



Original Article

## Water Quality Monitoring: To Access the Temporal and Monsoonal Variation in Pollution Level of River Gomti and Some Ponds in Vicinity of Lucknow City (India)

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### ABSTRACT

*This investigation deals with physico-chemical status of water resources (i.e. some ponds and Gomti river) in vicinity of Lucknow city during the pre and post monsoon period of the year 2009 and 2010. Water quality parameters like turbidity, colour, odour, electrical conductivity, pH, BOD, total suspended solid and the level of ion/nutrient like nitrate, nitrite, phosphate and ammonium were detected with reference to the monsoonal variation. The results indicate that ponds are in extreme polluted conditions. Gomti river water quality was also poor due to the city drainage systems, unplanned municipal wastes and industrial waste. Religious idol immersions are also found on the bank and in river water. On the other hand ponds are polluted mainly by local waste like daily garbage, faecal flow and plastic bag. It indicates that the unplanned urbanization is responsible for the deterioration of surface water bodies.*

**Keywords:** Surface water, Gomti river, Ponds, Monsoonal variation

### INTRODUCTION

Numbers of natural surface water bodies are exists on our earth which may be characterized by their size and existence of different flora and fauna in them e.g. Ponds, Lagoons, Lake, Rivers and Ocean. They affect their surroundings and have impact on the ground water quality of the region. Lucknow city have two major sources of surface water first one is river Gomti which flow through city and the other source is the natural ponds situated within the city. Pond is a small water body which are seasonal mainly depend on rain water and it play a important role in rain water harvesting due to this character ponds are one of the essential source of fresh/surface water were rivers are natural floating body. Rivers have also historical evidence in which they are describe as the resource of human settlement or civilization. Monitoring of water quality is very useful tool for communicating the information on overall feature of water because it is the one of the major source of transmitting diseases in urban cities and developing countries [1, 2]. Water quality monitoring is the initial move in the conservation, restoration and management of any aquatic ecosystem and the suitable physico-chemical quality of water with in maximum acceptable limit. [3, 4]. Report of United nation population fund 2007 [5] state that urbanization has become an un recoverable adverse global change over the 20<sup>th</sup> century, particularly the speedy urbanization impress negative impacts on environmental quality on the local region (IHDP, 2005) [6] Modifications related with urbanisation considerably effect water environment resulting in deterioration of water quality [7,8]. Unplanned urbanization and industrialization in India lead to fresh water scare commodity due to over exploitation of water resources [9].

Lucknow is the capital of Uttar Pradesh (26° 5/N latitude, 80° 56/E longitude, 128 m above the sea level), and it extend over area of 310 Km<sup>2</sup> with population of 2,815,601.[10] It has tropical climate. River Gomti flows through Lucknow city, through which it meanders for about 12 km. 26 city drains in the Lucknow area drained untreated sewage into the Gomti and about 19 drains are discharging about 200—250 MLD wastewater into the river in city lucknow. Industrial waste like vegetable Oil, milk dairy, and other industrial waste are also dumped in the river [11,12]. In case of

ponds the local garbage, household waste, sewage, religious idol immersion, dumped in ponds. Thus, presented study was undertaken as a comparative examination of the physico-chemical nature of river and ponds water in the vicinity of the city.

## MATERIALS AND METHOD

**Sampling Sites:** Four sites of the Gomti river viz. Sitapur over bridge (Inlet), Hanuman setu, Baikunth dham and Dilkusha rail over bridge (outlet) and 4 ponds namely Aashiana pond, Aliganj pond, Fazulla ganj pond, Bharat nagar pond were selected for the study of physico-chemical parameters (table 1). Table 2 represents the methods applied for the estimation of various water quality parameters.

### Data Analysis

The data was analyzed using one way ANOVA, (Analysis of Variance). The difference between treatments was considered significant at  $P \leq 0.05$ .

**Table 1** River and pond sites and their abbreviation

River Sites	Abbreviation
Sitapur over bridge (Inlet)	GR <sub>1</sub>
Saheed Park	GR <sub>2</sub>
Hanuman Setu	GR <sub>3</sub>
Dilkusha rail over bridge (Outlet)	GR <sub>4</sub>
<b>Pond Sites</b>	
Ashaiana Pond	PS <sub>1</sub>
Aliganj Pond	PS <sub>2</sub>
Fuzulla ganj Pond	PS <sub>3</sub>
Bharat nagar pond	PS <sub>4</sub>

**Table 2** Water quality parameters and their estimation methods

Parameter	Estimation Method
Colour	Determined visually
pH	pH meter (Tosniwal cat. no. 54)
EC ( $\mu\text{S cm}^{-1}$ )	Measured by Auto ranging conductivity meter (Toshniwal)
Temperature ( $^{\circ}\text{C}$ )	Measured at the sites by mercury thermometer
TSS ( $\text{mg L}^{-1}$ )	(Maiti 2001)
BOD ( $\text{mg L}^{-1}$ )	Measured by OXITOP inducting straining system
Odour	Natural smell observed are reported
Nitrate ( $\text{mg L}^{-1}$ )	(Cataldu et al. 1973)
Nitrite ( $\text{mg L}^{-1}$ )	(Steven and Oaks. 1973)
Ammonium ( $\text{mg L}^{-1}$ )	(Herbert et al. 1971)
Phosphate ( $\text{mg L}^{-1}$ )	(APHA. 1988 )

## RESULTS AND DISCUSSION

The parameters like colour, pH, Electrical Conductivity (EC), Temperature, Biological Oxygen Demand (BOD), and other essential ions are useful to consider the quality of water and also help in management of over exploration [18].

**1] Colour:** Water is a transparent universal solvent and its colour depends on the material dissolve in it. Colour is a very simple parameter for the determination of its quality and in all the studied sites it was found unsuitable in both the water bodies (stagnant and floating). Mostly turbid muddy colour was found in the river surface water at all the sites of river viz. GR<sub>1</sub>, GR<sub>2</sub>, GR<sub>3</sub> and GR<sub>4</sub> (table 3a, 3b, 4a, 4b). At the pond site PS<sub>1</sub> water has algal green colour in the pre monsoon of 2009, Which indicate that this site will survive no longer as it reached to eutrophic condition whereas site PS<sub>2</sub> found light muddy in pre-monsoon period (2009) (table 5a) but in post-monsoon (table 5b) its colour change to algal green. The other sites also showed the same condition in all the season of both the years. This situation is due to the over exploitation of the water bodies and inadequate system of waste disposal in the area.

**Table 3a.** Physico chemical parameter of river Gomti with in Lucknow city during pre-monsoon - 2009.

Parameters	Sites			
	GR <sub>1</sub>	GR <sub>2</sub>	GR <sub>3</sub>	GR <sub>4</sub>
pH	7.46±0.43	8.65±0.03 <sup>b</sup>	8.15±0.65	7.97±0.45
EC ( $\mu\text{S cm}^{-1}$ )	421.21±2.32	545.41±1.54 <sup>b</sup>	479.43±1.53	453.41±1.36
Temp. ( $^{\circ}\text{C}$ )	21.01±0.91	21.00±0.81	21.13±1.00 <sup>b</sup>	20.14±0.52
TSS ( $\text{mg L}^{-1}$ )	31.12±1.08 <sup>a</sup>	84.24±1.67	52.21±0.89	42.08±0.67
Odour	Objectionable	Objectionable	Objectionable	Objectionable
BOD	4.83±0.71	13.53±1.65 <sup>b</sup>	12.31±0.98	10.59±0.76
Nitrate ( $\text{mg L}^{-1}$ )	10.01±0.22	19.13±0.02 <sup>a</sup>	21.02±1.56	12.73±0.21
Nitrite ( $\text{mg L}^{-1}$ )	0.04±0.002	0.10± 0.03 <sup>b</sup>	0.05±0.003	0.03±0.001
Ammonium ( $\text{mg L}^{-1}$ )	3.50± 0.23	4.32±0.34	4.87±0.72 <sup>b</sup>	4.21±0.63
Phosphate ( $\text{mg L}^{-1}$ )	0.11±0.02	2.86±0.04 <sup>b</sup>	0.87±0.01	0.71±0.07

**Table 3b.** Physico chemical parameter of river Gomti with in Lucknow city during post -monsoon – 2009

Parameters	Sites			
	GR <sub>1</sub>	GR <sub>2</sub>	GR <sub>3</sub>	GR <sub>4</sub>
Colour	Light Muddy	Turbid muddy	Turbid muddy	Turbid muddy
pH	6.09±0.79 <sup>a</sup>	7.21±0.45	7.75±0.32	7.32±0.37
EC ( $\mu\text{S cm}^{-1}$ )	321.23±1.43 <sup>a</sup>	363.47±1.46	358.64±2.10	344.43±1.86
Temp. ( $^{\circ}\text{C}$ )	12.04±0.39 <sup>a</sup>	14.06±0.54	14.85±0.57	12.54±0.32
TSS ( $\text{mg L}^{-1}$ )	50.21±0.65	53.32±0.43 <sup>b</sup>	48.63±0.32	52.32±0.43
Odour	Objectionabl	Objectionable	Objectionable	Objectionable
BOD	4.25±0.32 <sup>a</sup>	14.53±0.24	13.62±0.32	10.16±0.52
Nitrate ( $\text{mg L}^{-1}$ )	5.01±0.22 <sup>a</sup>	8.13±0.02	21.02±1.56	10.73±0.21
Nitrite ( $\text{mg L}^{-1}$ )	0.03±0.001	0.06±0.005	0.09±0.005	0.02±0.001 <sup>a</sup>
Ammonium ( $\text{mg L}^{-1}$ )	2.13±0.04 <sup>a</sup>	3.02±0.06	3.07±0.025	4.25±0.17
Phosphate ( $\text{mg L}^{-1}$ )	0.6±0.02 <sup>a</sup>	1.02 ±0.04	1.63 ±0.01	0.42±0.07

**Table 4a.** Physico chemical parameter of river Gomti with in Lucknow city during pre -monsoon – 2010

Parameters	Sites			
	GR <sub>1</sub>	GR <sub>2</sub>	GR <sub>3</sub>	GR <sub>4</sub>
Colour	Light Muddy	Turbid muddy	Turbid muddy	Turbid muddy
pH	7.05±0.03	8.47±0.45 <sup>b</sup>	8.42±0.63	7.88±0.52
EC ( $\mu\text{S cm}^{-1}$ )	409.01±0.92	529.42±0.84 <sup>b</sup>	475.19±0.54	462.75±0.59
Temp. ( $^{\circ}\text{C}$ )	31.21±0.05	31.36±0.07	31.06±0.03	30.02±0.01 <sup>b</sup>
TSS ( $\text{mg L}^{-1}$ )	34.32±0.96 <sup>a</sup>	60.75±0.53	59.53±0.42	47.72±0.34
Odour	Objectionable	Objectionable	Objectionable.	Objectionable
BOD	4.97±0.63	16.74 ±0.32 <sup>b</sup>	15.53±0.27	14.02±0.29
Nitrate ( $\text{mg L}^{-1}$ )	18.75±0.26	22.97±0.53	24.12±0.97 <sup>b</sup>	19.85±0.79
Nitrite ( $\text{mg L}^{-1}$ )	0.05±0.003	0.08±0.003	0.03±0.002 <sup>a</sup>	0.06±0.003
Ammonium ( $\text{mg L}^{-1}$ )	4.32±0.05	6.06±0.07 <sup>b</sup>	4.93±0.64	5.03±0.42
Phosphate ( $\text{mg L}^{-1}$ )	0.18±0.07	0.23±0.01	0.20±0.002	0.22±0.03

**Table 4b.** Physico chemical parameter of river Gomti with in Lucknow city during pre -monsoon – 2010

Parameters	Sites			
	GR <sub>1</sub>	GR <sub>2</sub>	GR <sub>3</sub>	GR <sub>4</sub>
Colour	Turbid muddy	Turbid muddy	Turbid muddy	Turbid muddy
pH	7.35±0.83	6.53±0.54 <sup>a</sup>	8.22±0.43	7.57±0.41
EC ( $\mu\text{S cm}^{-1}$ )	354.01±0.9	359.98±0.32	345.43±0.73	343.32±0.54 <sup>a</sup>
Temp. ( $^{\circ}\text{C}$ )	13.42±0.7 <sup>a</sup>	14.32±0.32	14.12±0.32	14.16±0.53
TSS ( $\text{mg L}^{-1}$ )	41.73±0.75	58.65±0.65	52.32±0.58	55.21±0.53
Odour	Objectionable	Objectionable	Objectionable	Objectionable
BOD	4.05±0.32 <sup>a</sup>	15.75±0.50	16.83±0.27	10.83±0.43
Nitrate ( $\text{mg L}^{-1}$ )	6.43±0.31 <sup>a</sup>	12.96±0.63	19.96±0.53	13.94±0.72
Nitrite ( $\text{mg L}^{-1}$ )	0.04±0.007	0.10±0.01	0.09±0.008 <sup>b</sup>	0.04±0.002
Ammonium ( $\text{mg L}^{-1}$ )	3.03±0.02	4.03±0.03	2.09±0.029 <sup>a</sup>	3.95±0.13
Phosphate ( $\text{mg L}^{-1}$ )	0.12±0.04 <sup>a</sup>	0.74±0.009 <sup>b</sup>	1.95±0.13	0.72±0.007

**2] pH (Potential Hydrogen):** The determination of hydrogen ion concentration is very important as it helps in determining the nature (Acidic or Alkaline) of water. pH played a vital role in initiating and maintaining the rate of mostly biochemical reactions. Low rate of photosynthetic activities reduce the assimilation of carbon dioxide and bicarbonates. Which are responsible for increases in pH. The high pH indicates that carbon dioxide, carbonate and bicarbonate equilibrium is affected [19]. The hydrogen ion concentration in the river water varied between 7.0-8.65 and the maximum pH was recorded in pre-monsoon period, 2009 at GR<sub>1</sub> and GR<sub>2</sub> sites of Gomti river which were 8.65 and 8.15 respectively (table 3a). While 6.09 pH was observed during the post-monsoon period, 2009 at the site GR<sub>1</sub> and at the other sites of river the pH value was found between 7.21-7.25. In pre-monsoon period, 2010 pH value of 8.47-7.5 was observed in river water and in post-monsoon it ranges from 6-8. In year 2009 (table 4a, b and 5a, b) ponds showed acidic nature in both the season, only PS<sub>3</sub> site during post-monsoon period had shown the slight acidic nature (6.24) but it starts towards to basicity (7.21) in the pre monsoon of 2010, whereas, all the other ponds in the same year and in both the periods found acidic (table 6a, b).

**3] Electric Conductivity (EC):** Conductivity is the capability of water to carry out electrical flows and dissolve ions are the conductors i.e. SO<sub>4</sub><sup>2-</sup>, NO<sub>3</sub><sup>-</sup>, Cl<sup>-</sup> etc. however conductivity vary with water resources e.g. ground water, water drain from agricultural fields, municipal waste water, rainfall consequently, conductivity can point out mixing of pollution in the water body [2]. The EC value in river gomti ranged between 441-545  $\mu\text{S cm}^{-1}$ . The maximum value of 545  $\mu\text{S cm}^{-1}$  was observed at GR<sub>2</sub> site in the pre-monsoon period, 2009, while minimum value of 441  $\mu\text{S cm}^{-1}$  was observed at GR<sub>1</sub> (table 3a). In post-monsoon period of 2009, EC was observed between 363-323  $\mu\text{S cm}^{-1}$  in river Gomti (table 3b). In the year 2010, the maximum value was detected 529  $\mu\text{S cm}^{-1}$  at GR<sub>2</sub> and range was observed 529-409  $\mu\text{S cm}^{-1}$  whereas in post monsoon it is observed between 343-354  $\mu\text{S cm}^{-1}$  (table 4 a, b ). In pond EC was detected 665-291  $\mu\text{S cm}^{-1}$  in which PS<sub>1</sub> site had the highest value 665  $\mu\text{S cm}^{-1}$  and the lowest i.e. 292  $\mu\text{S cm}^{-1}$  was at PS<sub>3</sub> site, however, PS<sub>4</sub> site also showed remarkable and un ignorable (409  $\mu\text{S cm}^{-1}$ ) (table 5a, b ). In pre monsoon of 2010 at PS<sub>1</sub> it was found  $652 \pm 27.09 \mu\text{S cm}^{-1}$  and in post 2010 it was found 602- 210  $\mu\text{S cm}^{-1}$  (table 6a, b).

**4] Water temperature:** Temperature of any water body played very important role in the physical-chemical and biological behaviour of aquatic system [20]. It mainly depend on the geographical position, observation time and temperature of industrial effluent, waste which are disposed in water body. The water temperature was calculated from 20-21.32 °C and the maximum temperature i.e. 21.32 °C was recorded in pre-monsoon period during the year 2009 at the site GR<sub>2</sub>, while least temperature was recorded (20 °C) at site GR<sub>4</sub> (table 3a). In post monsoon period 2009, temperature was recorded in between 12-14 °C (table 3b). During pre-monsoon period in the year 2010 temperature was deliberated 30-31°C (table 4a) and in post monsoon it was calculated from 13 – 14 °C. In Pond during pre monsoon 2009 water temperature was found between 30-32°C and the maximum temperature was recorded at PS<sub>3</sub> (table 5a) . In post monsoon period 2009 it was measured 12-14 °C (table 5 b). In year 2010, during post monsoon period the temperature was found at average of 31 °C in all ponds where as in the post monsoon period the temperature was found in between 13-14°C (table 6a, b ) due to high atmospheric temperature and clear weather water temperature is recorded higher in pre monsoon season [21].

**5] Total Suspended Solids (TSS):** The value of TSS of river water varied between 84 to 31 mg L<sup>-1</sup>. Lowest value of TSS i.e. 31 mg L<sup>-1</sup> was recorded in the pre monsoon 2009 (table 3a) , at inlet of river in the city (GR<sub>1</sub>) while the higher value i.e. 58 mg L<sup>-1</sup> was observed at GR<sub>2</sub> in the post monsoon season of 2009 (table 3 b ) . In the year 2010, TSS value ranged from 34 to 60 mg L<sup>-1</sup> and the minor difference was noted between GR<sub>1</sub> and GR<sub>2</sub> in pre monsoon and in post monsoon season (table 4 a & b). In stagnant surface water TSS was found highest 69 mg L<sup>-1</sup> at PS<sub>3</sub> site and lowest 53 mg L<sup>-1</sup> at PS<sub>2</sub> (table 5a). In post monsoon it was detected from 63-56 mg L<sup>-1</sup> (table 5b). In the year 2010 post monsoon at site PS<sub>2</sub> TSS was unlikely increased up to 88 mg L<sup>-1</sup> ( table 6a) were as on same site it was reached up to 91 mg L<sup>-1</sup> during post monsoon 2010 ( table 6b). The noticeable increase of 19% was also observed at the site PS<sub>1</sub> during post monsoon season over the pre monsoon season, 2010 (table 6a, b).

**6] Odour:** It was found objectionable at all the sites of river Gomti during the years 2009 and 2010. The same condition was observed in the case of ponds during both the years. It was due to the mixing of organic and inorganic waste [13].

**7] Biological Oxygen Demand (BOD):** The occurrences of microbes and the rate of their action towards the dead organism are represented by biological oxygen demand. BOD level increases due to biodegradation of organic materials which exerts oxygen tension in a water body. The highest value of BOD is directly related with pollution status of water [22]. The BOD values ranged from 16.53-4.83 mg L<sup>-1</sup>. The maximum value 13.53 mg L<sup>-1</sup> was observed at GR<sub>2</sub> in the pre-monsoon period, 2009 ( table 3a) and it was also analyzed that there is much remarkable values found between the sites GR<sub>1</sub> and GR<sub>2</sub> which was about 3-4 fold higher between the minimum and the maximum in pre monsoon period of year 2009 (table 3a). While in the post-monsoon the minimum value 4.25 mg L<sup>-1</sup> was observed at GR<sub>1</sub>. The BOD values fluctuate from 4.25-14.53 mg L<sup>-1</sup> in the river and highest value of BOD i.e. 14.53 mg L<sup>-1</sup> was observed at GR<sub>2</sub> (table 3b). In the pre-monsoon period, 2010, the BOD values were approximately same as in the pre-monsoon period, 2009 (table 3a and 4a). In the post-monsoon at site GR<sub>3</sub>, BOD value was observed 16.83 mg L<sup>-1</sup> which was highest and remarkable (table 4b). Ponds are stagnant water body and they are badly affected by the local drains. BOD value observed during the pre monsoon period 2009 at PS<sub>1</sub>, PS<sub>2</sub>, PS<sub>3</sub>, PS<sub>4</sub> are 6.45, 5.18, 5.91 and 4.09 mg L<sup>-1</sup> respectively and the minimum observation was 4.09 mg L<sup>-1</sup> at site PS<sub>4</sub> (table 5a) . In post-monsoon period it was reduced at all the sites and found between 5.45-4.9 mg L<sup>-1</sup> but at the site PS<sub>4</sub> the BOD value was close to the value found in pre-monsoon period (table 5a, b). In 2010 the notable changes found at site PS<sub>4</sub>, there was about 27-30% of increment in the BOD values during pre-monsoon period 2010 (table 6a) over pre-monsoon period, 2009. In post-monsoon, 2010 BOD value ranges between 5.12 to 5.45 mg L<sup>-1</sup> at all the site and 4.56 mg L<sup>-1</sup> was found minimum at PS (table 6b).

**Table 5a.** Physico-chemical parameter of some ponds within Lucknow city during pre-monsoon year-2009

Parameters	Sites			
	PS <sub>1</sub>	PS <sub>2</sub>	PS <sub>3</sub>	PS <sub>4</sub>
Colour	Algal green	Light muddy	Light muddy	Light muddy
pH	8.48 ± 0.86 <sup>b</sup>	7.42 ± 0.98	6.24 ± 0.92 <sup>a</sup>	7.34 ± 0.60
EC (µS cm <sup>-1</sup> )	665 ± 26.23 <sup>b</sup>	318 ± 14.32	291 ± 17.71	409 ± 18.12
Temp. (°C)	32.11±0.15	30.76±0.09	33.13±0.13 <sup>b</sup>	31.12±0.11
TSS (mg L <sup>-1</sup> )	53.38±0.16 <sup>a</sup>	61.45±0.13	69.35±0.48 <sup>b</sup>	54.52±0.39
Odour	Objectionable	Objectionable	Objectionable	Objectionabl
BOD.	6.45±0.16 <sup>b</sup>	5.18 ± 0.14	5.91 ± 0.17	4.09 ± 0.18 <sup>a</sup>
Nitrate (mg L <sup>-1</sup> )	44.83± 13.48 <sup>b</sup>	36.96± 5.70	34.96± 1.99	35.60± 1.20
Nitrite (mg L <sup>-1</sup> )	0.21±0.01 <sup>b</sup>	0.12± 0.04	0.14±0.07	0.16± 0.04
Ammonium (mg L <sup>-1</sup> )	5.40± 0.03 <sup>b</sup>	2.20± 0.20	2.0±0.30 <sup>a</sup>	2.20± 0.40
Phosphate (mg L <sup>-1</sup> )	0.20±0.05	0.22±0.04	0.19±0.03 <sup>a</sup>	0.22±0.03

**Table 5b.** Physico-chemical parameter of some ponds within Lucknow city during post -monsoon year-2009

Parameters	Sites			
	PS <sub>1</sub>	PS <sub>2</sub>	PS <sub>3</sub>	PS <sub>4</sub>
Colour	Algal green	Turbid muddy	Light muddy	Light muddy
pH	8.13 ± 0.48	7.96 ± 0.70	7.46 ± 0.62	7.60 ± 0.20
EC (µS cm <sup>-1</sup> )	555 ± 23.10	271 ± 13.09	236 ± 16.13 <sup>a</sup>	291 ± 17.43
Temp. (°C)	14.15±0.90	13.23±0.12 <sup>a</sup>	16.22±0.24	13.61±0.34
TSS (mg L <sup>-1</sup> )	59.37±0.57	63.76±0.54	56.33±0.85	57.11±0.51
Odour	Objectionable	Objectionable	Objectionable	Objectionable
BOD.	5.45 ± 0.21	5.71 ± 0.13	4.36 ± 0.16	4.41 ± 0.17
Nitrate (mg L <sup>-1</sup> )	36.43±0.31	32.96±0.63 <sup>a</sup>	39.96±0.53	33.94±0.72
Nitrite (mg L <sup>-1</sup> )	0.15±0.002	0.10±0.04 <sup>a</sup>	0.19±0.007	0.14±0.005
Ammonium (mg L <sup>-1</sup> )	3.13±0.12	4.23±0.13	2.19±0.19	3.15±0.13
Phosphate (mg L <sup>-1</sup> )	0.16±0.02	0.71±0.05 <sup>b</sup>	0.37±0.14	0.69±0.009

**8] Nitrate:** The nitrate concentration fluctuated between 10-21 mg L<sup>-1</sup> the maximum value of nitrates i.e. 21 mg L<sup>-1</sup> was observed at GR<sub>3</sub> in pre-monsoon period, 2009, while minimum value of 10 mg L<sup>-1</sup> was detected at site GR<sub>1</sub> (table 3a). In the post-monsoon period low nitrate content i.e. 5.01 mg L<sup>-1</sup> was observed at GR<sub>1</sub> site and the maximum was noted at GR<sub>3</sub> (21 mg L<sup>-1</sup>) (table 3b). In the pre-monsoon period of 2010 the level of nitrate was recorded with increasing values at all the sites reflection of year 2009 in same season. Nitrate level was found minimum at GR<sub>1</sub> site (18 mg L<sup>-1</sup>) and maximum value was recorded at GR<sub>3</sub> site (24 mg L<sup>-1</sup>) (table 4a) in post-monsoon period, 2010. In case of ponds in post monsoon period, 2009 the nitrate levels are found much higher and range was found between 44-35 mg L<sup>-1</sup>. This is very severe condition. The maximum value 44.83 mg L<sup>-1</sup> was found at PS<sub>1</sub> and the other sites PS<sub>2</sub>, PS<sub>3</sub>, PS<sub>4</sub> showed 36.96, 34.96, 35.60 mg L<sup>-1</sup> NO<sub>3</sub><sup>-</sup> respectively (table 5a). In the same year during post-monsoon period there were minor differences found in the nitrate content of all the sites which was ranged between 36-39 mg L<sup>-1</sup> (table 5b). In 2010 during post-monsoon period level of nitrate at all the ponds were increased it showed the continuous increment in the distribution of nitrogenous waste in water. In post-monsoon nitrate values are ranged between 42-35 mg L<sup>-1</sup> (table 6b).

**9] Nitrite:** Nitrite values are observed among the 0.04-0.10 mg L<sup>-1</sup> in the pre-monsoon of 2009 and in post monsoon it was detected 0.02-0.09 mg L<sup>-1</sup> (table 3a, b). In pre monsoon 2010 the level of nitrite was found between 0.05-0.08. Post monsoon 2010 highest value was observed 0.10 mg L<sup>-1</sup> at site GR<sub>2</sub> whereas it ranged between 0.04-0.10 mg L<sup>-1</sup> (table 4a, b). The average value of nitrite in post monsoon, 2010 was found higher than its values observed during post-monsoon, 2009. In case of pond like nitrate, the concentration of nitrite was also found much higher in the post-monsoon period, 2009 (table 5a) the minimum value of nitrite was found 0.12 mg L<sup>-1</sup> at PS<sub>2</sub> site and range was observed between 0.21-0.12 mg L<sup>-1</sup> among at all four sites. In the post monsoon period nitrite range was found between 0.15-0.19 mg L<sup>-1</sup> (table 5b). In pre-monsoon period, 2010 at site PS<sub>1</sub> the nitrite concentration increased up to 65% in the comparison of post-monsoon, 2009 and in post-monsoon, 2010 range was found 0.25 -0.16 mg L<sup>-1</sup> ( table 6a) where as notable changes were observed at the site PS<sub>3</sub> (table 6b).

**10] Ammonium:** In the year 2009 pre-monsoon period concentration of ammonium was observed between 3.50-4.32 mg L<sup>-1</sup> and the highest value was detected at the GR<sub>2</sub> (4.87 mg L<sup>-1</sup>) and at other site the value was observed up to 4 mg L<sup>-1</sup>, whereas in post-monsoon period its level declined and ranged from 2.13-4.25 mg L<sup>-1</sup> (table 3a, b). The highest value was found at GR<sub>4</sub>. In the year 2010 in pre-monsoon period and its concentration fluctuated from 6.06-4.32 mg L<sup>-1</sup> (table 4a). In post-monsoon it was found between 3-4.03 mg L<sup>-1</sup> with highest value 4.03 at site GR<sub>2</sub> (table 4b). Swinging values of ammonium is sign of occurrence of micro-organisms which are responsible for oxidation/reduction of ammonium content. Level of ammonium in the ponds water during the pre monsoon period of 2009 was ranged between 5.40- 2.0 mg L<sup>-1</sup>. And the highest value was recorded at the PS<sub>1</sub> (5.40 mg L<sup>-1</sup>) (table 5a). In the post monsoon of the same year the range was found between 4.23-2.19 mg L<sup>-1</sup>. At the site PS<sub>2</sub> the increase in level of ammonium was notable it was found approximately 2-3 fold higher from the pH in post-monsoon season (table 5b). In year 2010 during the pre-monsoon, range of ammonium was observed 4.44-2.0 mg L<sup>-1</sup>. In post-monsoon very minor differences was found in the level of ammonium between the pre and post-monsoon season of the same year. Its range was 4.53-2.91 mg L<sup>-1</sup> (table 6a, b).

**11] Phosphate:** The regular importing of phosphorus in a water body can encourage the growth of aquatic plants and toxic microorganism (cyanobacteria) and due to this property it play vital role in eutrophication. In the pre-monsoon period 2009 the phosphates concentration ranged from 0.12-2.86 mg L<sup>-1</sup>, maximum value of 2.86 mg L<sup>-1</sup> was observed at GR<sub>2</sub>, while the minimum value of 0.11 mg L<sup>-1</sup> was observed at GR<sub>1</sub> and the same situation was found in post monsoon period and among at all the sites GR<sub>2</sub> have the highest concentration, the range of phosphates was found between 0.6-1.02 mg L<sup>-1</sup> (table 3a, b). In 2010 pre-monsoon period approximately all the sites possess same values within minor variations ranged between 0.18 mg L<sup>-1</sup> to 0.22 mg L<sup>-1</sup> whereas in post-monsoon period a distinguished value was observed at GR<sub>2</sub> site i.e. 1.95 mg L<sup>-1</sup> which is around 5 folds higher than the value found in pre-monsoon period in the same year (table 4a, b) [23] has also reported the highest level of phosphate in river in his study. The ponds condition is very unfavourable in the vicinity of city in case of PO<sub>4</sub><sup>-3</sup> in the pre-monsoon period, 2009 as PO<sub>4</sub><sup>-3</sup>

values varied from 0.10-0.22 mg L<sup>-1</sup>. The values of PO<sub>4</sub><sup>-3</sup> at PS<sub>2</sub> and PS<sub>3</sub> site were approximately same whereas the minimum value was found at the site PS<sub>3</sub> (table 5a). In pre-monsoon period PO<sub>4</sub><sup>-3</sup> ranged between 0.16-0.71 mg L<sup>-1</sup> (table 5 b). The significant changes are found at site PS<sub>4</sub>. In the year 2010 the level of PO<sub>4</sub><sup>-3</sup> was observed between 0.18-0.31 mg L<sup>-1</sup> and the highest level was found at PS<sub>2</sub> site (table 6a) and in post-monsoon the remarkable changes were observed at the PS<sub>4</sub> site there was almost 4 fold higher value was recorded in context of same period, 2009 (table 6b).

**Table 6a.** Physico-chemical parameter of some ponds within Lucknow city during pre-monsoon year-2010

Parameters	Sites			
	PS <sub>1</sub>	PS <sub>2</sub>	PS <sub>3</sub>	PS <sub>4</sub>
Colour	Algal green	Light muddy	Light muddy	Light muddy
pH	8.50 ± 0.68 <sup>a</sup>	7.12 ± 0.67 <sup>a</sup>	7.23 ± 0.08	7.86 ± 0.78
EC (µS cm <sup>-1</sup> )	652 ± 27.09 <sup>a</sup>	385 ± 18.65	326 ± 20.54	397 ± 19.23
Temp. (°C)	30.23±0.59	33.56±0.39	32.44±0.18	34.22±0.31 <sup>a</sup>
TSS (mg L <sup>-1</sup> )	38.78±0.23 <sup>a</sup>	88.36±0.34	72.39±0.56	65.64±0.67
Odour	objectionable	objectionable	objectionable	Objectionable
BOD (mg L <sup>-1</sup> )	7.51 ± 0.25 <sup>b</sup>	5.85 ± 0.18	5.26 ± 0.20	6.97 ± 0.19
Nitrate (mg L <sup>-1</sup> )	40.32 ± 11.46	39.08 ± 6.07	37.54 ± 1.0	33.76± 1.89 <sup>a</sup>
Nitrite (mg L <sup>-1</sup> )	0.23±0.02	0.16± 0.01	0.12±0.009 <sup>a</sup>	0.13± 0.01
Ammonium (mg L <sup>-1</sup> )	4.44± 0.31	3.19± 0.20	2.0±0.11 <sup>a</sup>	3.10± 0.31
Phosphate (mg L <sup>-1</sup> )	0.31±0.02	0.23±0.019	0.18±0.01 <sup>a</sup>	0.21±0.02

**Table 6b.** Physico-chemical parameter of some ponds within Lucknow city during post -monsoon year-2010

Parameters	Sites			
	PS <sub>1</sub>	PS <sub>2</sub>	PS <sub>3</sub>	PS <sub>4</sub>
Colour	Deep green	Algal green	Light muddy	Light muddy
pH	8.19 ± 0.88	7.78 ± 0.71	7.45 ± 0.08	7.87 ± 0.56
EC (µS cm <sup>-1</sup> )	602 ± 24.68	356 ± 15.87	312 ± 16.43 <sup>a</sup>	345 ± 17.31
Temp. (°C)	15.65±0.77	12.57±0.19 <sup>a</sup>	15.22±0.37	13.87±0.93
TSS (mg L <sup>-1</sup> )	57.65±0.97	91.54±0.43 <sup>b</sup>	78.30±0.76	71.19±0.59
Odour	Objectionable	Objectionable	Objectionable	Objectionable
BOD (mg L <sup>-1</sup> )	5.12 ± 0.14	4.56 ± 0.15 <sup>a</sup>	4.12 ± 0.16	5.45 ± 0.17
Nitrate (mg L <sup>-1</sup> )	42.34±1.97 <sup>b</sup>	39.99±1.63	41.01±0.53	35.46±2.02
Nitrite (mg L <sup>-1</sup> )	0.25±0.009 <sup>b</sup>	0.17±0.005	0.19±0.007	0.16±0.005
Ammonium (mg L <sup>-1</sup> )	4.53±0.32 <sup>b</sup>	3.23±0.13	2.91±0.21	3.53±0.13
Phosphate (mg L <sup>-1</sup> )	0.33±0.019 <sup>a</sup>	0.67±0.03	0.45±0.01	0.85±0.009

Values are mean of 6 replicates ± standard deviation, significance at p ≤ 0.05.

<sup>a</sup> Monsoonal significant values during 2009 and 2010.

<sup>b</sup> yearly significant values during 2009-2010.

## CONCLUSIONS

Studies have shown mesotrophic character, which is inclined towards the eutrophic condition of ponds and Gomti river. In order to have proper management of the ponds the disposals of the waste have to be controlled/prohibited in the ponds. In the case of Gomti river in vicinity of Lucknow city the same result are concluded. The un-planned urbanization, drainage system, un-controlled industrial waste disposal are responsible for the worst condition of river. Major steps are required for the remediation of Gomti river and ponds of the city for sustainable development and the restoration of the surface water bodies in the city.

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