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Assessment of Surface Water Quality of Hindon River Using Two Water Quality Indexes

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***Abstract*:Hindon River is a tributary of one of the blessed waterways called Yamuna waterway having a real beginning in Saharanpur, the range of Upper Sivalik in Uttar Pradesh. It streams around 400 KM from Ganges and Yamuna waterways. Hindon River flows through Muzaffarnagar, Meerut, Baghpat, and Ghaziabad before its confluence with Yamuna at Noida of Uttar Pradesh. In this study, the water sample from the Galeta, Baleni, and Noida in the season of Monsoon, Winter & Summer from June 2021 to May 2022 and analyzed the Twelve core Physico-chemical and Biological water quality parameters such as pH, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Total Dissolve Solid (TDS), Total Hardness (TH), Calcium Hardness (CH), Magnesium Hardness (MH), Chloride (Cl), Fluoride (F), Sulphate(SO_4^{-2}), Nitrate (NO_3^-) and Total Coliform (TC) and WQ data compared with designated use classification.**

The water quality index is a solitary worth that expresses the nature of water by integrating different water quality boundaries and complex information. Its goal is to provide a quick and easy way to convey the water quality for a variety of uses. The estimation of the WQI was finished utilizing the Weighted Arithmetic Water Quality index (WAWQI) and the Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI) compared Class C: Drinking water resource with conventional treatment followed by disinfection (BIS 2296:1982). The both Water Quality Index has been determined for every one of the three areas of Hindon River and the outcomes showed that the WAWQI were varying from 48.9 to 563.4 and CCMEWQI from 32.0 to 78.42. It is concluded from WAWQI and CCMEWQI the water of all seasons and all three locations of Hindon River most of the time showed unsuitable and poor water quality concerning class C.

***Keywords*:Hindon River, Water Quality Parameters, WAWQI, CCMEWQI**

I. INTRODUCTION

Surface water is used for many purposes, which include drinking, irrigation, animal farming, and recreation, and serves as a habitat for numerous organisms. Surface water is used as the main source of water for the provision of potable water after necessary treatment. Water quality is one of the major factors responsible for both health and the cause of disease in humans (TG. Kazi el al, 2009).

The stream Hindon, a tributary of the Yamuna follows its starting point from the lower Himalayan reaches lodging the Upper Shivalik. Streaming between the Ganges and the Yamuna waterways for right around 400 km, this waterway covers six regions including Muzaffarnagar, Meerut, Baghpat, Ghaziabad, Noida, and More prominent Noida lastly it meets the Yamuna outside Delhi.

The condition of Hindon River's water severely deteriorated, posing a health risk to inhabitants, wildlife and limiting socioeconomic growth in the area. The primary sources of urban water pollution include untreated home sewage discharged into rivers and industrial pollution from paper, sugar, distillery, and slaughterhouse operations. The agricultural contamination caused by agricultural runoff containing chemicals, pesticides, and other non-point sources of pollution (Hindon 2030: 2016) According to the CPCB (CPCB:2015) Hindon receives a significant amount of pollution from numerous industries and household sewage from the towns, particularly Saharanpur, Muzaffarnagar, Meerut, & Ghaziabad, located in its basin region.

Keeping in view the need of restoring the water quality of the stream, the current study means to work out the Water Quality Index (WQI) like the Weighted Arithmetic Water Quality index (WAWQI) and the Canadian Council of

Ministers of the Environment Water Quality Index (CCME WQI) of Hindon Stream to evaluate the appropriateness of its water for class C of Designated Best Use Water Quality Criteria (CPCB Standards 1995).

II. Material & Methods

Details of Study Area

Hindon is among one of the significant waterways of Yamuna in western Uttar Pradesh, India (Hindon 2030: Vision to Action Plan 2016), having a bowl area of around 7000 km^2, and lies between scope 28° 30' to 30° 15'N and longitude 77° 20' to 77° 50' E. The detail of sampling areas displayed in guide of Hindon Stream in Figure 1 **(**Lewis, H. et al. 2007,Vinod Kumar et al. 2018) and **Table - I**. This river is sandwiched between two significant streams: Ganga on the left and Yamuna on the right. Hindon begins from upper Shiwalik (Lower Himalayas). The main tributary rivers of Hindon are Kali West, Krishni, PurkaTanda River, Dhamola, Paavdhoi, Sheela, Naagdev and ChachaRaav. There are about 865 villages situated near Hindon River. The primary source of Hindon water is rain and tributaries water. Hindon is a rainy stream as it gets a huge amount of water in the monsoon season (July to September). The width of the Hindon river goes from 20m to 160m. There are three water quality stations from upstream to downstream on stream Hindon, first at Geleta, Second at Baleni, and third at Noida at Uttar Pradesh. Every one of the three areas images and Google earth pictures are displayed in Figure 2A, 2B, 3A, 3B and 4A and 4C respectively.

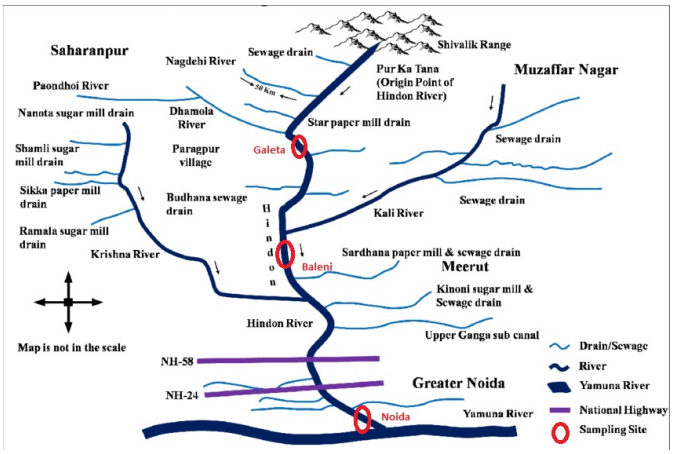

Figure 1.Map of the Hindon River showing different drains and all three sampling locations (Uttar Pradesh), India (Source: **(**Lewis, H. et al. 2007, Vinod Kumar et al. 2018)(Modified by the authors).

Sample Collection and Analysis

Water samples were collected three times in a month at morning hours between in the range of 8:00 and 10:00 A.M. from Galeta, Baleni and Noida areas of Hindon River in Monsoon, Winter and Summer from June 2021 to May 2022. All water samples were collected in one-liter new polyethylene containers and three glass bottles (two 300 ml for DO and BOD and one 100 ml for Total Coliform) and no air bubbles were brought during the sampling into the water bottles. The collected water sample was transported in an Ice Box from each of the three locations to National River Water Quality Laboratory, CWC, New Delhi according to standard protocol **(**WQAA, 2005**)** and examined twelve core Physico-chemicals and biological water quality parameters such as pH, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), All out Disintegrate Strong (TDS), Complete Hardness (TH), Calcium Hardness (CH), Magnesium Hardness (MH), Chloride (Cl), Fluoride (F), Sulfate (SO_4^{-2}), Nitrate (NO_3^-) and Total Coliform (TC) according to Standard methods for the examination of water and waste water **(**APHA 2017**).**

Description of water quality index

Water Quality File (WQI) is viewed as the best technique for assessing the water quality of streams. The old style system for evaluating the water quality relies upon the examination of experimentally determined parameter values with the existing guidelines **(**Debels P. et al. 2005**).** The different water quality parameters are incorporated a mathematical condition to rate water quality, choosing the suitability of water for desired application **(**SutharS et. al. 2010**).**

The index was first developed by Horton in 1965 in US by selection of ten most commonly applied water quality parameters like dissolved oxygen (DO), pH, Coliforms, explicit conductance, alkalinity and chloride and so on, has been extensively applied and it recognised in Europe, Africa and Asian countries. The water quality index was modified by different specialists. In addition, one more WQI like Hortan's index has been formed by Brown in 1970 **(**Brown et. al. 1972**).**

This index used water quality parameters which contrast by number and types. The weight of every parameter is relying upon its specific guidelines and the assigned weight indicates the parameters importance and effect on the index. A standard WQI procedure keeps three phases which consolidate

1) Selection of water quality parameters,
2) Determination of quality function for every water quality parameters, and
3) Aggregation through mathematical equation.

The most used water quality indices such as Weighted Athematic Water Quality Index (WAWQI), National Sanitation Foundation Water Quality (NSFWQI), Canadian Council of Ministers of Water Quality Index (CCMEWQI) and British Columbia Water Quality Index (BCWQI) **(**TyagiS et. al. 2013**).** In this review for appraisal the water quality of Hindon River by Weighted Athematic Water Quality Index (WAWQI) and Canadian Council of Ministers of Water Quality Index (CCMEWQI).

TABLE 1
Details of Water Quality Sites at Hindon river, Utter Pradesh

Site Name	District	Catchment Area SqKm	River Name/Tributory/ SubTributory	Type	Latitude	Longitude
Noida	Gautambhud Nagar	5566	Ganga/Yamuna/ Hindon	GDSQ	28°36'07.50"	77°25'27.17"
Baleni	Baghpat	4925	Ganga/Yamuna/ Hindon	GDQ	28°57'31.86"	77°28'12.34"
Galeta	Baghpat	4841	Ganga/Yamuna/ Hindon	GDSQ	29°04'56.66"	77°26'14.13"

*G = Gauge, D = Discharge, S = Silt, Q = Water Quality

Figure 2 A: Photograph of Galeta Site

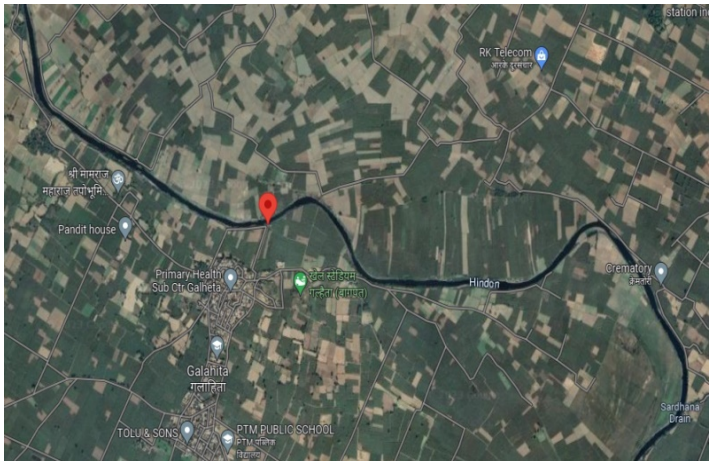

Figure 2 B Google Earth Image of Galeta Site

Figure 3 A: Photograph of Baleni Site

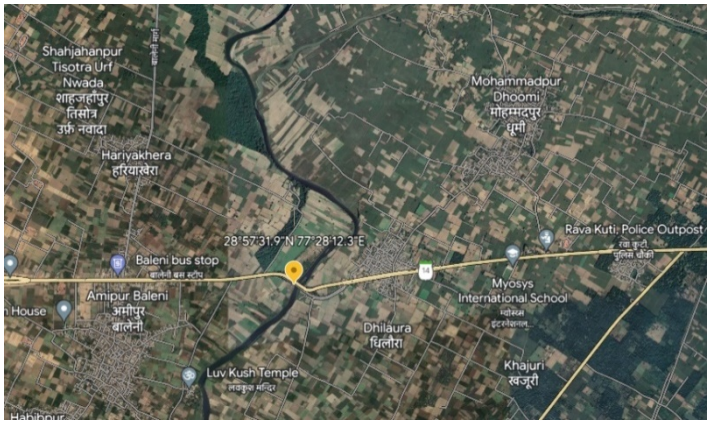

Figure3 B: Google Earth Image of Baleni Site

Figure 4 A: Photograph of Noida Site

Figure 4 B : Google Earth Image of Noida Site

Weighted Arithmetic Water Quality Index (WAWQI)

With the assistance of the analysed water quality parameters **(**Ochuko U et. al. 2014**),** the weighted arithmetic water quality index was able to classify the water quality as indicated by its level of purity. The following formula was utilized to ascertain the WAWQI:

$$\text{WAWQI}=\Sigma QiWi/\Sigma Wi$$

The quality rating scale (Qi) for every parameter is determined by utilizing the accompanying equation:

$$Qi=100[(Vi-Vo)/(Si-Vo)]$$

Where;

Vi is estimated concentration of i^{th} parameter in the analyzed water,

Vo is the ideal value of this parameter in pure water (Vo= 0 in general),

Si is recommended standard value of i^{th} parameter.

By involving the following equation for computation of unit weight (Wi) for each the water quality parameters:

$$Wi=K/Si$$

Where;

K = proportionality constant and can be determined by utilizing the following equation:

$$K=1\ \Sigma(1/Si)$$

The rating of water quality as per WAWQI is given in **Table II**.

TABLE 2
Water Quality Rating as per WAWQI Method

WAWQI Value	Rating of Water Quality	Usage Possibilities	Grading
0 – 25	Excellent water quality	Drinking, irrigation, industrial	A
25 – 50	Good water quality	Drinking, irrigation, industrial	B
50 – 75	Poor water quality	Irrigation, industrial	C
75 – 100	Very Poor water quality	Irrigation	D
> 100	Unsuitable	Proper treatment is required before use	E

Canadian Council of Minister of the Environment (CCME) Water Quality Index (WQI)

The British Columbia Ministry of Environment, Lands and Parks index is foundation of establishment for the CCME WQI. The Canadian Council of Ministers (CCME) has develped a water quality index to make sense of troublesome and specialized realities in regards to water quality **[**CCME 2001**].** The CCME WQI is an experimentally based specialized instrument that looks at information on many water quality factors to determined water quality benchmarks. The WQI numerically coordinates three variance measurements (extension, recurrence, and size) to get a solitary worth that quantifies the overall water quality of a location in relation to the benchmark of choice (e.g : protection of aquatic life). Three variables factor combined to formulate the CCME WQI:

1. the number of parameters whose guidelines are not met (**Scope**)
2. the frequency with which the guidelines are not met (**frequency),** and
3. the amount by which the guidelines are not met **(Amplitude**).

The combination of the three variables (scope, frequency and amplitude) as the summation to produce a single value between 0 and 100 that describes water quality.

The Canadian Water Quality index (CWQI) formula is determined involving three factors as follows:

$$WQI = 100 - \left(\sqrt{\frac{{F_1}^2 + {F_2}^2 + {F_3}^2}{1.732}}\right)$$

Where: F_1 = Represent Scope: The percentage of variables that exceed the guideline or the number of variables whose objectives are not met.

F_1 = [Number of failed variables /Total number of variables] *100

F_2 = Represent Frequency: The percentage of individual tests within each variable that exceeded the guideline or the frequency by which the objectives are not met.

F_3 = [Number of failed tests / Total number of tests]*100

F_3 = Represent Amplitude: The extent to which the failed test exceeds the guideline or the amount by which the objectives are not met.

Excursion = [Failed test value / Objective]-1

$$\text{Normalized sum of excursions } (nse) = \sum_{i=1}^{n} \frac{excursions}{No\ of\ tests}$$

$$F_3 = \left[\frac{nse}{0.01\ nse + 0.01}\right]$$

The constant 1.732, is a scaling factor (square root of three) to ensure the index varies between 0 and 100.

The rating of water quality according to WAWQI is given in **Table III**.

TABLE 3
Water Quality Rating as per CCMEWQI Method

CCMEWQI Value	Rating of Water Quality
95-100	Excellent
80-94	Good
65-79	Fair
45-64	Marginal
0-44	Poor

III. Results & Discussion

The summary of the results of Galeta, Baleni and Noida are shown in **Table IV, V** and **VI** respectively. The WAWQI values were varying from 56.8 to 563.4 for all three sites from upstream to downstream (Galeta, Baleni and Noida) of Hindon River from 01/06/2021 to 31/5/2022 as shown in Table VII. The WAWQI of Galeta was varying from 56.8 to 204.4, Baleni from 58.8 to 180.9 and Noida from 48.90 to 563.4 in Monsoon, Winter and Summer respectively. Hence it is concluded from the results that the Water Quality of Hindon River was shown poor water quality, very poor water quality and unsuitable with reference to Class 'C'. In the winter season, WAWQI is most of the time shown unsuitable with reference to Class 'C'. Moreover, it is also observed that most of the time Noida was shown a higher WAWQI value as compared to Galeta and Baleni. Hence, the water quality of Noida was more deteriorated as compare to Galeta and Baleni.

The CCMEWQI value was varying from 32.0 to 78.4 of all three sites from upstream to downstream (Galeta, Baleni and Noida) of Hindon river from 01/06/2021 to 31/05/2022 as shown in Table VIII. The CCMEWQI of Galeta was varying from 32.0 to 64.6, Baleni from 58.4 to 78.4 and Noida from 38.81 to 63.71 in Monsoon, Winter and Summer. In the winter season, CCMEWQI is most of the time shown unsuitable with reference to Class 'C'. Hence, it is concluded from the results the water quality of the Hindon River was shown as fair, Marginal and Poor water quality with reference to class 'C'. Moreover, it is also observed that most of the time Noida showed lower values of CCMEWQI value as compared to Galeta and Baleni. Henceforth water quality of Noida was more deteriorated as compared to Galeta and Baleni. Both WAWOI and CCMEWQI values are showing Hindon River water is severely polluted at all three locations that from upstream to downstream (Galeta, Baleni and Noida)

There are number of sources of the water pollution discharged into the Hindon River and its tributaries Krishni and Kali which form completely a type of rain-fed water resource. The Hindon River is receiving untreated industrial waste water form Sugar, Pulp & Paper, Distillery, Textile, Slaughter House, Tannery etc. The residential sewerage from the towns mainly situated in its basin area which are being discharged directly or through number of drains. In addition to aforementioned point sources, the numbers of non-point sources such as agrochemical run-off, open-defecation practices, animal bathing etc. are contributing to the of severe water quality pollution in Hindon River.

TABLE 4
Summary Table of Water Quality Data at Galeta site of Hindon River

Season		Monsoon				Winter				Summer			
Month		Jun-21	Jul-21	Aug-21	Sep-21	Oct-21	Nov-21	Dec-21	Jan-22	Feb-22	Mar-22	Apr-22	May-22
Parameter*	Class C	Monthly Average #											
pH	8.5	7.8	7.8	7.6	7.8	8.0	7.8	7.9	7.8	8.0	8.1	8.0	8.2
DO	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BOD	3.0	16.1	26.2	36.4	41.1	33.7	51.7	71.4	70.3	65.0	29.2	33.1	32.8
TDS	1500	671	778	367	483	523	768	779	572	613	577	582	824
TH	300	290	292	178	206	266	277	343	360	393	374	358	348
CH	200	183	183	141	140	186	228	220	239	275	269	240	266
MH	100	108	110	37	66	80	49	123	122	118	105	117	82
Cl	600	82.0	88.7	43.3	49.6	44.2	80.7	91.5	140.8	135.3	72.5	95.1	116.8
F	1.5	0.4	0.5	0.5	0.4	0.5	0.6	0.5	0.5	0.6	0.7	0.7	0.9
SO_4	400	36.0	40.3	37.6	50.0	29.2	70.8	98.3	31.5	84.5	98.8	72.7	68.7
NO_3	50	1.6	1.9	1.5	1.3	1.2	1.3	1.5	2.0	2.2	2.6	2.7	3.1
Tcoliform	5000	3766666	1733333	91333	223333	2400000	3766666	8300000	2466666	2100000	2400000	3766666	5033333

* all parameters in mg/L and Tcolform in MPN/100 ml *, #sample collected thrice a month & 36 times in a year.*

TABLE 5
Summary Table of Water Quality Data at Baleni site of Hindon river

Season		Monsoon				Winter				Summer			
Month		Jun-21	Jul-21	Aug-21	Sep-21	Oct-21	Nov-21	Dec-21	Jan-22	Feb-22	Mar-22	Apr-22	May-22
Parameter*	CLASS C	Monthly Average #											
pH	8.5	7.3	7.3	7.7	7.5	7.4	7.5	7.9	7.5	7.5	8.0	7.7	7.9
DO	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
BOD	3.0	18.8	17.6	20.2	17.7	26.1	18.4	33.9	41.9	41.9	65.0	39.6	30.2
TDS	1500	291	194	250	346	357	474	332	324	324	613	219	362
TH	300	146	110	123	146	201	205	131	120	120	393	137	159
CH	200	113	79	98	98	146	131	92	86	86	275	93	120
MH	100	34	30	25	48	55	75	39	34	34	118	44	39
Cl	600	24.4	18.6	23.6	24.5	32.6	45.1	42.1	48.9	48.9	135.3	22.3	41.0
F	1.5	0.2	0.3	0.4	0.3	0.3	0.3	0.3	0.4	0.4	0.6	0.6	0.7
SO_4	400	26.3	22.1	24.4	32.8	31.8	47.5	47.4	40.0	40.0	84.5	22.5	28.2
NO_3	50	1.6	1.6	1.5	1.3	1.2	1.0	1.5	1.2	1.2	2.2	1.6	1.8
Tcoliform	5000	6067	1466	1897	3500	10333	17333	10633	11633	11633	21000	8400	8667

* all parameters in mg/L andTcolform in MPN/100 ml , *#sample collected thrice a month & 36 times in a year.*

TABLE 6
Summary Table of Water Quality Data at Noida site of Hindon river

Season		Monsoon				Winter				Summer			
Month		Jun-21	Jul-21	Aug-21	Sep-21	Oct-21	Nov-21	Dec-21	Jan-22	Feb-22	Mar-22	Apr-22	May-22
Parameter*	CLASS C	Monthly Average #											
pH	8.5	7.5	8.0	7.4	7.6	7.5	7.3	8.0	7.1	7.2	8.1	7.9	7.9
DO	4.0	0.0	0.0	0.0	2.1	0.0	0.0	0.0	1.1	1.4	0.0	0.0	0.0
BOD	3.0	53.6	33.8	14.7	13.3	71.8	108.9	135.3	208.7	135.3	26.2	29.2	29.4
TDS	1500	1060	1116	307	349	505	1008	888	980	688	1064	1259	836
TH	300	272	242	193	161	232	334	231	271	253	268	269	237
CH	200	188	164	119	116	162	216	151	184	170	182	188	176
MH	100	85	78	74	45	70	117	80	87	83	86	81	61
Cl	600.0	248.8	213.3	54.1	53.4	35.2	124.2	192.5	275.8	280.5	297.0	251.3	145.6
F	1.5	0.4	0.5	0.5	0.4	0.5	0.5	0.4	0.5	0.5	0.6	0.7	0.8
SO_4	400.0	73.4	54.4	41.8	31.3	31.5	71.8	108.9	208.7	135.3	148.3	79.7	62.3
NO_3	50.0	1.7	1.4	1.1	0.9	0.9	0.8	1.0	1.2	1.3	1.5	1.5	1.7
Tcoliform	5000	503333	433333	50333	193333	566667	730000	1020000	353333	270000	376667	603333	920000

* All parameters in mg/L and Tcolform in MPN/100 ml , *# sample collected thrice a month & 36 times in a year.*

TABLE 7

Weighted Arithmetic Water Quality Index (WQWQI) of Hindon River

Season	Month	Galeta		Baleni		Noida	
		Quality Rating	Description	Quality Rating	Description	Quality Rating	Description
Monsoon	Jun 2021	56.8	Poor Water Quality	59.8	Poor Water Quality	156.4	Unsuitable
	July 2021	86.4	Very Poor Water Quality	58.17	Poor Water Quality	106.03	Unsuitable
	Aug 2021	112.1	Unsuitable	67.57	Poor Water Quality	54.94	Poor Water Quality
	Sep 2021	56.9	Poor Water Quality	58.89	Poor Water Quality	48.91	Poor Water Quality
Winter	Oct 2021	105.2	Unsuitable	81.75	Very Poor Water Quality	205.15	Unsuitable
	Nov 2021	155.2	Unsuitable	60.73	Poor Water Quality	301.83	Unsuitable
	Dec 2021	204.4	Unsuitable	102.09	Unsuitable	369.56	Unsuitable
	Jan 2022	201.6	Unsuitable	125.54	Unsuitable	563.4	Unsuitable
Summer	Feb 2022	197.3	Unsuitable	180.91	Unsuitable	372.16	Unsuitable
	Mar.2022	102.3	Unsuitable	97.09	Very Poor Water Quality	88.53	Very Poor Water Quality
	Apr.2022	108.9	Unsuitable	123.53	Unsuitable	97.27	Very Poor Water Quality
	May 2022	111.6	Unsuitable	101.55	Unsuitable	100.93	Unsuitable

TABLE 8
Canadian Council of Minister of the Environment (CCME) Water Quality Index (WQI) of Hindon River

Season	Month	Galeta		Baleni		Noida	
		Quality Rating	Description	Quality Rating	Description	Quality Rating	Description
Monsoon	Jun 2021	42.98	Poor Water Quality	72.73	Fair Water Quality	43.81	Poor Water Quality
	July 2021	36.34	Poor Water Quality	70.79	Fair Water Quality	44.77	Poor Water Quality
	Aug 2021	64.69	Fair Water Quality	76.91	Fair Water Quality	63.71	Fair Water Quality
	Sep 2021	61.07	Fair Water Quality	78.42	Fair Water Quality	50.86	Marginal Water Quality
Winter	Oct 2021	48.09	Marginal Water Quality	68.22	Fair Water Quality	43.17	Poor Water Quality
	Nov 2021	42.19	Poor Water Quality	69.70	Fair Water Quality	48.13	Marginal Water Quality
	Dec 2021	32.08	Poor Water Quality	65.21	Fair Water Quality	41.28	Poor Water Quality
	Jan 2022	35.89	Poor Water Quality	62.56	Fair Water Quality	43.08	Poor Water Quality
Summer	Feb 2022	36.64	Poor Water Quality	58.47	Marginal Water Quality	44.70	Poor Water Quality
	Mar.2022	37.28	Poor Water Quality	67.32	Fair Water Quality	45.64	Marginal Water Quality
	Apr.2022	46.51	Marginal Water Quality	67.28	Fair Water Quality	38.81	Poor Water Quality
	May 2022	37.80	Poor Water Quality	66.96	Fair Water Quality	41.95	Poor Water Quality

IV. CONCLUSION

In the current study, the WAWQI and CCMEWQI are assessed for three locations such as Galeta, Baleni and Noida at Hindon River by utilizing twelve water quality parameters from 01/06/2021 to 31/05/2022. The WAWQI values were varying from 56.8 to 563.4 at all three sites of Hindon River and out of these three sites, the most of time Noida site was showing a higher value of WAWQI as compared to Galeta and Baleni. Hence WAWQI was showing water quality of Noida is more deteriorated as compared to Galeta and Baleni. The CCMEWQI values were varying from 32.0 to 78.4 for all three sites of Hindon River. Out of these three sites, Noida was showing a lower value as compared to Galeta and Baleni. Hence the CCMEWQI was also showing the water quality of Noida was more deteriorated during the study period in all the season. Moreover, the WAWQI and CCMEWQI were showing all three locations water quality was not in good condition. The major source of river water pollution is the direct discharge of untreated wastewater from nearby industries containing toxic waste and the domestic sector. The presence of harmful synthetic chemicals and nutrients beyond the acceptable limit, which directly and indirectly effect the widely variety of vegetation of the aquatic framework as well as the human being and give high WQI values in river water. It is further recommended that to maintain the water quality of the Hindon River, a conservation plan should be taken to address the water pollution of Hindon River.

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