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RESEARCH ARTICLE

QUALITATIVE STUDY OF YAMUNA WATER ACROSS THE DELHI STRETCH.

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Abstract

The Yamuna River, a tributary of the Ganges, is one of the most polluted rivers in India and especially in urban cities like Delhi is of a critical water quality. The discharge of untreated waste water is the main reason of the decrease in water quality. While emission sources like dumping of waste material, religious offering of flowers or food, immersion of idols, holy baths, clothes washing or cattle bathing can lead to serious pollution, industrial wastewater pollution is a serious matter of concern. The rapid growth and the high population density in India have made the situation worse and out of control. Although there are many schemes and policies such as The Yamuna Action Plan phase I, II and III, an improvement is seemingly noticeable. River Yamuna enters the Delhi Stretch at the Palla Village and is exited from the Okhla Barrage, this study is aimed to compare and analyze the water parameters upon its entrance and exit. The CPCB monitoring of Yamuna is done at 4 stretches in the Delhi stretch which are Wazirabad Barrage, Nizamuddin Bridge, ITO, and Okhla Barrage. The tests included parameters such as Biological Oxygen Demand, Chemical Oxygen Demand, Dissolved Oxygen, Chloride Content, pH and other physical parameters too. These results were measured during non-monsoon season where only 20 % of the annual rainfall appears. The results can vary in monsoon season but in comparison to the average values of CPCB most results were similar.

Introduction:-

Water Sources:-

The earth has an abundance amount of water, but unfortunately, only a small percentage (about 0.3%), is even usable by humans. The other 99.7% is in the oceans, soils, icecaps, and floating in the atmosphere. Climate change has also altered the global hydrological cycle [49]. Even though a very less amount of water is usable, even much of the 0.3% that is usable is unattainable. The distribution of water is as: ocean water: 97.2 %, glaciers and other ice: 2.15 %, groundwater: 0.61 %, freshwater lakes: 0.009 %, inland seas: 0.008 %, soil moisture: 0.005 %, atmosphere: 0.001 %, rivers: 0.0001 % [1, 44-45].

Surface water is far easier to reach, which is why this becomes the most common source of potable water. The main sources of raw water in Delhi are through the river Yamuna (surface water and Western Yamuna Canal WYC), the Ganga (Upper Ganga Canal), Bhakra-Beas storage, groundwater through tube wells and ranney wells (specially designed high-capacity wells named after its founder Leo Ranney). The estimated water availability of NCT of Delhi from surface water sources, mainly the Yamuna, the Ganga and the WYC is approximately 1150.25 million cubic meters (mcm). The river Yamuna contributes 723 mcm, which is surely a significant part of the total water requirement. It enters at Palla, North West Delhi and then traverses through NCT and leaves at Jaipur in the South.

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The total area of river zone is approximately 9700 Ha, of which about 1600 Ha of land is irrigated and 8100 Ha is dry land which contributes as runoff pollution into the river.

Water Quality Monitoring:-

Any physical, chemical or biological changes in the characteristics of water results in the pollution of water body [41, 44-45, 48]. These changes have to be monitored in order to determine the quality of water relative to the requirements to any human need or purpose and or of one or more of the biotic species. The key indicators of water quality are water temperature, pH, transparency /turbidity, nutrients, dissolved oxygen and salinity. Water Quality Monitoring is important as it identifies the changes or trends, short term or long term that appear in water bodies over time. This data is useful for the designing and development of the pollution prevention and management strategies and for giving early warnings against the possible future crisis or problems. Water monitoring also ensures compliance with regulations [2-5, 35-37].

In India, Central Pollution Control Board (CPCB) is responsible for accessing and monitoring the water quality. CPCB started a National Water Quality Monitoring programme in the year 1978 under Global Environmental Monitoring System (GEMS), with 24 surface water and 11 ground water stations. Along with this a National Programme of Monitoring of Indian National Aquatic Resources (MINARS) was initiated in the year 1984, with 113 stations spread over 10 river basins. At present there are 870 monitoring stations which covers 189 rivers with 567 stations, 53 lakes with 55 stations, 4 tanks with 4 stations, 2 ponds with 2 stations, 3 creeks with 3 stations, 3 canals with 12 stations, 9 drains with 9 stations, 218 wells with 218 stations [6,7].

Water Quality Index:-

Water quality depends on a number of physical, chemical and biological parameters and presenting data for all the parameters separately to the public is not feasible. So in order to turn this complex water quality data into more understandable and accessible information for the public water quality index is calculated. Water Quality Index (WQI) is a number that seeks to express the overall quality of water combining various parameters over a given location and time. The index is similar to indices like air quality index [8, 9, 39, 41, 46].

Indian Quality Standards:-

In India water quality standards are given by Bureau of Indian Standards (BIS) and Central Pollution Control Board (CPCB). As per ISI-IS: 2296-1982, the tolerance limits of parameters are specified as per classified use of water depending on various uses of water [10-12]. The classifications adopted in India are as follows in table 1.1:

Table 1.1:-Classification of different uses of water

Classification	Designated Use
Class A	Drinking water source without conventional treatment but after disinfection
Class B	Outdoor bathing
Class C	Drinking water source with conventional treatment followed by disinfection
Class D	Fish culture and wild life propagation
Class E	Irrigation, industrial cooling or controlled waste disposal

The surface water quality standards for designated uses as specified by CPCB, 1979 and the Bureau of Indian Standards, 1982 [13-15] is tabulated in the table 1.2:

Table 1.2:-Water quality standards (Source: BIS, 1982 and CPCB, 1979)

S.No.	Water Quality Parameter	Characteristic of water body				
		A	B	C	D	E
1.	Dissolved Oxygen (DO) mg/l (Minimum)	6	5	4	4	3
2.	Biochemical Oxygen Demand (BOD), mg/l (max)	2	3	3	-	-
3.	Total coliform organisms MPN/100ml (max)	50	500	500	-	-
4.	Total Dissolved Solids (TDS) mg/l (max)	500	-	1500	-	2100
5.	Chlorides (as Cl^-) mg/l (max)	250	-	600	-	600
6.	Colour, Hazen Units (max)	-	10	300	300	-
7.	Sodium Absorption Ratio (max)	-	-	-	-	20
8.	Boron (as B), mg/l (max)	-	-	-	-	-

9.	Sulphates (as SO_4^{-2}), mg/l (max)	400	-	400	-	1000
10.	Nitrates (as NO_3^-) mg/l (max)	2	-	50	-	-
11.	Free Ammonia (as NH_3) mg/l (max)	-	-	-	1.2	-
12.	Conductivity at 25^0C micro mhos/cm (max)	-	-	-	1000	2500
13.	pH value	6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5	6.0-8.5
14.	Arsenic (as As), mg/l (max)	0.05	0.2	0.2	-	-
15.	Iron (as Fe), mg/l (max)	0.3	-	-	0.5	-
16.	Fluoride (as F), mg/l (max)	1.5	1.5	1.5	-	-
17.	Lead (as Pb), mg/l (max)	0.1	-	0.1	-	-

Methodology:-

Study Area:-

The Yamuna River originates from the Yamunotri glacier near Bandar Punch at 38°59'N 78°27'E in the Mussoorie range of the lower Himalayas at an elevation of 6,387 m above the sea level in the District Uttarkashi, Uttarakhand, India. The catchment area of the River Yamuna includes parts of Uttarakhand, Uttar Pradesh, Himachal Pradesh, Haryana, Rajasthan, Madhya Pradesh and Delhi [16, 17].

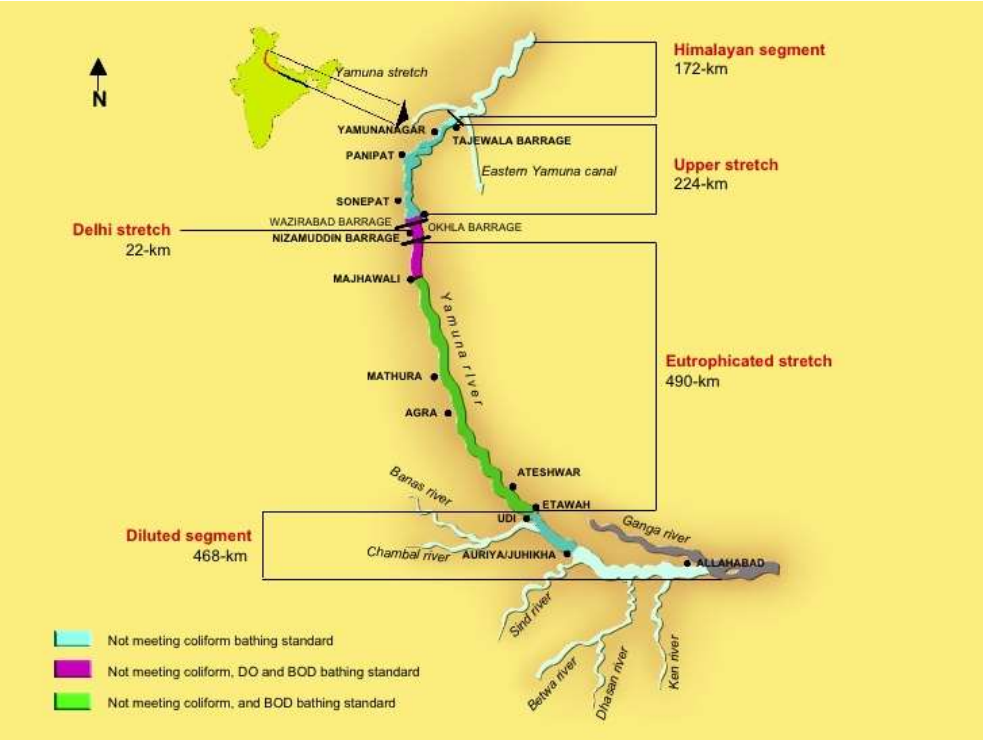


Figure 2.1:-Different Segments of River Yamuna

The River Yamuna is divided majorly in five segments (figure 2.1), the Himalayan segment, the Upper stretch, the Delhi stretch, the Eutrophicated stretch, and the Diluted segment. The Himalayan segment stretches 172 km from the river source at Yamunotri to the Tajewala barrage in Haryana. The river is clean here. The Upper stretch is 224 km in length. The river flows through the small towns of Haryana and Uttar Pradesh [18, 26]. The river water is relatively cleaner in this stretch but suspected to be contaminated in the near future. The Delhi stretch of River Yamuna is merely 22 km. The river turns into sewer here due to industrial disposal and waste water treatment plants' discharge. The Eutrophicated stretch of River Yamuna is 490 km long stretch. Here, the river is full of organic matter such as human feces. When the organic matter decomposes it gobble up all the oxygen of the water. Lower oxygen levels in water lead to death of fishes and threat to the survival of other aquatic lives [19]. The water of this stretch of river is not suitable for bathing and other purposes. The Diluted segment is 428 km long stretch starting from Chambal confluence to where River Yamuna merges in the River Ganga. The Chambal's waters breathe new life into the river. Water of this stretch cleanses itself by decomposing organic matter into oxygen- rich

environment. But today, due to increased pollution to a huge extent at previous stretches, the self cleansing ability of this stretch has reduced considerably [20, 21]. The catchment area of river Yamuna is provided in table 2.1.

Table 2.1:-Catchment Area of Yamuna River

Name of State	Total catchment area (in sq. km)
Uttar Pradesh	3,771
Uttrakhand	70,437
Himachal Pradesh	5,799
Haryana	21,265
Rajasthan	1,02,883
Madhya Pradesh	14,028
Delhi	1,485

The length of the River Yamuna in NCT's municipal boundary is approximately 50 km [22]. The Yamuna enters the city 1.5 km before the Village Palla and leaves at Jaitpur, downstream of the Okhla Bridge. The wastewater received by the river in the catchment area of Delhi is from Najafgargh, Magazine Road, Sweepers Colony, Khyber Pass, Metcalf, Mori Gate, Tonga Stand, Civil Mill, Shahdara, Tuglakabad, Kalkaji, Maharani Bagh, Power House, Moat, Sen Nursing Home, No. 12 A, No. 14, Barapulla, Sarita Vihar, Near LPG Plant, Near Bridge Sarita Vihar and Tehkhand Drains. The Yamuna also gets direct load from wastewater treatment plant at Okhla and Hindon Cut [23, 24].

Figure 2.2:-Location of River Yamuna in Delhi

The study covers the sampling and analysis at the Palla Village and the Okhla Bridge (figure 2.2). Village Palla is located at 23 km upstream Wazirabad barrage and Okhla is located at 39 km downstream of Palla and meets the Agra Canal [25].

Sampling:-

The two locations were chosen for sampling in order to study the contribution of Delhi in polluting the River Yamuna (figure 2.3). The two locations chosen are:

1. Village Palla: Village Palla is located at28.846002˚ N 77.212117˚ E. This location was reachable. Sample was collected with the help of nearby villagers who were able to step into the river. Village Palla is located near the junction of Haryana and Uttar Pradesh from where the river Yamuna enters Delhi. Sample collected form Palla help in determining the amount of contaminants in the river before entering Delhi boundary.
2. Okhla Barrage: Okhla barrage is located at 28.542120˚ N 77.316230˚ E. This location was also reachable and sample was collected with the help of nearby people. This location is chosen for sampling as here the river Yamuna leaves Delhi. All the polluting waste streams fall into Yamuna before Okhla.

Figure 2.3:-Sampling Locations on Delhi Map

Method of Sampling:-

The sampling was done considering the guidelines of CPCB. Transparent bottles were used for sample collection. The bottles were washed, before sampling, with dilute acid followed autoclave. One sample at each site was collected from the middle of the channel of the stream. Samples were collected from below the surface area in human reach and mouth of bottle was directed toward the current to avoid collecting surface scum.

Laboratory Tests:-

Both the samples were tested for various physical and chemical characteristics in the laboratory [27, 28]. Temperature, colour and odor of river water samples were measured immediately after sample collection. The tests were conducted in the laboratory for pH values, Dissolved Oxygen (DO), Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD) and contents of Chlorides [29]. The temperatures of the samples collected from River Yamuna at two locations were immediately tested after sample collection using mercury thermometer. The colour and odor of both the samples were detected using human observations of vision and smell. pH was calculated using pH meter after calibration. Modified Winkler- Azide method was used to calculate DO levels in the river water samples [30]. The sample was collected in 300mL BOD bottles using DO sampler. 1mL $MnSO_4$ followed by 1mL alkali- iodine- azide reagent was added to the sample and mixed well. The precipitate was allowed to settle leaving the 150mL clear supernatant. 1 mL of concentrated H_2SO_4 was added and precipitate was mixed into the solution. 200mL of the solution is titrated against $Na_2S_2O_3$ solution using 2mL starch as indicator.

For COD, 25mL water sample was taken in COD flask and one blank sample of 25mL was prepared. Few glass beads were added to the flasks. A pinch of $HgSo_4$ followed by 10mL of $K_2Cr_2O_4$ was added to both the sample and the blank. 35mL of concentrated H_2SO_4 (containing Ag_2SO_4) was added slowly. It was then boiled by reflux method and kept for cooling. The cooled solutions were titrated against N/4 Ferrous Ammonium Sulphate using ferroin indicator. The end point achieved was green to reddish in colour [31]. In case of BOD, 25% to 100% dilution, using distilled water, is required by the river water. Sample collected at Palla was diluted to 25% and that of at Okhla was diluted to 100% depending upon their contamination. The samples were diluted 25% and 100% by volume in 300mL BOD bottles. Phosphate buffer, magnesium sulphate, calcium chloride and ferric chloride are added to this water and kept in the incubator for 3 days along with blank sample. After 3 days, 2mL of 50% $MnSO_4$ and 2mL of KI were added and shaken well and were kept to settle down. After settlement, 2mL of concentrating H_2SO_4 was added and titrated against N/80 Sodium Thiosulphate using starch as indicator. The end point obtained was colourless [32-34]. Chlorides were tested by taking 10mL sample in conical flask. 3- 4 drops of Potassium Chromate

indicator was added to it and titrated against N/35.5 $AgNO_3$. Brick red colour is obtained as the end point. Ammonia was estimated using 1 mL of water sample in Nessler tube and distilled water added to it to make it 50 mL. 1 mL of Nessler reagent is added and it was kept for 4 to 5 minutes for colour development. Different doses of ammonia were prepared. The amount of ammonia was calculated considering the dose to which the colour of the sample matched.

Results and Analysis:-

Results:-

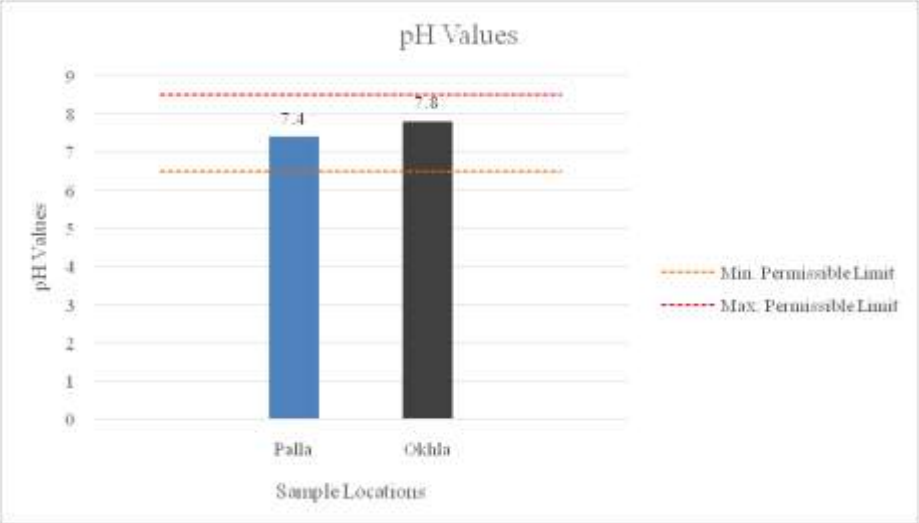
The samples were analyzed for various physical and chemical parameters and readings so calculated are tabulated below in table 3.2:

Table 3.2:-Results of laboratory analysis of samples

S. No.	Parameters	SI Units	Permissible Limits	Palla Village	Okhla Barrage
1	Temperature	Celsius	23.8	17.8	17.5
2	Odour		Agreeable	Agreeable	Foul Smell
3	Colour		Transparent	Transparent	Blackish
4	pH		6.5-8.5	7.4	7.8
5	Chloride content	mg/l	250	177	**376**
6	Dissolved Oxygen (min-max)	mg/l	4	8.65	**0.85**
7	BOD	mg/l	3	**8.8**	**57.5**
8	COD	mg/l	50	36	**140**
9	Ammonia	mg/l	0.8	**4.0**	**2.2**

pH:-

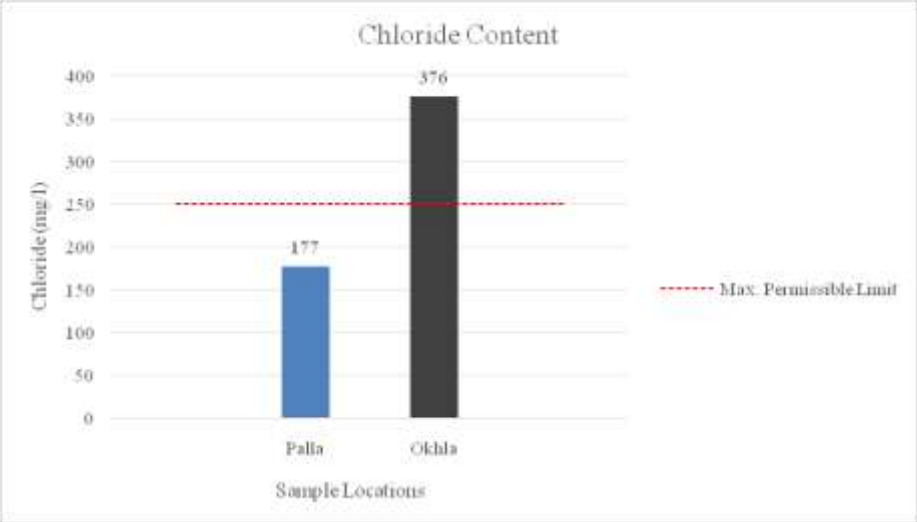
pH levels of sampling sites near Palla and Okhla proved to be within permissible limits as depicted in graph 3.1. While the pH levels of Palla are slightly less alkaline, the alkalinity of Okhla water is due to industrial waste emission from Wazirabad Barrage and emissions from Nizamuddin Bridge location.



Graph 3.1:-Comparison of the pH values of the samples

Chloride content:-

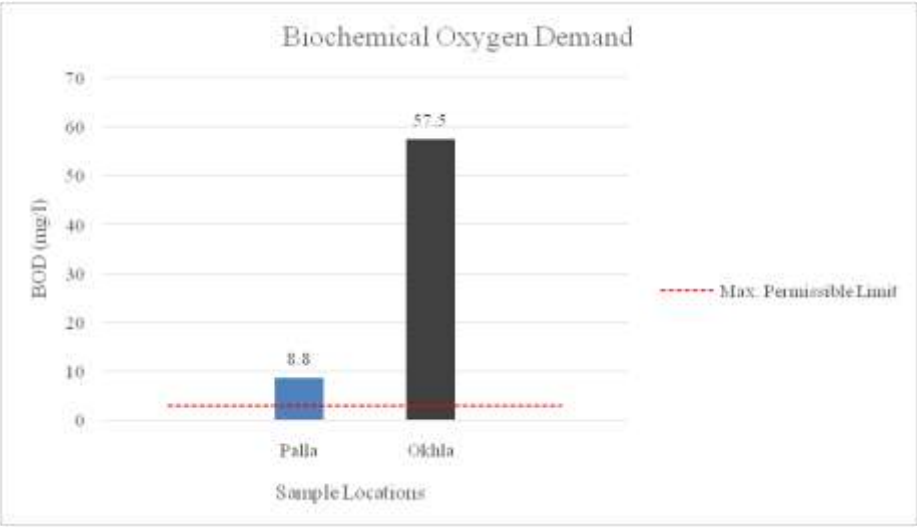
Chloride as free ions is one of the major inorganic anions in water and wastewater. The salty taste produced in potable water is due to the presence of chloride ions. High amount of chloride increases corrosive nature. The Chloride content at Palla is seen within the limits while the Okhla water sample is 376 mg/l that is way above the permissible limits. This is majorly due to the scanty rainfall in Yamuna- Delhi stretch catchments which helps the industrial waste emission to wash off thus decreasing the chloride content. The comparison of the chloride contents at two sapling locations is shown in graph 3.2.



Graph 3.2:-Comparison of the chloride content of the samples

Biochemical Oxygen Demand:-

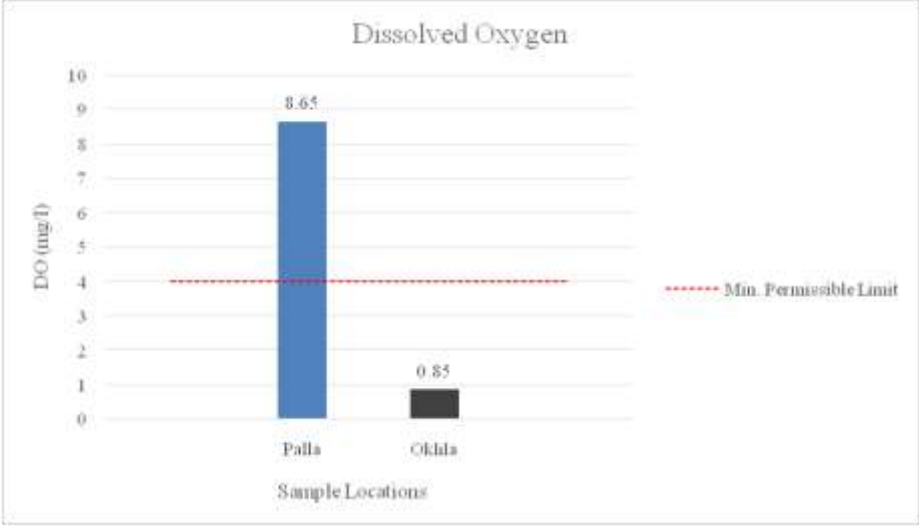
Bio-chemical Oxygen Demand (BOD) at Palla meets the prescribed standards of 3 mg/l and was found to be 8.8 mg/l as depicted in graph 3.3. At Okhla D/s BOD values were found well above the limit of 3 mg/l that is 57.5mg/l. This trend indicates the rapid industrial waste emissions which are proving to be a matter of concern even after several water preservation schemes for Yamuna.



Graph 3.3:-Comparison of the BOD values of the samples

Dissolved Oxygen:-

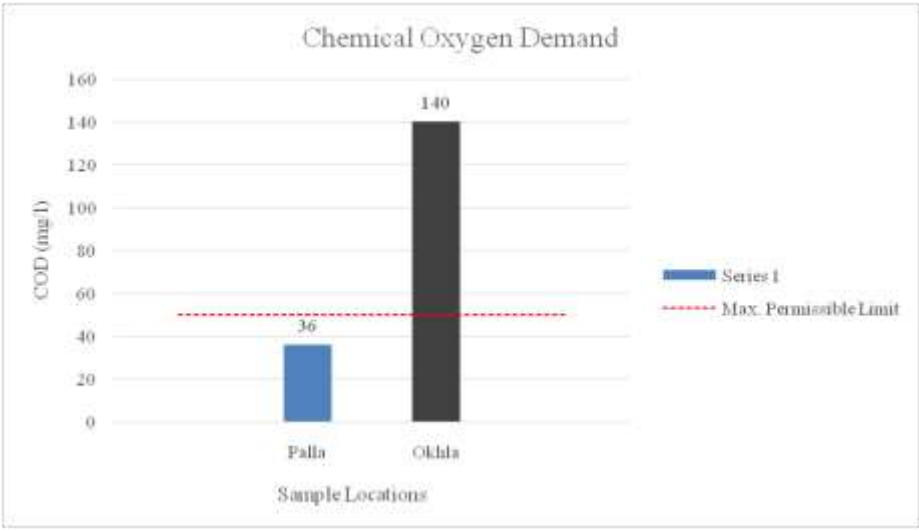
The presence of dissolved oxygen (DO) is essential to maintain the higher forms of biological life and to keep proper balance of various populations thus making the water bodies healthy. The chemical and biochemical processes undergoing in a water body are largely dependent upon the presence of oxygen. The main sources of dissolved oxygen are from the atmosphere and the photosynthetic processes of the green plants. Estimation of dissolved oxygen is a key test in water pollution and waste treatment process control. The solubility of oxygen in water depends upon the partial pressure of oxygen in air, temperature of water and mineral content of water. DO content of Yamuna waters while entering the Delhi Stretch at Palla Sampling location is well above permissible limits which indicates that it can sustain aquatic life while DO levels after exit through Okhla barrage is quite low which is a matter of concern from a water pollution perspective. Treatment can be effectively done by magnetic adsorption [40]. The DO levels at both the sampling locations have been depicted in the graph 3.4.



Graph 3.4:-Comparison of the DO values of the samples

Chemical Oxygen Demand:-

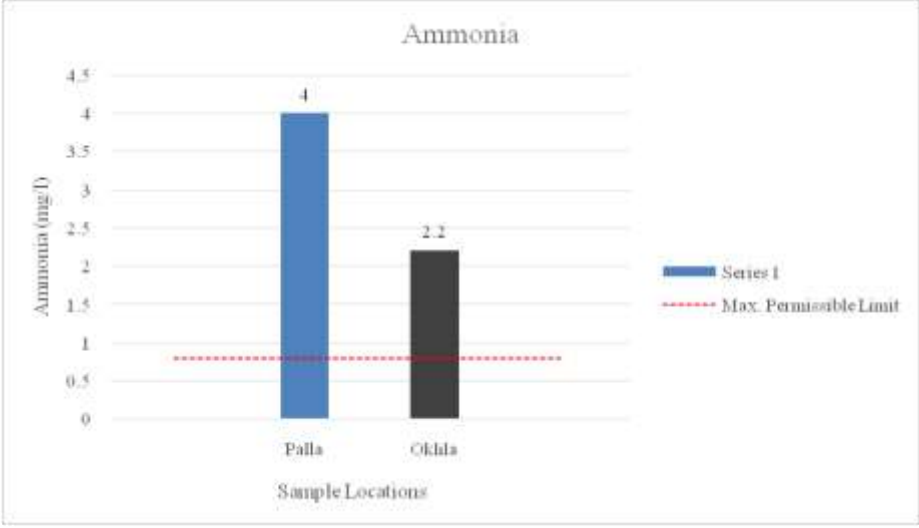
Increased levels of COD indicate organic and inorganic pollutants in river water. COD level of Palla is 36 mg/L which is present within the maximum permissible level of 50 mg/L (graph 3.5). After Palla River Yamuna receive a large amount of wastewater from various drains. The COD levels starts increasing from Nizamuddin Bridge. Due to this, the COD level of river water at Okhla is 140 mg/L which is much more than the limit.



Graph 3.5:-Comparison of the COD values of the samples

Ammonia:-

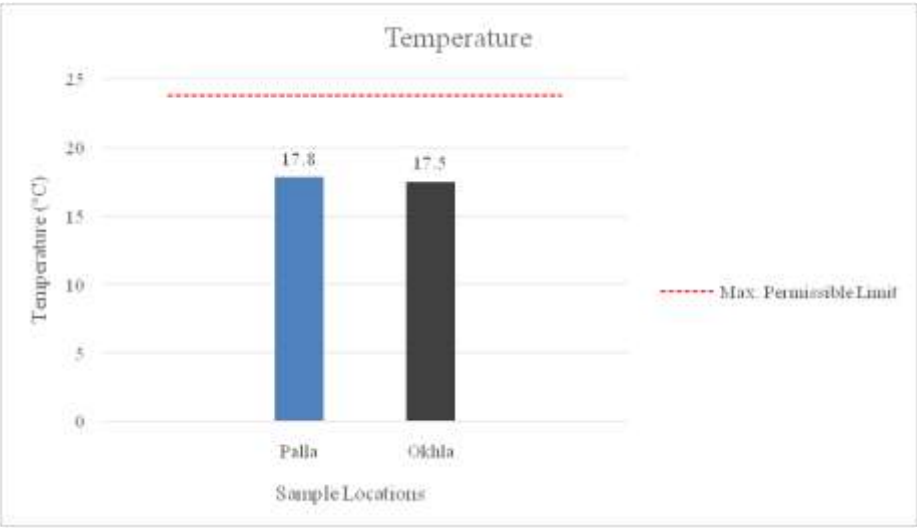
Level of Ammonia at Palla is 4 mg/L which is much higher than the maximum permissible limit of 0.8mg/L as shown in the graph 3.6. This high level is due to fertilizers used in irrigation and discharge of industrial waste from Panipat and Sonepat area. The levels of ammonia again increase to dangerous levels at Wazirabad and ITO barrage due to wastewater discharge. The COD level at Okhla comes down to 2.2 mg/L which is still very high than the maximum permissible limit.



Graph 3.6:-Comparison of Ammonia levels of the samples

Temperature:-

The temperature river water at both the locations are within the maximum permissible limit of 23.8° C. The temperature of river water at Palla is 17.8° C and that of at Okhla is 17.5° C. If the temperature increases beyond maximum permissible limit it leads to threat to the growth, reproduction and sustainability of aquatic life. The comparison of the temperatures measured at the sampling sites is depicted in the graph 3.7.



Graph 3.7:-Comparison of the temperatures of the samples

Conclusion:-

The 2 locations of sampling gives a clear picture of Yamuna water pollution where at the first end i.e. Palla sampling site the parameters such as Dissolved Oxygen, Chloride and Ammonia content has been under permissible limits, there is a different picture at the farther end of Yamuna at the Delhi stretch. The Okhla Barrage has seen some adverse pollution before entering the catchment area; this is mainly due to the diffusion and emission of waste from Industrial areas at Wazirabad Barrage and Nizamuddin Bridge. In a broader view most parameters were higher as the standard values which indicates a bad water quality. As domestic discharge causes 85 % of the pollution, new wastewater treatment plants both centralized and decentralized should be built. In order to save money people could be made aware of using water carefully, so the amount of water to be treated will decrease. Furthermore the Government of India could adopt new laws or targets for improving the water and in achieving the Millennium Development Goals.

References:-

1. Coastlearn.org, 2018. [Online]. Available: http://www.coastlearn.org/water_quality_management/concepts-wqp.html. [Accessed: 30- Apr- 2018].
2. Water Quality Monitoring, Standards And Treatment, *Fao.org*, 2018. [Online]. Available: http://www.fao.org/docrep/X5624E/x5624e05.htm. [Accessed: 13- Apr- 2018].
3. *Water.usgs.gov*, 2018. [Online]. Available: https://water.usgs.gov/owq/WhyMonitorWaterQuality.pdf. [Accessed: 15- Apr- 2018].
4. *Longwood.edu*, 2018. [Online]. Available: http://www.longwood.edu/cleanva/images/Sec5.WQMchapter.pdf. [Accessed: 15- Apr- 2018].
5. Why is Water Quality Monitoring Important? Envirotech Online, *Envirotech-online.com*, 2018. [Online]. Available: https://www.envirotech-online.com/news/water-wastewater/9/breaking-news/why-is-water-quality-monitoring-important/34104. [Accessed: 12- Apr- 2018].
6. HOME :: Welcome to Central Pollution Control Board, *Cpcb.nic.in*, 2018. [Online]. Available: http://cpcb.nic.in/nwmp-monitoring-network/. [Accessed: 16- Apr- 2018].
7. HOME :: Welcome to Central Pollution Control Board, *cpcb.nic.in*, 2018. [Online]. Available: http://cpcb.nic.in/openpdffile.php?id=UmVwb3J0RmlsZXMvMjA0XzE1MjQ2NTA4OTNfbWVkaWFwaG90bzEyODI3LnBkZg==. [Accessed: 17- Apr- 2018].
8. What Is A Water Quality Index, *Bcn.boulder.co.us*, 2018. [Online]. Available: http://bcn.boulder.co.us/basin/watershed/wqi_info.html. [Accessed: 06- Apr- 2018].
9. D. Sharma and A. Kansal, Water quality analysis of River Yamuna using water quality index in the national capital territory, India (2000–2009), *Applied Water Science*, vol. 1, no. 3-4, pp. 147-157, 2011.
10. *Scclmines.com*, 2018. [Online]. Available: https://scclmines.com/env/DOCS/Surface%20Water%20Standards.pdf. [Accessed: 09- Apr- 2018].
11. *Cgwb.gov.in*, 2018. [Online]. Available: http://cgwb.gov.in/documents/wq-standards.pdf. [Accessed: 14- Apr- 2018].
12. Articles, *Indiawaterportal.org*, 2018. [Online]. Available: http://www.indiawaterportal.org/articles/indian-standard-drinking-water-bis-specifications-10500-1991http://nihroorkee.gov.in/rbis/india_information/water%20quality%20standards.htm. [Accessed: 11- Apr- 2018].
13. Water Quality Standards, *Ismenvis.nic.in*, 2018. [Online]. Available: http://ismenvis.nic.in/Database/Environmental_Standards_7391.aspx. [Accessed: 11- Apr- 2018].
14. S.K. Singh, Deepika (2017) Assessment of water quality parameters of Bhalswa Lake in New Delhi, International Journal of Environmental Engineering - Inderscience, 9(1), 52-69. DOI: 10.1504/IJEE.2017.10008926
15. WHO, World Health Organization, (2011), Guidelines for Drinking-water Quality 4th Edition.
16. Yamuna River - World Water Database, *World Water Database*, 2018. [Online]. Available: http://www.waterdatabase.com/rivers/yamuna-river/. [Accessed: 16- Apr- 2018].
17. Central Water Commission Yamuna Basin Organization 2009, available at http:// www.cwc.nic.in /regional/delhi/welcome.html, accessed during April 2018.
18. CPCB, Central Pollution Control Board (2204), Report on Status of Sewerage and Sewage Treatment Plants in Delhi.
19. CPCB, Central Pollution Control Board (2006), Report on Water Quality Status of Yamuna River 1999-2005.
20. Evaluation of Operation and Maintenance of Sewage Treatment Plants in India-2007 (2008) Central Pollution Control Board, Ministry of Environment & Forests.
21. CSE, (2009), State of Pollution in Yamuna, Centre for science and environment, Delhi, India.
22. Jain P., (2009), Sick Yamuna, Sick Delhi- Searching a correlation. Peace Institute Charitable Trust
23. Mishra Anil Kumar, (2010), A River about to Die: Yamuna, Journal of Water Resource and Protection, 2, pp 489-500.
24. Water Quality Status of Yamuna River (1999-2005), Assessment and Development of River Basin Series. Available: ADSORBS/41/2006- 7,CPCB.http://www.cpcb. nic. in /newitems/11.pdf. Accessed: [20- Apr- 2018].
25. Water Quality Status of River Yamuna, Sulabhenvis.nic.in, 2018. [Online]. Available: http://www.sulabhenvis.nic.in/Database/WaterQualityStatus_6984.aspx. [Accessed: 30- Apr- 2018].
26. Shekhar Singh, S. and SK, S. (2015). Environmental Concerns in National Capital Territory of Delhi, India. Journal of Climatology & Weather Forecasting, 03(03).

27. Shashank Shekhar Singh, S.K.Singh(2015). Evaluating Water Quality of River Yamuna in Delhi by Regression Analysis International journal of Engineering and Management Research 5(3) : 218-221
28. De AK (1993) Environmental Chemistry. Wiley Eastern Limited Publication. 8. Goel PK (2006) Water Pollution-Causes, Effects and Control. New Delhi: New Age International.
29. Water Quality Characteristics, *Vicare - Module 2 - Chapter 2*. [Online]. Available: http://echo2.epfl.ch/VICAIRE/mod_2/chapt_2/main.htm. [Accessed: 30-Apr-2018].
30. Kumar Ashok, Bisht B.S., Joshi V.D., Singh A.K. and Talwar Amitabh (2010), Physical, chemical & Bacteriological Study of Water from Rivers of Uttrakhand, Journal of Human Ecology, 32(3), pp 169-173.
31. Characteristics of Water - Physical, Chemical and Biological, The Constructor, 2018. [Online]. Available: https://theconstructor.org/environmental-engg/characteristics-of-water-physical-chemical-biological/4735/. [Accessed: 30- Apr- 2018].
32. Lenove SC, Arnold E, Greenberg R, Rhodes T (1990) Standard methods for the examination of water and waste water. American Public Health Association 1015 fifteenth street N.W. Washington DC.
33. Sarah Khan and S.K. Singh (2013), DO-BOD Modeling of River Yamuna for Delhi Segment Comparing the Actual Case of Low Water Discharge with that of the Flow Required to be Maintained to Meet Out Environmental Flow Concern of Various Stretches. International Journal of IRSEET, Vol.2.Issue-5.
34. Kaur H., Singh,S.K., Mathur R.P. and Singh N., (1998), Pollution of River Satluj by BudhaNalla, Proc. of 23rd annual convention of ISTE and seminar on Environment and Development, 21-23 Nov., Ludhiana.
35. S.K. Singh, Deepika (2017) Assessment of water quality parameters of Bhalswa Lake in New Delhi, International Journal of Environmental Engineering - Inderscience, 9(1), 52-69. DOI: 10.1504/IJEE.2017.10008926
36. Vandana Shan, SK Singh, AK Haritash (2017) Major Ions Chemistry of Surface Water in Bhindwas Wetland.. International journal of Advanced Research and Innovation 5 (1), 117-121
37. SK Singh, S Mannan (2017). Spatial And Temporal Analysis Of Water Quality Parameters Of A Himalayan Lake (Dal Lake) By Multivariate Statistical Analysis; International Journal of Advanced Research 5 (1), 135-147
38. Paridhi Rustogi and Prof. S. K. Singh (2017). Revival And Rejuvenation Strategy Of Water Bodies In A Metropolitan City: A Case Study Of Najafgarh Lake, Delhi, India. International Journal of Advanced Research 5 (2), 189-195
39. Vandana Shan, S.K.Singh, A.K.Haritash (2017), Water quality Indices to determine the surface water quality of Bhindawas Wetland..Proceedings of International conference on Emerging areas of Environmental Science and Engineering EAESE-2017,February 16-18,2017
40. Dhruv Mehta, SiddharthMazumdar, S.K. Singh (2015). Magnetic adsorbents for the treatment of water/wastewater : A review . journal of Water Process Engineering- Elsevier 7 (9): 244-265
41. Tarundeep Gill ,S.K.Singh, P. Albino Kumar (2015).Treatment of Heavy Metals Contaminated industrial waste water by functionalized polymers, International Journal of Advanced Research, 3(9): 178-181
42. Deepika and S. K. Singh (2015). Water Quality Index Assessment Of Bhalswa Lake, New Delhi , International Journal of Advanced Research 3(5): 1052-1059
43. JN Sharma, Raj S. Kanakiya, S.K. Singh (2015) , Limnological study of water quality parameters of Dal lake, India, International Journal of Innovative Research in Science, Engineering and Technology, 4(2): 380-386
44. Haritash AK, Vandana Shan, Singh P., Singh S.K. (2015). Preliminary Invstigatons of water quality of Bhindwas bird sanctuary. Proceedings of national conference on recent advances in Civil and Environmental Engg., Haryana, 28-29 Nov. 2015
45. Aenab AM, SK Singh (2014), Al-Masab Al-Aam River (Third River) and Surface Water Pollution within Baghdad Division, International Journal of Engineering Innovation & Research (IJEIR) Volume 3, Issue 4 ISSN: 2277-5668, PP 444-451.
46. Aenab AM, SK Singh (2014), Critical Assessment of River water Quality and Wastewater Treatment Plant (WWTP), IOSR Journal Of Environmental Science, Toxicology And Food Technology (IOSR-JESTFT) , Volume 8, Issue 2 Ver. IV (Mar-Apr. 2014), PP 44-48
47. Raj Shailesh Kanakiya, SK Singh, JN Sharma (2014) Determining the Water Quality Index of an Urban Water Body Dal Lake, Kashmir, India, IOSR Journal of Environmental Science, Toxicology and Food Technology; 8 (12): 64-71
48. Lokesh Kumar, S K Singh (2014), Characterization of Rural Drinking Water Sources in Bhiwani District, Haryana: A Case Study, International Journal of Interdisciplinary Research and Innovations, Volume 2, Issue 4, pp. 27-37

49. Vijender Kumar Malik, Ram Karan Singh and S. K. Singh (2010), Impact of climate change on water Resources: A review on Global Perspective, Indian Journal of Development Research and Social Action, Volume 6, Number 1,