 2017

Sampling location		Ca^{2+} (mg/L)	Mg^{2+} (mg/L)	Na^{+} (mg/L)	SO_4^- (mg/L)	NO_3^- (mg/L)
S-1	PEM	120	36	28	59	3.5
	M	98	28	24	53	3.9
	POM	112	44	32	47	2.9
S-2	PEM	94	37	22	49	4.5
	M	102	44	19	48	5.1
	POM	128	36	18	52	4.7
S-3	PEM	110	28	16	47	3.8
	M	118	24	18	53	3.7
	POM	136	31	17	49	4.1
S-4	PEM	97	39	12	38	3.4
	M	83	16	10	43	3.6
	POM	96	40	14	41	3.2
S-5	PEM	116	47	11	47	4.8
	M	135	52	10	39	4.5
	POM	114	38	12	43	4.9



	pH	EC	TDS	TSS	TA	TH	DO	COD	BOD
Min	6.44	1076	923	77	382	273	0.8	232	74
Max	7.91	2122	1570	234	457	551	5.1	532	141

Fig.-2: Trend of Physicochemical parameters in River Water (July 2016-June 2017)



	Ca2+	Mg2+	Na+	SO4-	NO3-
Min	83	16	10	38	2.9
Max	136	52	32	59	5.1

Fig.-3: Trend of Ion Concentration in River Water (July 2016-June 2017)

Water Quality Index

In the first step for WQI of river water, the quality rating of each parameter is calculated with the formula: $Q_n=100*[(V_n – V_i) / (V_s- V_i)]$. If quality rating $Q_n = 0$ implies the complete absence of pollutants, while $0 < Q_n < 100$ means the pollutants are within the prescribed standard and when $Q_n >100$, it indicates that the pollutants are above the standards. In the second step, the unit weight (W_n) which is assigned to all the physicochemical parameters (i.e. pH, TDS, TSS, TA, TH, DO, BOD, Calcium, Magnesium, Sulphate and Nitrate) is calculated using the formula: $W_n= k / V_n$. These unit-weights transform all the concerned parameters of different units and dimensions to a common scale. Table 5 shows the drinking water quality standards and the unit weights assigned to each parameter used for calculating the WQI. Unit weight of DO and BOD i.e., 0.234 and 0.467 respectively had significance and impact in water quality assessment. Water Quality Index reveals water quality on many levels that affect host life and a potential peril to various uses of water.

In this study, calculated WQI value ranged from 1369 to 2199for all locations in all seasons and unveiled that water quality of Hindon River deteriorated at all location and was unsuitable (Bad)for purposes like drinking, fish farming and irrigation. The water quality was found to be most deteriorated during pre-monsoon season as compared to monsoon and post-monsoon season. The unsuitability of water was attributed by increasing industrial activities and domestic sewage disposal. In Table 3, 4 and 6, Physico-chemical parameter values and WQI score clearly showed the contribution of untreated waste from industries and small-scale factories, domestic waste, Kali River and Krishni River for pollution of all Hindon River.

Table-5: The Unit Weight of each of the Physicochemical Parameters used for WQI Determination

Parameters	CPCB*/BIS Standard (IS 10500)	Unit Weight (W_n)
pH	6.5-8.5	0.165
EC	-	-
TDS	500	0.003
TSS*	100	0.014
Total Alkalinity	200	0.007
Total Hardness	200	0.007
DO*	6	0.234
BOD*	3	0.467
COD	-	-
Calcium	75	0.019
Magnesium	30	0.047
Sodium	-	0.007
Sulphate	200	-
Nitrate	45	0.031

Table-6: Summary of WQI of the Hindon River

Sampling Location	Pre-Monsoon		Monsoon		Post-Monsoon	
	WQI	WQS	WQI	WQS	WQI	WQS
SL1	2108	Unsuitable	1538	Unsuitable	1687	Unsuitable
SL2	1763	Unsuitable	1369	Unsuitable	1575	Unsuitable
SL3	2043	Unsuitable	1646	Unsuitable	1732	Unsuitable
SL4	2199	Unsuitable	1567	Unsuitable	1872	Unsuitable
SL5	1779	Unsuitable	1195	Unsuitable	1709	Unsuitable
Average	1978.57		1462.94		1714.84	

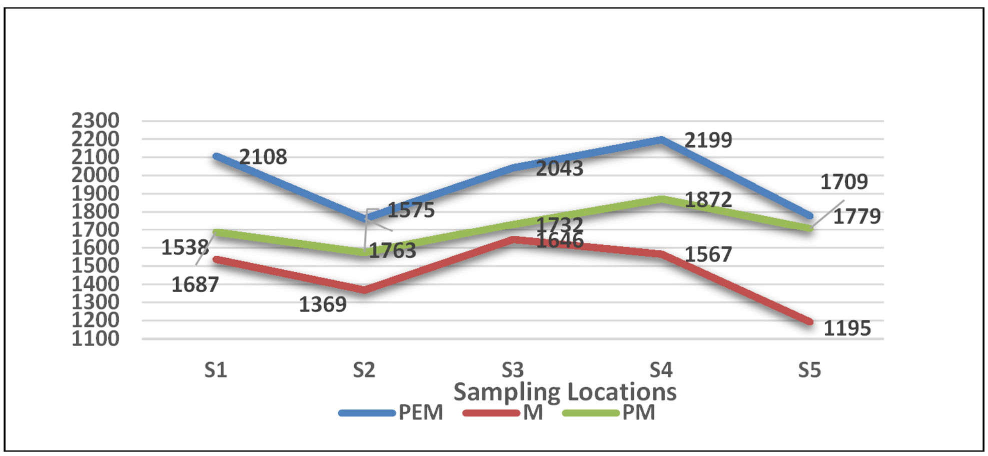


Fig.-4: Water Quality Index Rating of sampling locations of Hindon River

CONCLUSION

The present study gives insight for 12 months during (July 2016-June 2017) of the Hindon River water based on WQI values which determine the overall quality of river water. According to the criteria of water quality, this river can be categorized as being extremely polluted and effective treatment measures are urgently required to enhance the river water quality by defining a sustainable water quality management plan for river restoration. The high WQI values in river water were mostly just because of the presence of major harmful toxic chemical elements and nutrients beyond their permissible limits, which directly indirectly affects the flora and fauna of the aquatic system as well as human population.

Pollution level acceleration generally causes greater deterioration of the ecological system. To recover the water quality of the Hindon River, treatment of various effluents before discharged directly and indirectly into Hindon water is required.

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