International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2015): 78.96 | Impact Factor (2015): 6.391

Assessment of Wastewater Drainages in Urban and Rural Region of Allahabad (Uttar Pradesh, India) through Water Quality Index (WQI)

Arti Yadav[1], Pawan Kumar Yadav[2]

[1]Department of Botany, University of Allahabad, Allahabad, Uttar Pradesh, India

[2]Center for Environmental Science and Technology, Banaras Hindu University

Abstract: ***Water quality index (WQI) is a dimensionless number that combines multiple water quality factors into a single number by normalizing values to subjective rating curves. Conventionally it has been used for evaluating the quality of water for water resources such as rivers, streams and lakes, etc. Factors included in WQI vary depending upon the designated water uses of the water body and local preferences. Some of the factors include dissolved oxygen (DO), pH, biological oxygen demand (BOD), chemical oxygen demand (COD), total coli form bacteria, temperature, and nutrients (nitrogen and phosphorus), etc. These parameters are measured in different ranges and expressed in different units. The WQI takes the complex scientific information of these variables and synthesizes into a single number. The WQI can serve as a simple first step tool in these efforts of evaluating the effects of the conservation practices in improving and/or sustaining the quality of water in the watershed. By regularly monitoring the physical and chemical makeup of water quality, it is possible to detect changes (both good and bad) and implement response measures to mitigate detrimental change before a situation worsens. At the same time, water quality monitoring data can be used to track response to management regimes aimed at improving water quality.***

Keywords: Water Quality Index (WQI), Wastewater, Ganga, Allahabad

1. Introduction

Water is a precious resource among of all natural resources mankind have on earth. It is important to all living organisms, most ecological systems, human health, food production and economic development (Postel *et al.*, 1996). It is the fundamental resource which is essential for different sectors, such as agricultural sector, industrial sector and all the small business units. This important natural resource for human development is being polluted by indiscriminate disposal of sewage, industrial waste and plethora of human activities, which affects its physico-chemical and microbiological quality. Increasing problem of deterioration of river water quality is a worldwide problem and make necessary to monitoring of water quality of rivers and drains discharged into rivers. The major activities responsible for pollution in river Ganga at Allahabad are sewage discharge, agriculture and industrial effluents discharge mainly from Naini industrial area, Phaphamau area and Phulpur fertilizers factory which directly discharges into the river. The existing Sewage Treatment plants (STP) at Gaughat and Rajapur are not able to cope with the situation. The water is available to us for consumption, washing, irrigation, hydroelectricity generation (Shivhare.S, Singh.P, Tiwari.A, Mishra.A, (2013)). WQI is widely used tool in different parts of the world to solve the problems of data management and to evaluate success and failures in management strategies for improving water quality. In the present paper an attempt has been made to assess the physico-chemical properties with respect to water quality index (WQI) in three seasons viz: Winter ,summer, and monsoon during 2011- 2013 of three drains in Allahabad viz: Mori gate Drain , Mawaiya Drain and Bairagiya Drain.

2. Research Methodology

2.1 Study Area

To study the wastewater drainages in urban and rural areas of Allahabad, three drains are selected one from rural areas (Bairagiya Drain) and two from the urban area (Mori Gate Drain and Mawaiya Drain). The study was carried out from December 2011 to June 2013. The three drains carry approximately (87840 CuM D) per day wastewater which is finally discharge into the river Ganga. The wastewater of these drains is used by farmers to irrigate their fields. Six different sites were selected for the regular monitoring of the physiochemical studies of the drain during the study period. The location of these drains, Mori gate drain, Mawaiya drain and Bairagiya drain respectively in Allahabad are shown in map (Figure 1).

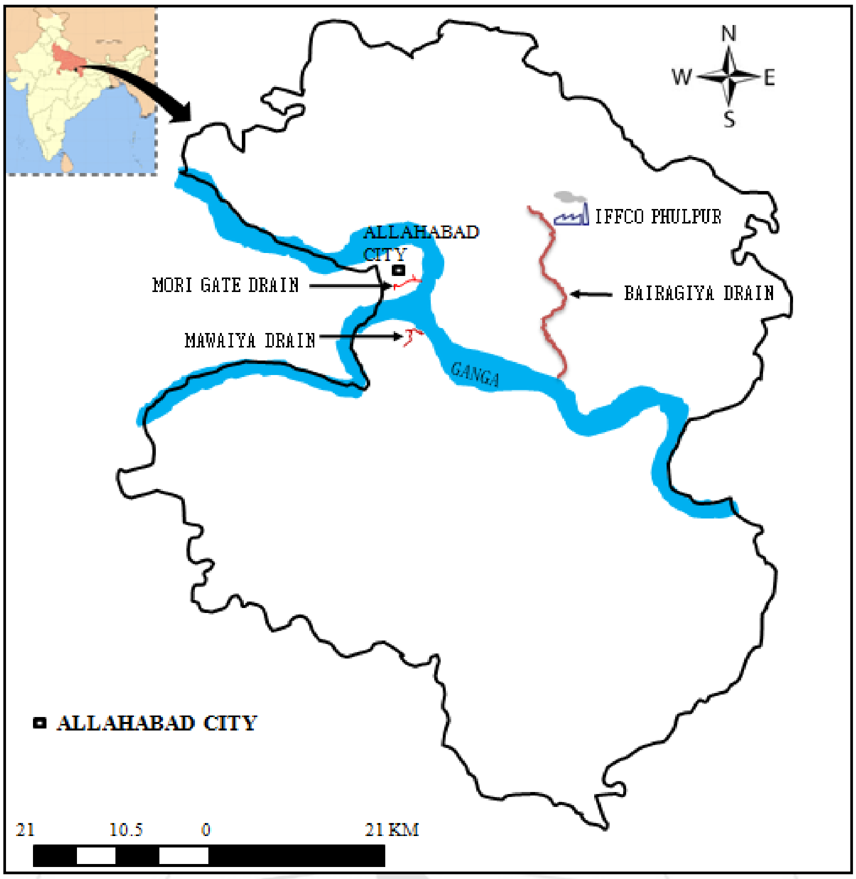

Figure 1: Study areas representing three drains Mori gate drain, Mawaiya drain and Bairagiya drain connected to river Ganga in Allahabad, Uttar Pradesh (India)

Description of drains selected for study:

1) ***Mori Gate Drain:*** Drains runs from Allahabad city and carry mainly domestic wastewater, this wastewater is utilize by people for growing vegetable in summers under bridge of NH 2.
2) ***Mawaiya Drain:*** Drains flows in Naini, Allahabad and carries both industrial as well as domestic wastewater to River Ganga. Farmers utilize wastewater from this drain to irrigate their fields.
3) ***Bairagiya Drain:*** Drain flows from Phulpur to join River Ganga at Rasulpur. This drain carries mainly domestic sewage and runoff water from villages. Farmers utilize wastewater from this drain to irrigate their fields.

The study area covers from Eastern Uttar Pradesh to entire Allahabad of the Gangetic plain. The study sites are given below with their geographical co-ordinates for each drain.

Table 1: Geographical coordinates of sampling sites of Mori gate drain

Sampling Points of Mori Gate drain	Latitude	Longitude	Reference places near to sampling points
Mori Gate Drain Site-1	25°26'10.64"N	81°51'37.61"E	100 meters from Kidganj Road New Bairahana, near Hotel Deepanjali, Allahabad
Mori Gate Drain Site-2	25°26'17.17"N	81°51'59.91"E	200 meters from Triveni Road, South to Chiranjiv Hospital Allahabad
Mori Gate Drain Site-3	25°26'21.89"N	81°52'11.77"E	10 meters from Parade Ground Road and 400 meters from Alopibagh Flyover, Allahabad
Mori Gate Drain Site-4	25°26'26.78"N	81°52'25.42"E	200 meters from NH 2 near Sardar patel Sansthan Hospital Alopi Bagh
Mori Gate Drain Site-5	25°26'27.86"N	81°52'56.96"E	500 meters from Daraganj Railway Site along Daraganj Ghat Road
Mori Gate Drain Site-6	25°26'23.15"N	81°53'4.26"E	Under Bridge of NH 2 joining river Ganga

Table 2: Geographical coordinates of sampling sites of Mawaiya drain

Sampling Points of Mawaiya drain	Latitude	Longitude	Reference places near to sampling points
Mawaiya Drain Site-1	25°23'46.50"N	81°53'27.00"E	1000 meters from Prayag Vidhi Mahavidyalaya on the bank of river Ganga (Mawaiya drain joins Ganga)
Mawaiya Drain Site-2	25°23'46.50"N	81°53'27.00"E	600 meters from Delhi Public School, Naini, Inter College, Arial, Naini Allahabad
Mawaiya Drain Site-3	25°22'15.47"N	81°52'35.98"E	700 meters from Dr. Murli Manohar Joshi,
Mawaiya Drain Site-4	25°23'18.82"N	81°53'17.80"E	500 meters from Kashiram Awas Yojna
Mawaiya Drain Site-5	25°22'31.10"N	81°53'5.15"E	1500 meters from E S I Hospital, Allahabad, Uttar Pradesh
Mawaiya Drain Site-6	25°22'15.47"N	81°52'35.98"E	200 meters from Bharat Pumps & Compressors Ltd Allahabad, on NH 27

Table 3: Geographical coordinates of sampling sites of Bairagiya drain

Sampling Points Bairagiya Drain	Latitude	Longitude	Reference places near to sampling points
Bairagiya Drain Site-1	25°31'55.60"N	82° 3'35.78"E	500 meters from NH 7 near IFFCO Phoolpur, Allahabad
Bairagiya Drain Site-2	25°29'7.46"N	82°4'1.19"E	1200 meters North from Allahabad Bypass Road, Allahabad
Bairagiya Drain Site-3	25°28'39.07"N	82° 3'36.85"E	Below the bridge of Allahabad Bypass Road, Allahabad
Bairagiya Drain Site-4	25°23'44.17"N	82° 4'3.72"E	Below the bridge of NH 2 near Jagatpur, Allahabad
Bairagiya Drain Site-5	25°20'42.43"N	82° 4'8.08"E	1000 meters river Ganga Mand Village
Bairagiya Drain Site-6	25°19'3.79"N	82° 5'6.78"E	Joining point to river Ganga on the Dumduma village.

2.2 Wastewater sampling procedures

The periodic samplings were carried out in monsoon, winter and summer seasons (with three replicates) in two consecutive years 2012-2013 and 2013-2014. The site of sampling is selected randomly by considering the population, location and source of pollutions. There were 18 sampling sites (6 from each drain system) were selected for the study proposes. Drains wastewater samples were collected at depths varying from 10 to 15 cm with the help of a waste water samples which consisted of a glass bottle and a cord tied to a lid. The whole assembly was lowered into water to the desired depths and the cord of the lid was pulled and released only when displaced air bubble ceased to come to the surface. The whole assembly was withdrawn and the water was then transferred into precleaned polypropylene bottles. All the containers which used in sampling purposes were thoroughly washed and rinsed with 10% HNO_3 following by double distilled water. The bottles were filled leaving no air space, and then the bottle was sealed to prevent any leakage. Each container was clearly marked with the name and address of sampling site, sample description and date of sampling. All the procedures were adopted according to the standard methods recommended by APHA, (1985).

2.3 Analysis of Physico-chemical Parameters of Wastewater Samples

For water analysis and assessment regarding the suitability of water for human consumption and other domestic purposes, specialized sampling and sample handling procedures are required. The water samples were analyzed for various parameters in the laboratory. Various physico-chemical parameters like Temperature, pH, Total Dissolved Solids (TDS), Hardness, and Biochemical Oxygen Demand (BOD), Dissolved Oxygen (DO), Electrical Conductivity (EC), Chloride, Sulphate, Total Alkalinity, Chemical Oxygen Demand (COD) have been monitored for river water. In general, the standard methods recommended by APHA (1985) were adopted for determination of various physico-chemical parameters. A brief description is given below. Physicochemical parameters like Temperature, pH, Dissolved Oxygen (DO), Electrical Conductivity (EC), Alkalinity, and Total Dissolved Solids (TDS) were measured using water analysis kit model ITS-701.

2.4 Water Quality Index (WQI)

A commonly-used water quality index (WQI) was developed by the National Sanitation Foundation (NSF) in 1970 (Brown and others, 1970). The NSF WQI was developed to provide a standardized method for comparing the water quality of various bodies of water. It is a 100 point scale that summarizes results from a total of nine different physico-chemical measurements completed by the data taken from the analysis of undertaken rivers water. These nine factors are given below;

1. Temperature
2. pH
3. Dissolved Oxygen
4. Turbidity
5. Fecal Coliform
6. Biochemical Oxygen demand
7. Total Phosphates
8. Nitrates
9. Total suspended Solids

In these nine parameters some were judged more important than others, so a weighted mean is used to combine the values. According to the book Field Manual for Water Quality Monitoring, the National Sanitation Foundation (NSF).

Table 4: Water quality Factors and their Corresponding weight

Factor	**Weight**
Dissolved oxygen	0.17
pH	0.11
Biochemical oxygen demand	0.11
Temperature change	0.10
Total phosphate	0.10
Nitrates	0.10
Turbidity	0.08
Total solids	0.07

When test results from fewer than all nine measurements are available; we preserve the relative weights for each factor and scale the total so that the range remains 0 to 100. The WQI ranges have been defined as (Brown and others, 1970). The 100 point index can be divided into several ranges corresponding to the general descriptive terms shown in the table below. In this study five factors are considered and according weight was calculated for each factor to scale up from 0 to 100.

Table 5: Water quality Index of Ranges

Water Quality Index Legand	
Range	**Quality**
90-100	Excellent
70-90	Good
50-70	Medium
25-50	Bad
0-25	Very bad

3. Results and Discussion

Water quality assessment is a tool that provides valuable information for the policy and decision makers. The Water Quality Index (WQI) is a single number that expresses the overall water quality at a certain location and turns complex water quality data into information that is understandable and usable by the general public. It is one of the most effective tools to communicate information on the quality of water to the concerned citizens and policy makers. Horton (1965) proposed the first WQI followed by other indices including National Sanitation Foundation (NSF) of USA which is accepted as a more convenient WQI based on expert or panelist's opinion (Brown, McClelland *et al* 1970). Besides the National Sanitation Foundation Water Quality Index (NSFWQI), some other water quality indices used worldwide in practice include the Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI) 1999, British Columbia Water Quality Index (BCWQI) and Oregon Water Quality Index (OWQI) (Debels, Figueroa *et al*., 2005; Kannel, Lee *et al.*, 2007). Water quality along with the quality index of each quality parameter is presented in table 6, 7 and 8.

Table 6: Water Quality Index of Mori Gate Drain

Year			2011-2012			2012-2013		
	Unit	Weighting Factor	Winter season	Summer season	Monsoon season	Winter season	Summer season	Monsoon season
DO	% saturation	0.17	9.7	10.66	10.87	8.53	11.2	11.67
Quality Index	-		7	7	7	6	8	8
Fecal Coli form	Colonies/100 ml	0.16	-	-	-	-	-	-
Quality Index	-		-	-	-	-	-	-
pH	-	0.11	5.53	5.38	5.68	5.58	6.38	6.68
Quality Index	-		42	38	46	43	67	78
BOD	mg/L	0.11	352	389	331	365	399	361
Quality Index	-		2	2	2	2	2	2
Temperature Change	^oC	0.1	-	-	-	-	-	-
Quality Index	-		-	-	-	-	-	-
Phosphate	mg/L	0.1	3.51	3.43	3.18	3.64	3.48	3.28
Quality Index	-		19	19	20	18	19	20
Nitrate	mg/L	0.1	4.22	4.46	4.7	4.43	4.56	4.79
Quality Index	-		69	68	67	68	67	66
Turbidity	NTU	0.08	-	-	-	-	-	-
Quality Index	-		-	-	-	-	-	-
Total Solid	mg/L	0.7	-	-	-	-	-	-
Quality Index	-		-	-	-	-	-	-
Water Quality Index			25	24	26	25	30	32
Water Quality			Bad	Very Bad	Bad	Bad	Bad	Bad

Table 7: Water Quality Index of Mawaiya Drain

Year			2011-2012			2012-2013		
	Unit	Weighting Factor	Winter season	Summer season	Monsoon season	Winter season	Summer season	Monsoon season
DO	% saturation	0.17	7.78	9.28	10.08	8.86	11.54	11.01
Quality Index	-		6	7	7	6	8	8
Fecal Coli form	Colonies/100 ml	0.16	-	-	-	-	-	-
Quality Index	-		-	-	-	-	-	-
pH	-	0.11	7.59	7.41	7.44	7.69	7.61	7.64
Quality Index	-		92	93	94	91	92	92
BOD	mg/L	0.11	345	390	218	355	380	319
Quality Index	-		2	2	2	2	2	2
Temperature Change	^oC	0.1	-	-	-	-	-	-
Quality Index	-		-	-	-	-	-	-
Phosphate	mg/L	0.1	2.5	2.76	2.42	3.05	3.76	3.42
Quality Index	-		24	23	25	21	18	19
Nitrate	mg/L	0.1	4.94	3.74	3.98	4.84	3.84	3.95
Quality Index	-		65	75	70	66	73	71
Turbidity	NTU	0.08	-	-	-	-	-	-
Quality Index	-		-	-	-	-	-	-
Total Solid	mg/L	0.7	-	-	-	-	-	-
Quality Index	-		-	-	-	-	-	-
Water Quality Index			34	36	36	34	35	35
Water Quality			Bad	Bad	Bad	Bad	Bad	Bad

Table 8: Water Quality Index of Bairagiya Drain

Year			2011-2012			2012-2013		
	Unit	Weighting Factor	Winter season	Summer season	Monsoon season	Winter season	Summer season	Monsoon season
DO	% saturation	0.17	17.67	24.80	24.14	16.61	23.89	23.30
Quality Index	-		11	15	15	10	15	14
Fecal Coli form	Colonies/100 ml	0.16	-	-	-	-	-	-
Quality Index	-		-	-	-	-	-	-
pH	-	0.11	7.52	7.83	7.74	7.56	7.84	7.8
Quality Index	-		92	89	91	92	89	90
BOD	mg/L	0.11	36	38	32	36	42	30
Quality Index	-		2	2	2	2	2	2
Temperature Change	^{o}C	0.1	-	-	-	-	-	-
Quality Index	-		-	-	-	-	-	-
Phosphate	mg/L	0.1	2.15	1.92	1.68	3.15	2.92	2.68
Quality Index	-		26	28	29	20	22	23
Nitrate	mg/L	0.1	4.028	3.93	3.84	6.02	5.96	4.81
Quality Index	-		70	71	82	60	60	66
Turbidity	NTU	0.08	-	-	-	-	-	-
Quality Index	-		-	-	-	-	-	-
Total Solid	mg/L	0.7	-	-	-	-	-	-
Quality Index	-		-	-	-	-	-	-
Water Quality Index			37	38	40	34	35	36
Water Quality			Bad	Bad	Bad	Bad	Bad	Bad

The NSFWQI seems to be one of the most comprehensive forms of WQI based on expert opinion.WQI for three seasons for two years calculated (table 6, 7 and 8) from the field observations and trend drawn (fig.2). From the figure it is clear the WQI of all the three drains were under value of 50 and hence were in category bad in conditions regarding water quality.

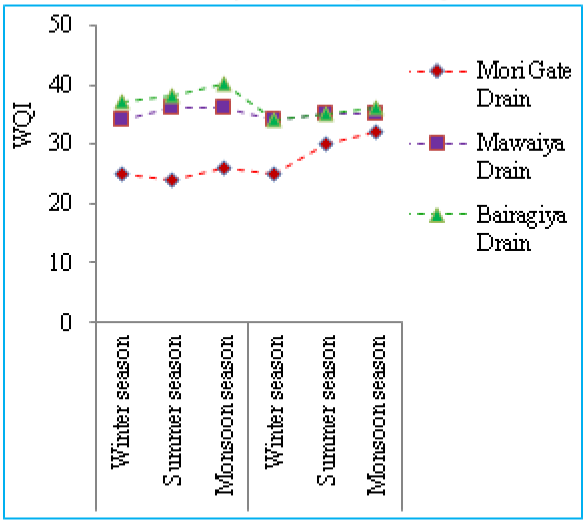

Figure 2: Water Quality index of three drains Mori gate drain, Mawaiya drain and Bairagiya drain connected to river Ganga in Allahabad, Uttar Pradesh (India)

The graph shows the water quality of Mori gate drain was improved along time whereas the other two drains degraded along time scale in water quality context. The WQI values are lower than other researches on WQI in India such as Water Quality Assessment of SukhnaLake of Chandigarh City of India by Chaudhry et al. 2013, water bodies like Halai, Koloroi, Kalyani, Salim Ali, Dahi-Khura, Ramgarh, Kalakho and Dalvoy Lake (Jain, Sharma and Thakur 1996; Sreenivasan Venkatanarasimha and Franklin 1997; Srinivasa and Kotaiah 2000; Thorat and Masaraat 2000; Shastri and Pendse, 2001; Moundiotiya, Sisodia et al 2004; Sisodia and Moundiotiya 2006; Mahesha and Balasubramanian 2010). Padmanabha and Belagali (2005) monitored the water quality of four lakes in Mysore city during November 2004 to April 2005. Based on pH, total alkalinity, total hardness, chloride, calcium, magnesium, total dissolved solids, dissolved oxygen and BOD, it was found that the water of these lakes was severely polluted and unfit for human consumption. Mahesha and Balasubramanian (2010) found the Dalvoy Lake of Mysore city as having poor water quality. Sisodia and Moundiotiya (2006) found that the Kalakho Lake of Rajasthan has poor water quality. The all researches were performed for river or lake and none of them were for the drains which collect the wastewater of the city or town. The WQI of the drains have lower values due to untreated sewage of north part of Allahabad city and Naini in case of Mori gate drain and Mawaiya drain and agricultural runoff in case of Bairagiya drain respectively. The lower DO, high BOD and high concentration of nitrates and phosphates in these drains resulted in poor quality of water which is categories under bad and very bad water quality in the NSFWQI.

4. Conclusion

The water quality index state that quality of Mori gate drain is improving with time whereas the quality of wastewater is degrade with the time as WQI value decreased with time of other two drains. Water quality parameters of the drains in urban and rural wastewater are within the acceptable limits of the irrigation standards of FAO. Hence, this urban wastewater can be used for cultivation of crops. But continuous use of wastewater for irrigation may pollute the ground water of the location through percolation and vertical movement. Continuous cultivation with the application of organic rich urban wastewater and large amount of plant residues left on the soil surface will lead to heavy accumulation of macro nutrients such as nitrogen, phosphorous and potassium in the soil matrix, which may exceed the prescribed standards. Urban wastewater has to be treated before its application for irrigation continuously; else the environment will be degraded to a level, beyond redemption.

References

[1] APHA (American Public Health Association) (1985). Standard methods for the examination of water and wastewater. Washington DC: American Public Health Association.
[2] Brown, R. M., McClelland, N. I., Deininger, R. A. and Tozer, R.G. 1970. A water quality Index-Do we dare? Water Sewage works, 117(10): 339-343.
[3] CCME (Canadian Council of Ministers of the Environment). 1999 (updated 2012). Canadian Environmental Quality Guidelines. Winnipeg, MB, Canada.
[4] Chaudhry P., M. P. Sharma, R. Bhargave, S. Kumar and P. J. S. Dadhwal (2013). Water quality assessment of Sukhna lake of Chandigarh city of India. Hydro Nepal. 12: 26-31.
[5] Debels, P., R. Figueroa, R. Urrutia, R. Barra and X. Niell. 2005. Evaluation of water quality in the Chilla riverof Central Chile using physicochemical parametersand a modified water quality index, Environmental Monitoring and Assessment,110: 301-322.
[6] Horton, R.K., 1965. An index number for rating water quality, Journal of Water Pollution Control Federation, 37(3): 300-306.
[7] Jain, S.M., M. Sharma and R. Thakur, 1996, Seasonal variations in physicochemical parameters of Halai reservoir of Vidisha district, India, Indian Journal of Ecobiology, 8(3): 181-188.
[8] Kannel, P.R., S. Lee, Y. S. Lee, S.R. Kanel and S. P. Khan. 2007. Application of water quality indices and dissolved oxygen as indicators for river water classification and urban impact assessment, Environmental Monitoring and Assessment, 132: 93-110.
[9] Mahesha and Balasubramanian. 2010. Analysis of water quality index (WQI) in Dalvoy Lake, Mysore city, India, Nature Environment and Pollution Technology, 9(4): 663-670.
[10] Moundiotiya, C., Sisodia, R., Kulshreshtha M., and Bhatia, A. L. 2004. A Case Study of Jamwa Ramgarh wetland with special reference to physicochemical properties of water and its environs, Journal of Environmental Hydrology, 12(24): 1-7.
[11] Padmanabha, B. and Belagali, S.L. 2005. Comparative study on the water quality index of four lakes in the Mysore city, Indian journal of Environmental Protection, 25(10): 873-876.
[12] Postel, S. L., Daily, G.C. and Ehrlich, P.R. (1996): Human appropriation of renewable fresh water. Science, 271: 785-788.
[13] Shastri, Y. and Pendse, D. S. 2001. Hydrobiological study of Dehikhuta reservoir. J. Environ. Biol. 22: 67-70.
[14] Shivhare. S, Singh.P, Tiwari.A, Mishra.A, (2013). *Journal of Chemical, Biological and Physical Sciences*, 4:78-786.
[15] Sisodia, R. and Moundiotiya, C. 2006. Assessment of water quality index of wetland Kalakho lake, Rajasthan, India, Journal of Environmental Hydrology, 14(23): 1-11.
[16] Sreenivasan A., Venkatanarasimha, P. K. and Franklin, T. 1997. Limnological study of a shallow water body (Kolovoi Lake) in Tamil Nadu, India, Journal of Indian Hydrobiology, 2(2): 61-69.
[17] Srinivasa, G. S. and Kotaiah, B. 2000. Seasonal variation of water quality in tropical Kalyani reservoirs, near Tripathi, Indian Journal of Environmental Protection, 20(6): 452- 455.
[18] Thorat, S. R. and Masaraat, S. 2000. Pollution status of Salim Ali Lake, Aurangabad, India, Journal of Pollution Research, 19(2): 307-309.

Author Profile

Dr. Arti Yadav, D Phil in Environmental Science from University of Allahabad.

Pawan Kumar Yadav, M. Sc. (tech) Environmental Science and Technology from Banaras Hindu University