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ORIGINAL ARTICLE

Seasonal variations in the physico-chemical parameters of river Yamuna in the Delhi- Mathura region

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ABSTRACT
Since the age of Vedas river Yamuna has been considered as one of the holy river in India. Yamuna starts its journey from Yamunotri at an elevation of 6000m (approx.). During its journey of more than 960Km it passes across the states of Himachal Pradesh, Uttarakhand, Haryana, Delhi NCR, Uttar Pradesh, Rajasthan and Madhya Pradesh. Rapid industrialization, growing population and over exploitation of water resources has transformed Yamuna into a runnel. The alarming level of toxic pollutants poses a threat to the life sustainable ability of river Yamuna making its water too toxic even for irrigation and washing. The marked decrease in dissolve oxygen (DO) in Delhi NCR region makes the water too toxic for the human consumption. In this study we have made a comparative analysis of different physicochemical properties of water samples collected from different sites within Delhi-Mathura region under different seasonal variations (April, 2014 to March 2015). pH, total hardness; dissolve oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD); total dissolved solids (TDS) and alkalinity of water samples collected from three specific sites (Pandav Nagar at Delhi; Chir Ghat at Vrindavan, Mathura upstream and Gokul Barrage, Mathura downstream) were measured, compared and analyzed. Therefore assessing the quality of Yamuna water determining its major causes of contamination and advocating the guidelines for restoring the piousness of this holy river.
KEYWORDS- *River Yamuna, Seasonal variations and physico-chemical parameters.*

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INTRODUCTION

Water is the essence of life and is essentially required to sustain it. Ocean constitutes 97% of the total water reservoir on Earth, while less than 3% of fresh water is present in the form of rivers, lakes and underground aquifers, which can be used for human activities [1]. Since times immortal, rivers have been the life line of all ancient civilizations such as Mohenjo-Daro, Harappa etc. India is the "Land of Rivers", which have been referred to as life sustaining and pious as it had served the basic necessities of the people since the Vedic era. Among all, river Yamuna holds the most prominent position as it is the largest tributary of river Ganga [2]. It originates from Yamunotri and travel approx 1370 km prior to merger into river Ganga. Yamuna River has not only provided fresh waters for agriculture, daily necessities of life but have also been the trade highways since long [3]. All these factors have led to the establishment of large number of industries contributing towards socio-economic development of the country [4]. Water pollution has been found to be directly correlated with human population and industrialization. Latest reports and surveys have declared the Yamuna water to be too toxic and unfit for human activities. The reasons for deterioration of river Yamuna can be traced down along the course of its journey [5, 6]. The entire journey of the river could be categorized into five different segmnts i.e. Himalayan Segment, Upper Segment, Delhi Segment, Eutriphicated Segment and Diluted Segment [7, 8] (Fig. 1.).

Water of the Himalayan segment appears to be the least contaminated one and has been reported to meet all the standard quality parameters [10]. The level of pollution has been found to be directly related to the population density of the region. Wazirabad barrage serves at the gateway of river Yamuna guiding its entrance into the national capital. The Gangetic planes have been the most fertile piece of lands since ages and so have a population density of 11,297 per sq km. Due to its large population size and industrialization Delhi segment has been the most polluted one within the entire journey of Yamuna. Within Delhi several sewages such as Shahadara drain, Najafgarh drain, etc are poured directly into it [9]. Before leaving Delhi the water of river Yamuna is stored at Okhla barrage. Water beyond Okhla barrage is mainly constituted by the industrial effluents, domestic and sewage water generated from Delhi NCR, Noida, Sahibabad and Shahadara drain [11]. Delhi NCR alone contributes about 3296 MLD (million liters per day) of sewage into river Yamuna transforming it into a runnel [12-14]. According to central pollution control board (CPCB), the water of river Yamuna has placed under category "E", i.e. unfit for human activities [15]. Thus the study was uptake in order to access the quality of river Yamuna at three different geographical locations within the Delhi-NCR regions (from Pandav Nagar Delhi to Gokul Barrage, Mathura downstream) determining major sites of contamination, framing guidelines for minimizing environmental impacts within Delhi-Mathura region.

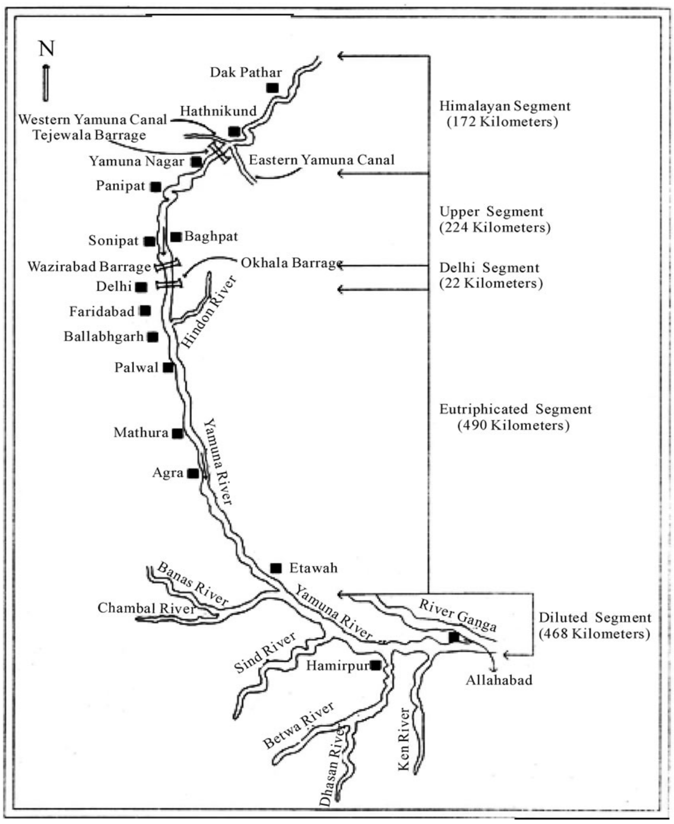

Fig. 1.-Various segments during the course of river Yamuna [8,9]

MATERIALS AND METHODS-

During the present study water samples were collected from the following three different sites-

Table 1: Collection of water samples from different sites along river Yamuna.

Collection Site	Geographical location	Associated predominant polluting activity
Pandav Nagar, Delhi	28°36′4.9032″ N; 77°5′44.5212″ E	Industrial effluents, household garbage and domestic sewage
ChirGhat, Vrindavan (Mathura upstream)	27°35′10.428″ N; 77°41′46.4604″ E	Floral waste, dead bodies, Industrial effluents and domestic sewage
Gokul Barrage, Mathura (Mathura downstream)	27°26′36.0″ N; 77°42′50.2″ E	Floral waste, Industrial effluents and domestic sewage

The collected water samples were aseptically transported to the laboratory and stored at 4°C before physico-chemical analysis. The collected water samples were accessed for pH, total hardness; dissolve oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD); total dissolved solids

(TDS) and alkalinity. The physiochemical properties of water samples collected were measured and compared with respect to each other.

pH

pH reflects the acidity or alkalinity of the analyzed samples[16]. 50 ml of water sample collected from different sites were taken in a beaker and pHs of the samples were determined using calibrated pH meter at room temperature (37°C).

TOTAL HARDNESS

Hardness refers to the amount of dissolve calcium and magnesium ions in water samples [17]. 50 ml of water sample was transferred to 250 ml capacity Erlenmeyer flask. The solution was acidified with hydrochloric acid, boiled and cooled down to room temperature. It was alkalized with ammonia and the solution obtained was filtered through filter paper. To the filtrate obtained 1 ml of ammonia buffer of pH 10 was added. To it, 3 drops of Eriochrome Black T solution or pinch of Eriochrome Black T ground with NaCl were added. The solution thus obtained was titrated with 0.01 M EDTA until color changes from violet to blue. The titer volume of solution was recorded.

$$Permanenthardness\,(M3) = \frac{V2\ M2}{n2} = \frac{V4\ M4}{n4}$$

V_2 = Volume of EDTA

M_2 = Molarity of EDTA

V_4 = Volume of water sample containing permanent hardness

M_4 = Molarity of water sample containing permanent hardness

$$Totalhardnessofwater = M3\ X\ 100\ X\ 1000\ Mg/L$$

DISSOLVE OXYGEN

Dissolved oxygen has been referred to as an important parameter in accessing water quality as it serves as a substrate molecule in different biochemical reactions within aquatic biome [17]. Water samples were collected in a BOD glass bottle (250 ml) in such a way that water bubble should not come out. 2ml of manganese sulfate and 2 ml of alkaline iodine-azide solutions were pipetted separately. These solutions were added in succession at the bottom of bottle and place the stopper of bottle. Shake the bottle upside down for about 6-8 times. A brown precipitate was developed. Leave the bottle for a few minutes, the precipitate settles down.

Add 2 ml of concentrated H_2SO_4 in the bottle. Shake properly so that the brown precipitate may dissolve. Take a clean flask and pour 50 ml of this water sample. Titrate it against 0.025N sodium thiosulfate solution taking in a burette until pale straw colors develops. Two drops of starch solution was added to it. Colour of contents changes from pale to blue. Again titrate it against thiosulphate solution until the blue colour disappears. The volume of sodium-thiosulphate solution used in titration was determined.

The amount of dissolved oxygen (DO) (mg/litre) was accessed using the following formula-

$$DO\ (mg/L) = \frac{8\ X\ 1000\ X\ N}{V}\ X\ V$$

Where, V= volume of water sample used for titration

v= volume of sodium thiosulphate (titrant)

N= Normality of titrant

8= It is a constant since 1ml of 0.025 sodium thiosulfate solution is equivalent to 0.2 mg oxygen.

BIOLOGICAL OXYGEN DEMAND (BOD)

BOD is a direct measure of the organic pollutant present in aquatic system and is directly proportions to the concentration of organic matter present [18]. Adjust the pH of the water sample at 7.0 by adding 1N acid//N alkali. Transfer this water into BOD bottles very gently, so as bubbles should not come out. 1ml of allylthiourea was added to each bottle to avoid nitrification. Measure dissolved oxygen following the steps as described for dissolved oxygen. Incubate the other BOD bottle at 27^0C for 3 days in a BOD incubator. The amount of oxygen was measured as done earlier.

Calculate the BOD of water by using the following formula-

$$BOD\ (mg/l) = D_1 - D_2$$

Where, D1 = Initial dissolved oxygen (mg/l) in the first sample (mg/l)

D2 = Dissolved oxygen (mg/l) in the second sample after 3 days of incubation.

CHEMICAL OXYGEN DEMAND (COD)

COD measures the amount of oxygen used in the oxidation of effluents in the present of a strong chemical oxidant such as potassium dichromate or permanganate [17]. The COD was used as a parameter in

accessing the sustainability of organic and inorganic effluents towards oxidation. 50ml of water sample was poured in a conical flask (100ml capacity). Similarly, 50ml of distilled water was taken in a flask. 5ml $K_2Cr_2O_7$ solution was added separately in both the flasks. The flasks were incubated at 1000C for one hour by keeping in a water bath. Thereafter, flasks were removed and to cool for 10 minutes. 5ml KI solution and 10 ml of H_2SO_4 solutions were added in each flask. 0.1 M sodium thiosulfate solution was taken in a burette fitted in titration assembly. Note the amount of sodium thiosulfate solution used in each case. 1ml of starch solution was added to both the flasks. Colour turns to blue. Again titrate with sodium thiosulfate as above till blue colour completely disappears. Note the volume of sodium thiosulfate used for both the water samples.
Calculate the COD (mg/l) of water by using the following formula:

$$COD\ (mg/l) = \frac{8 X C X VB - VA}{Vs}$$

Where, C = Concentration of titrant (mM/l)
V_A= Volume (ml) of titrant used for control
V_B= Volume (ml) of titrant used for water samples
V_s = Volume (ml) of water sample taken

TOTAL DISSOLVED SOLIDS (TDS)
TDS refers to the amount of organic, inorganic and dissolved matters in water body [19]. Weight the empty evaporating dish. Water sample (250 ml-500 ml) was filtered through Whatman filter paper no.4. Sample was transferred into the evaporating dish. Evaporate it on a water bath. Weight of the dish was noted along with the contents after cooling in desiccators. Calculate the total dissolve solids (TDS) and express in mg per liter by using the formula:

$$TDS\ (mg/litre) = \frac{B - A}{V} X\ 10^6$$

Where A= Initial weight of the dish (g)
B= Final weight of the dish (g)
V= Volume of the water sample taken (ml)

ALKALINITY
Alkalinity is a chemical measurement of the buffering ability of water to neutralize acids [20]. 50 ml of water sample was taken in a conical flask (100ml capacity). Few drops of Phenolphthalein indicator was added to it. If colour of water does not change, it means that phenolphthalein alkalinity (PA) is nil due to absence of carbonates in the water sample. Moreover, if pink colour develops, determine the phenolphthalein alkalinity. 0.1 N HCl solution was poured into burette in titration assembly and titrates with the water sample. Note the end point when pink colour disappears. Another 50ml of water sample was taken in flask and 2-3 drops of methyl orange was added to it. Orange colour appears. 0.1N HCl solution was taken into burette in titration assembly and titrates with the water sample (methylene orange added) until yellow colour changes into pink. End point was noted.
Calculate phenolphthalein alkalinity (PA) and total alkalinity of water sample as below:

$$Phenolphthalein\ indicator\ (mg/litre) = \frac{Volume\ of\ 0.1\ N\ HCl\ solution\ used\ as\ titrant}{Volume\ of\ water\ sample}$$

$$Methylene\ orange\ alkalinity\ (mg/litre) = \frac{Volume\ of\ 0.1\ N\ HCl\ solution\ used\ as\ titrant\ X\ 100}{Volume\ of\ water\ sample}$$

RESULTS
The result of physico-chemical parameters illustrates that the level of pollution drastically increases from Delhi to Mathura region. Seasonal variations in physico-chemical parameters (pH, hardness; DO, BOD, COD; TDS and alkalinity) were observed in water samples collected from the different sites (Table 1). The minimum value of both pH and hardness was recorded at Pandav Nagar, Delhi while maximum at GokulBarage, Mathura downstream. The pH was found to vary from (7.49 ± 0.3) to (8.42 ± 0.42) with an average value of (8.05 ± 0.4). Hardness of water samples varied from (760 ± 15.2) mgL^{-1} to (818 ± 16.3) $mgL^{-1}$with an average value of (788.66 ± 15.7) mgL^{-1} (Table 2) (Fig. 2.). In the present study the minimum values of DO, BOD, COD was found to be (1 ± 0.01) mgL^{-1} (Pandav Nagar, Delhi); (7.2 ± 0.3) mgL^{-1}

(ChirGhat, Vrindavan, Mathura Upstream) and (17.4 ± 0.8) mgL^{-1} (Pandav Nagar, Delhi) with an average of (3.6 ± 0.1) mgL^{-1}, (11.92 ± 0.59) mgL^{-1} and (38.04 ± 1.9) mgL^{-1} respectively.
The maximum value DO, BOD, COD was determined to be (5.6 ± 0.2) (Chirghat, Vrindavan), (18 ± 0.9) (Pandav Nagar, Delhi) and (17.4 ± 0.8) (Pandav Nagar, Delhi) (Table 2) (Fig. 2.). The TDS and alkalinity values varied from a minimum of (1316 ± 26.3) mgL^{-1} and (285 ± 5.7) mgL^{-1} at Pandav Nagar, Delhi while maximum of (1840 ± 36.8) mgL^{-1} and (580 ± 11.6) mgL^{-1} at Gokul Barage, Mathura downstream (Fig. 2.). The average TDS and alkalinity value were found to be (1624.4 ± 32.4) mgL^{-1} and (446.6 ± 8.9) mgL^{-1} respectively. Thus the data indicated the poor quality of river Yamuna water in Delhi-NCR region (Delhi to Mathura) making it non potable for human consumption and domestic uses.

Table 2: Accessing water quality of collected samples by measuring different physiological parameters.

Site	Physiochemical Parameter	Minima	Maxima	Average	Standard limits	
					WHO, 2004	**ISI, 1993**
Water samples from different sites within NCR Yamuna river	pH	7.49 ± 0.3	8.42 ± 0.42	8.05 ± 0.4	6.5-8.5	6.5-9.5
	Total Hardness (mg/L)	760 ± 15.2	818 ± 16.3	788.6 ± 15.7	-	-
	Dissolve Oxygen (DO) (mg/L)	1 ± 0.05	5.6 ± 0.2	3.6 ± 0.1	-	3.0
	Biological Oxygen Demand (BOD) (mg/L)	7.2 ± 0.3	18 ± 0.9	11.92 ± 0.59	6.0	-
	Chemical Oxygen Demand (COD) (mg/L)	17.4 ± 0.8	72 ± 3.6	38.04 ± 1.9	10.0	-
	Total Dissolved Solids (TDS) (mg/L)	1316 ± 26.3	1840 ± 36.8	1624.4 ± 32.4	500-1500	500-2000
	Alkalinity (mg/L)	285 ± 5.7	580 ± 11.6	446.6 ± 8.9	200	-

The values represent mean SEM of analysis performed in triplets. Statistical analysis using one way ANOVA/ DMRT revealed results to be significant ($p < 0.01$).

Table 3: Accessing water quality of collected samples by measuring different physiochemical parameters.

Site of Sample Collection	Physiochemical Parameter	Seasonal Variations				Yearly Average
		Summer	**Monsoon**	**Post Monsoon**	**Winter**	
Pandav Nagar, Delhi	pH	7.49 ± 0.3	7.95 ±0.3	7.73 ± 0.3	8.05 ± 0.4	7.80 ± 0.3
	Total Hardness (mg/L)	760 ± 15.2	772 ± 15.4	785 ± 15.7	762 ± 15.2	769.7±15.3
	Dissolve Oxygen (DO) (mg/L)	1.0± 0.01	1.8 ± 0.09	2.1 ± 0.1	3.6 ± 0.1	2.12 ± 0.1
	Biological Oxygen Demand (BOD) (mg/L)	18 ± 0.9	9 ± 0.4	13 ± 0.6	16 ± 0.8	14 ± 0.7
	Chemical Oxygen Demand (COD) (mg/L)	56 ± 2	17.4 ± 0.8	28 ± 1.4	32.2 ± 1.6	33.4 ± 1.6
	Total Dissolved Solids (TDS) (mg/L)	1770±35.4	1710 ± 34.2	1478 ± 29.5	1316 ± 26.3	1561±31.2
	Alkalinity (mg/L)	545 ± 10.9	485 ± 9.7	368 ± 7.3	285 ± 5.7	420.7 ±8.4
ChirGhat, Vrindavan (Mathura upstream)	pH	7.92 ± 0.39	8.16 ± 0.4	8.05 ± 0.4	8.28 ± 0.41	8.10 ± 0.4
	Total Hardness (mg/L)	780 ± 15.6	796 ± 15.9	810 ± 16.2	785 ± 15.7	792.7±15.8
	Dissolve Oxygen (DO) (mg/L)	3.2±0.1	3.9 ± 0.1	4.9 ± 0.2	5.6 ± 0.2	4.4 ± 0.2
	Biological Oxygen Demand (BOD) (mg/L)	13.8 ± 0.6	7.2 ± 0.3	10.4 ± 0.52	11.4 ± 0.5	10.7 ± 0.53
	Chemical Oxygen Demand (COD) (mg/L)	58 ± 2	21.3 ± 1	30.2 ± 1.5	36.3 ± 1.9	36.4 ± 1.8
	Total Dissolved Solids (TDS) (mg/L)	1805 ± 36.1	1780 ± 35.6	1560 ± 31.2	1413 ± 28.2	1639.5±32
	Alkalinity (mg/L)	560 ± 11.2	505 ± 10.1	410 ± 8.2	328 ± 6.5	450.7 ± 9
Gokul Barrage, Mathura (Mathura downstream)	pH	8.10 ± 0.4	8.31 ± 0.41	8.18 ± 0.4	8.42 ± 0.4	8.25 ± 0.4
	Total Hardness (mg/L)	792 ± 15.8	808 ± 16.1	818 ± 16.3	796 ± 15.9	803.5 ± 16
	Dissolve Oxygen (DO) (mg/L)	3.1 ± 0.15	3.9 ± 0.19	4.8 ± 0.24	5.4 ± 0.1	4.3 ± 0.21
	Biological Oxygen Demand (BOD) (mg/L)	14 ± 0.7	7.6 ± 0.38	10.6 ± 0.53	12.1 ± 0.6	11.07 ± 0.5
	Chemical Oxygen Demand (COD) (mg/L)	72± 3.6	25.3 ± 1.2	34.6 ± 1.7	45.2 ± 2.2	44.27 ± 2.2
	Total Dissolved Solids (TDS) (mg/L)	1840 ± 36.8	1795 ± 35.9	1586 ± 31.72	1470 ± 29.4	1672.7± 33
	Alkalinity (mg/L)	580 ± 11.6	518 ± 10.3	428 ± 8.5	348 ± 6.9	468.5 ± 9.3

The values represent mean SEM of analysis performed in triplets. Statistical analysis using one way ANOVA/ DMRT revealed results to be significant ($p < 0.01$).

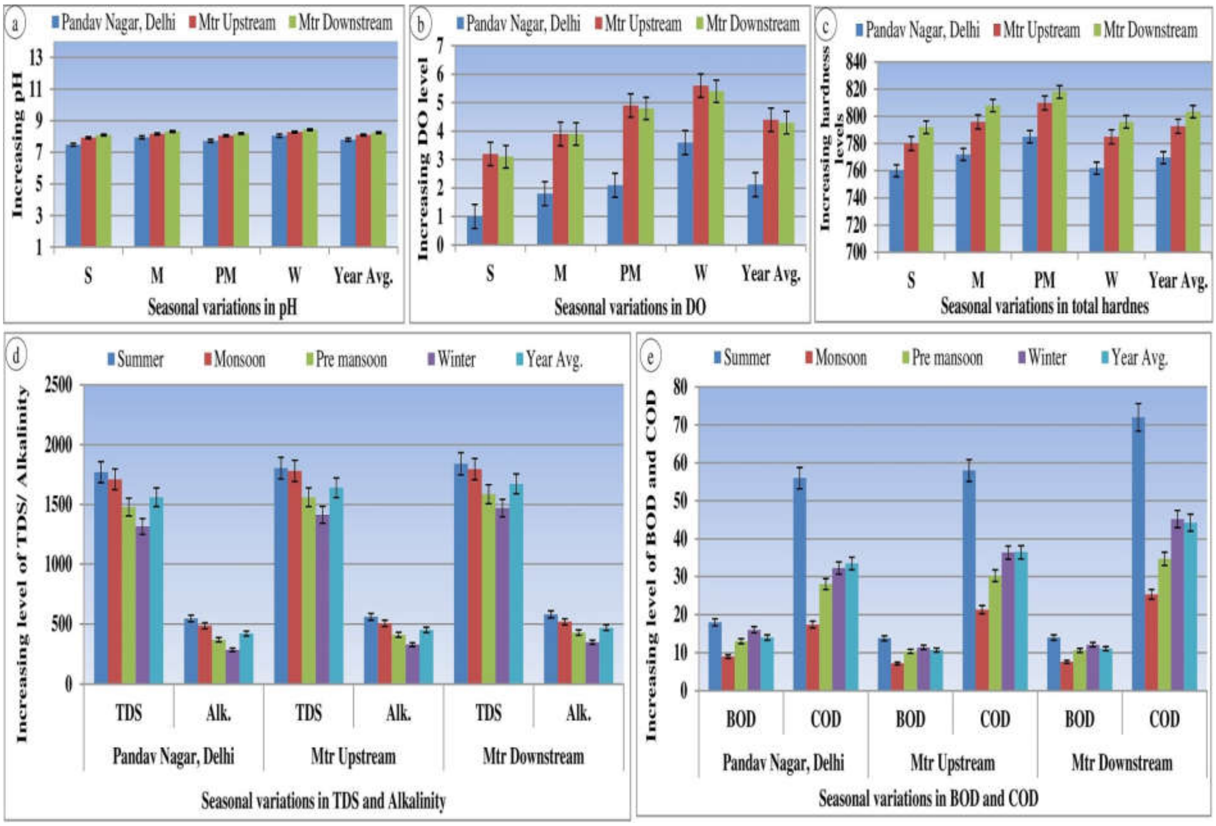

Fig. 2.-Variations among the different physiochemical parameters of water samples collected from different sites during different seasons. **(a)** Seasonal variations in the pH of water samples **(b)**Seasonal variations in the DO of different water samples **(c)**Seasonal variations in the total hardness of different water samples**(d)**Seasonal variations in the TDS and alkalinity of different water samples**(e)**Seasonal variations in the BOD and COD of different water samples.

DISCUSSION

Several researchers have indicated that the assessment of water pollution could be made by measuring different physiochemical parameters (pH, hardness; DO, BOD, COD; TDS and alkalinity) at various locations along the course of the river [21-25]. The various physiological parameters measured at different sites are as follows:

pH AND TOTAL HARDNESS-

In the present study the pH has been found to vary from (7.49 ± 0.3) to (8.42 ± 0.4) in between the three collection sites, displaying its alkaline nature (Table 1). Maximum pH (8.42 ± 0.4) was recorded in winter season while minimum (7.49 ± 0.3) in summer (Table 2) (Fig. 2.). The mean pH was determined to be (8.05 ± 0.4) (Table 2). The decreased pH in summer might be credited to the excessive release of CO_2 through breakdown of organic compounds as a result of increasing respiratory rate of aquatic organisms. pH acts as a key factor influencing the sustainability of living organisms, it is an agent to access the toxicity of wastes and influences of its recycling or eutrophication in environment [26, 27]. However, the pH values were found to be within the limits as per WHO and ISI standard of drinking water [28, 29]. The total hardness was found to vary from (760 ± 15.2) mgL^{-1} to (818 ± 16.3) mgL^{-1} (Table 1). Maximum (818 ± 0.3) mgL^{-1} total hardness was recorded in post monsoon season while minimum (760 ± 15.2) mgL^{-1} in summer (Table 2) (Fig. 2.). The maximum value could be due to leaching of calcium, magnesium salts along with bicarbonate, carbonate, sulfate, chlorides and other anions into the water bodies. The mean total hardness was found to be (788.6 ± 15.7) mgL^{-1} (Table 2). This high value could possible lead to several water born diseases in humans if consumed [24].

DO, BOD AND COD-

The data obtained from the present study revealed that DO varied from (1 ± 0.01) $mgL^{-1}$to (5.6 ± 0.2) mgL^{-1}(Table 2) (Fig. 2.). Maximum DO (5.6 ± 0.2) $mgL^{-1}$was observed in winter season while minimum (1 ± 0.01) mgL^{-1}in summer (Table 2). This alteration could be credited to the increase in bacterial load during summer season causing its depletion. The mean DO was found to be (3.6 ± 0.1) mgL^{-1}(Table 2).

The aquatic photoautotroph serves as the major source of dissolve oxygen while its sink includes the heterotrophic microbes consuming it during the degradation of organic compounds [25].
The BOD limit for water samples ranged from (7.2 ± 0.3) $mgL^{-1}$to (18 ± 0.9) mgL^{-1} (Table 2) (Fig. 2.). Maximum BOD (18 ± 0.9) $mgL^{-1}$was recorded in summer while minimum (7.2 ± 0.3) mgL^{-1}in monsoon (Table 2). During summer the decreased water level triggers a decrease in DO and an increase in BOD which might be attributed to enhance microbial activity of aerobes involved in the breakdown of organic matter at this elevated temperature [24, 25]. The increase in river water level during monsoon elevated the DO and decreases the BOD due to dilution of organic effluents. The mean BOD was determined to be (11.92 ± 0.59) mgL^{-1}(Table 2). The BOD value at all sites was way above the prescribed WHO standards (6 mgL^{-1}) [28]. This high level of BOD might be credited to the major sources of organic contaminants in the form of municipal sewage from treatment plants or raw sewage. It has been estimated that up to 85% of total municipal sewage is discarded directly into Yamuna [30]. Najafgarh drain contributed a BOD load of 76.47 tons/day while Shahadara drain accounts for 44.57 tons/day of untreated or partially treated effluents [31-33]. In Mathura alone, 43 MLD (Million liters per day) of domestic waste is poured directly into river Yamuna [34].
COD value of Yamuna water varied from (17.4± 0.8) mgL^{-1} to (72 ± 3.6) mgL^{-1} across different sites (Table 2) (Fig. 2.). Maximum COD was (17.4± 0.8) mgL^{-1} noticed in summer while minimum (72 ± 3.6) mgL^{-1} in monsoon (Table 2). This highest value of COD in Mathura region could be attributed to high amount of floral wastes from temples, agriculture wash offs, including fertilizers, pesticides, etc. The mean COD was recorded to be (38.04 ± 1.9) mgL^{-1}(Table 2). The COD limits at all sites were found well above the prescribed limits of WHO guidelines (10 mgL^{-1}) for drinking water [28]. This enhanced COD level was found to lower the DO of water posing a threat to aquatic flora and fauna [21, 35].

TDS and Alkalinity-

The TDS vale of water samples ranged from (1316± 26.3) mgL^{-1} to (1840 ± 36.8) mgL^{-1} across different sites (Table 3) (Fig. 2.). Maximum TDS (1316 ± 26.3) $mgL^{-1}$was reported in summer and minimum (1840 ± 36.8) mgL^{-1} during winter season (Table 2). This maximum value in summer could be credited to the increase in the amount of suspended matter including surface runoff, leaching of chemical fertilizers, insecticides and pesticides, domestic sewage, etc. The mean TDS value of Yamuna water was found to be (1624.4 ± 32.4) mgL^{-1} (Table 2), which was well above the permissible value (500 mgL^{-1}) for drinking water as per Bureau of Indian standard indicating the detrimental impact of environmental pollution on water quality [23, 29].
The alkalinity value was found to vary from (285 ± 5.7) mgL^{-1} to (580 ± 11.6) mgL^{-1} (Table 3) (Fig. 2.). Maximum alkalinity was reported in summer (580 ± 11.6) mgL^{-1}while minimum (285 ± 5.7) mgL^{-1}in winter season (Table 2). The maximum value in summer could be credited to high photosynthetic rate fixing large volume of carbon dioxide, washing discharge including caustic compounds and industrial effluents. The mean alkalinity value was found to be (446.6 ± 8.9) mgL^{-1} (Table 2), which was found to be above the prescribed limit of drinking water by WHO (200 mgL^{-1}) [28]. Alkalinity determines the aquatic life of a water body as it refers to as the buffering capacity of the water samples against rapid pH changes that could possibly occur due to enhance photosynthetic activity [21, 23].

CONCLUSION

The increasing population size, industrialization, over exploitation of chemical fertilizers and unregulated dumping of domestic and industrial waste into River Yamuna has continuously depleted its water quality. results have highlighted that the water quality of River Yamuna continuously deteriorated along the Delhi segment with the addition of enormous effluents through diverse sources. Almost all the parameters such as pH (8.05 ± 0.4), total hardness (788.6 ± 15.7) mgL^{-1}, dissolve oxygen (3.6 ± 0.1) mgL^{-1}, biological oxygen demand (11.92 ± 0.59) mgL^{-1}, chemical oxygen demand (38.04 ± 1.9) mgL^{-1} and alkalinity (446.6 ± 8.9) mgL^{-1} were far above the standard prescribed limits of WHO and that of Indian standards [28, 29]. Among all physico-chemical parameters alkalinity and biological oxygen demand to be almost twice of their standard prescribed limits, while COD exhibited the largest increase in its value above the standard limits. thus these results indicates that a control should be established over the use of chemical fertilizers, pesticides, insecticides as well as a strict regulation should be made over the dumping of domestic and industrial effluents. Our study advocates use of bioremediation technology, organic farming and vermicomposting and sustainable development to preserve our cultural heritage in the form of River Yamuna.

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CONFLICT OF INTEREST STATEMENT-
The authors declare no financial and commercial interest.

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