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Physico-chemical analysis of water quality in and around Naini industrial area of Allahabad

Sunil Mishra, Preeti Rajoriya and Vivek Kumar Singh

Abstract
Water is the driving force of nature and essential for a healthy lifestyle. It has always played a life sustaining role in growth and welfare of human kind. The rapid increase in the population and the need to meet the increasing demands of irrigation, human and industrial consumption, the available water resources are being depleted and the water quality has deteriorated. Therefore, the current study is an attempt to investigate the physico-chemical parameters for groundwater of Naini industrial area of Allahabad district. Four sampling sites were selected and physical and chemical contaminants estimation was adopted by the standard methods. The results revealed that all the parameters are highly affected at Sandwa and Naini railway station followed by Udyog Nagar and Labour colony. Correlation coefficient showed significant relationship. The study revealed the increase in water pollution levels of the Naini industrial area. We are leaving behind a legacy that will make the life of tomorrow more threatened than it is felt today, from now strong steps should be initiated to protect life on earth.

Keywords: Allahabad, physico-chemical parameters, ground water, correlation coefficient

Introduction
Water is known as the elixir of life and one of the most essential natural resources known on earth (Pandey *et al.* 2014; Ahsan and Imtiyaz, 2017) [21, 2]. It covers about 2/3 of the earth surface and plays vital role in evolution of civilization as well as in sustaining life on earth (Balasankar and Nagarajan 2000; Madhuri *et al.* 2004) [3, 4]. It has not only played an important role to all living organisms, most ecological systems, human health, food production, economic development, in promoting agricultural production but also in the history of countries, in religion, mythology and art (Postel *et al.* 1996; Sundararajan and Anand 2011; Pandey *et al.* 2014) [5, 6, 21].

India is rich in water resources, endowed with a network of rivers and blessed with snow covered in the Himalayan range that can meet up the variety of water requirements of the country (Das *et al.* 2018) [7]. However, with the rapid increase in the population of the country and to meet the increasing demands of irrigation, human and industrial consumption, the available water resources in many parts of the country are being depleted and the water quality has deteriorated (Bhargva, 1985) [8]. In India, innumerable large towns and many new megacities derive a major component of their domestic, irrigation and industrial water supply from groundwater, both from municipal well fields and from large numbers of private boreholes.

Ground water pollution (contamination) may be defined as the artificial induced degradation of natural ground water quality. Ground water which has been affected by man to the extent that it has higher concentration of dissolved or suspended constituents that maximum permissible concentration fixed by national or international standard for portable, industrial or agricultural purpose is known as (Matthess *et al.* 1985) [9]. In India, most of the population is dependent on groundwater, as the only source of drinking water supply. The groundwater is believed to be comparatively much clean and pollution free than surface water. Ground water in hard rock is relatively better than the water in the alluvial area.

Ground water quality is vital concern for mankind since it is directly linked with human welfare. Water quality monitoring has one of the highest priorities in environmental protection policy (Simeonov *et al.* 2002; Mor *et al.* 2003) [10, 11]. The water quality may yield information about the environments through which the water has circulated (Raju *et al.* 2009) **[13]**. There are large numbers of sources and causes that are capable of modifying ground water quality ranging from septic tanks to irrigated agriculture.

In contrast with surface water Pollution, subsurface water pollution is not easy to detect and is even trickier to control (Todd 1980) [14]. The prolonged discharge of industrial effluents, domestic sewage and solid waste dump causes the groundwater to become polluted and creates health issues. The overexploitation of groundwater has detrimentally affected in terms of the quality and the quality is identified in terms of its physico-chemical parameters (Sargaonkar and Deshpande 2003; Mane *et al.* 2010; Kamble *et al.* 2011; Pavendan *et al.* 2011; Yadav and Kumar 2011) [15, 12, 16, 17, 23].
Agriculture, rapid urbanization and geochemical processes have direct or indirect effects on the chemical composition of groundwater (Singh *et al.* 2016) [19]. Chemical composition is the most invoked factor as well as biological, physical and radiological factors are also considered in characterizing water quality. The problems of groundwater quality are much more acute in the areas, which are densely populated, densely industrialized and have shallow groundwater tables. Groundwater quality can be affected by the composition and solubility of rock materials in the soil or aquifer, water temperature, partial pressure of CO_2, acid-base reactions, oxidation-reduction reactions, loss or gain of constituents as water percolates through clay layers and mixing of ground water from adjacent layer. Rain and snow are the major sources of recharging ground water. They contain small amounts of dissolved solids and gases such as CO_2, SO_2, and O_2. As precipitation infiltrates through the soil, biologically-derived CO_2 reacts with the water to form a weak solution of carbonic acid. The reaction of O_2 with reduced iron minerals such as pyrite is an additional source of acidity in ground water, thereby increases the concentrations of chemical constituents such as Ca, Mg, Cl, Fe and Mn.
Allahabad is located in the southern part of the state of Uttar Pradesh, at 25°27′N 81°50′E25.45°N 81.84°E, it is an old and unique city in India. The three immense rivers Ganga, Yamuna and the unseen or mythical Saraswati have convergence, known as Triveni Sangam (Pandey *et al.* 2014) [1]. The Ground water of Naini industrial area of Allahabad is polluted with a variety of natural wastes, domestic wastes and agricultural wastes. Owing to earlier mentioned reasons, current study is an attempt to assess ground water for physico-chemical parameters and to establish correlation between physico-chemical parameters of ground water samples.

Materials and Methods
The experiment was conducted at Department of Molecular and Cellular Engineering, Jacob Institute of Biotechnology and Bioengineering, Sam Higginbottom University of Agriculture, Technology and Sciences, Allahabad.

Sampling site description
Naini industrial area of Allahabad is a suburban area, located in the eastern Gangetic plain of the Indian sub-continent at 25019`and 25054`N latitude, 8304`and 83058`E longitude and 67.50 m above the sea level. The selected sampling sites are populated areas and these were designated as-
S_1=Sandwa, S_2=Udyog nagar, S_3=Labour colony and S_4=Naini railway station

Sample collection
Before sampling, evacuation of the stored water from the hand pump was used for fresh ground water sample.

Physico-chemical estimation of ground water of various region of Naini industrial area of Allahabad
The following physico-chemical parameters estimated including colour, odour, taste (Table 1).

Table 1: various physico-chemical parameters and the instruments/ methods used to assess ground water quality

Parameters	Instrument /Standard Methods (APHA, 1995) [20]
Physical Contaminants Estimation Electrical conductivity (µS/cm), Temperature (°C)	EC meter, Thermometer,
Chemical Contaminants Estimation pH	pH meter
Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Alkalinity (TA), Total Dissolved Solids (TDS)	Winkler-azide method, Electrode method, Potassium permanganate oxidation method, Titration method, Evaporating method

Among these parameters temperature, pH were analyzed in experimental field while EC, BOD, TA were determined by standard method of APHA (1995) [20] and DO was determined without delay in research laboratory.

Results and Discussion
Physical Contaminants Estimation
A set of physical contaminants has been established which change the quality of water with their variation from standard values, only those constituents which are of paramount importance and play important role in quality change. Physical parameters include temperature, colour, taste and odour. All the ground water samples observed from the Naini industrial area of Allahabad were colourless. The taste of water samples was good but best at room temperature and the samples were odourless. The combined effect of taste and odour is frequently classified as taste. The taste developing constituents in water are major cations *i.e.* calcium, magnesium, sodium and potassium. The physico-chemical parameters of ground water samples taken from different sampling sites are displayed and portrayed in the form of tables and figures.

Temperature
Water temperature is very important parameter as it influences the activities such as behavior, metabolism and respiration of the water body. In the current study, the observed temperature ranges from minimum of 24.8 °C to 27.6 °C. The highest value recorded was 27.6 °C at S4 while the lowest value recorded was 24.8 °C at S1 (Fig 1A). The average value of temperature was 25.9 of the ground water (60-120 feet depth). It also indicates that temperature of the water samples increases as the atmospheric temperature increases. Our results are almost similar with Raghuvanshi *et al.* 2014 [21]. In general, the rate of chemical reaction decreases with decreasing temperature hence it is very important component on groundwater contamination. It also affects every aspect of the treatment and delivery of potable water WHO (1984) [22] standards recommended.

EC
EC is the reciprocal of electrical resistance and the measure of the ability of a conductor (water) to convey electricity. The observed EC value was ranges from 296.8 µmohs/cm to 671.8 µmohs/cm. The highest value recorded was 671.8 µmohs/cm at S1 and S4 while the lowest value was 296.8 µmohs/cm

combined with S2. As shown in the Fig 1B the S1 and S4 showing the highest line consistency and the S2 showed the lowest line consistency. High values of EC are due to high concentration of ionic constituents present in water. The importance of EC was its measure of salinity, which greatly affects the taste and thus has significant impact on its uses. There was not a single occurrence of the value of EC above RPML WHO (1984) [22] standards recommended at S-2 for the entire study period.

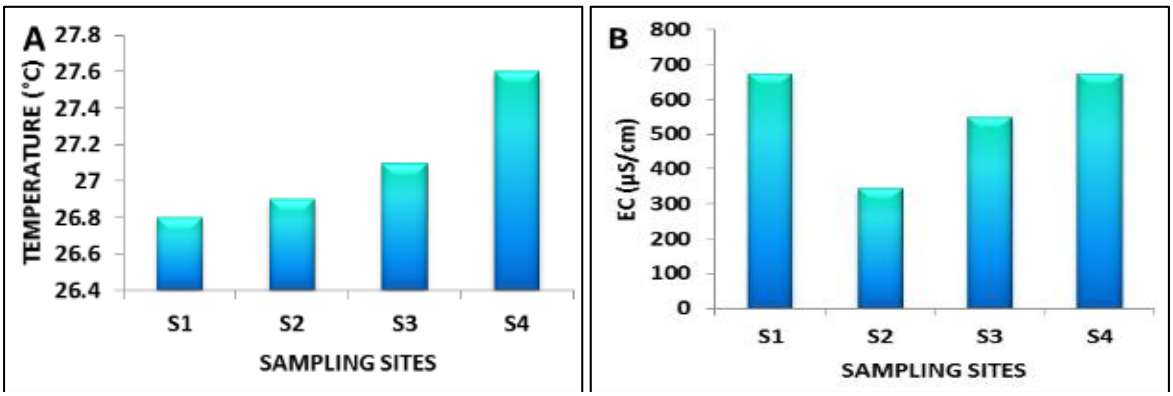

Fig 1: Graphical representation of physical contaminants estimation: (A) Temperature and (B) EC of ground water at four sampling sites of Naini industrial area of Allahabad

Chemical Contaminants Estimation

Chemical analysis of ground water normally include major cations and anions, trace element of special environmental importance are also included and these are as follows-

PH

PH refers to a scale of intensity of acidity or alkalinity. In the current study, the observed pH values ranges from lowest of 6.7 to the highest value of 7.2. Only 25% of the water samples lie below 7. As shown in Fig 2A water sample of S1 was slightly acidic and the other sites have neutral pH. It is regarded as a measure of concentration of H+ ions in water hence the pH of neutral water is as 7 WHO (1984) [22] standards recommended. The higher level of pH may be attributed in the utilization of free CO_2 in high algal population.

DO

DO is the amount of O_2 dissolved per litre volume of the water. The observed DO may ranges ranges from 4.9 mg/l to 8 mg/l. The highest value recorded was 8 mg/l at S3 while the lowest value recorded was 4.9 mg/l of S1 (Fig 2B). Water of good quality should be saturated with DO. The decrease in the DO level is the indication that the water body is polluted by organic matter. It is one of the most important parameters for assessing the purity of water body. Maximum permissible limit for DO as per WHO and USPHS is 4.6-60 mg/l. Our results are in good agreement with Yadav and Srivastava 2011; Medudhula *et al.* 2012; Raghuvanshi *et al.* 2014 [18, 24, 21]. DO was within the permissible limit in all the water samples and the main source is diffusion from air. It is a physical phenomenon and depends upon the solubility of oxygen, influenced by water temperature, water movements and salinity.

BOD

BOD is a measure of the amount of organic materials in an aquatic solution supporting the growth of micro-organisms. The BOD values observed was ranges from a minimum of 1.4 mg/l to a maximum of 4.6 mg/l. The highest value recorded was 4.6 mg/l at S2 and the lowest value observed was 1.4 mg/l at S3 (Fig 2C). 75% of water samples lie in the range of 1-3 mg/l and the remaining 25% lie in the range of 3-5 mg/l. The low BOD values in all cases show good sanitary condition of water. The BOD in all the samples are lower than the permissible limit of WHO (1984) [22] standards recommended 6 mg/l. It indicates that there is no biological pollution load on water bodies. The higher value of BOD indicates a higher level of organic pollution and thus higher consumption of DO.

COD

COD determines the amount of O2 required for chemical oxidation of organic matter using potassium dichromate under reflux conditions. The COD value ranges from 10 mg/l to 44 mg/l. The highest value recorded was 44 mg/l at S1 and the lowest value recorded was 10 mg/l at S3 (Fig 2D). The average value recorded was 19.12 mg/l. The COD values observed were found higher than the maximum permissible limit of 10 mg/l prescribed by WHO (1984) [22] standards at all the sampling sites. Similar results were reported by Raghuvanshi *et al.* 2014 [21]. The high value is mainly due to the entry of municipal sewage, various industrial effluent and agricultural wastes in to the environment. This result clearly indicates that the underground water sample contain more of non-biodegradable chemical pollutants.

TDS

TDS refers to the dissolved and suspended matter in water. The observed values of TDS range from 190 mg/l to 430 mg/l. The highest value recorded was 430 mg/l at S4 and the lowest value recorded was 190 mg/l at S2 (Fig 2E). As shown in the S1 and S4 are on the top consistently and S2 is present at the lowest stage. TDS influence other qualities of the drinking water, such as taste, hardness, corrosion properties and tendency to incrustation. The TDS in all the samples are lower than the permissible limit of I.S.I (1983) 500 mg/l and WHO (1984) [22] standards recommended. Similar results were also reported by Raghuvanshi *et al.* 2014 [21]. The higher concentration of TDS in water is adverse as it reduces euphotic zone, light penetration, transparency and thus interferes with plankton community and primary productivity of the river and creates imbalance for aquatic life (Verma *et al.* 2012) [25]. Hydro chemical investigations, which are significant for assessment of water quality, have been carried

out to study the source of dissolve ions in the groundwater (Anand and Singh 1996) [26].

TA

TA is the capacity to neutralize acid. The highest value recorded was 122 mg/l at S1 and the lowest value recorded was 74 mg/l at S3 (Fig 2F). The average value of TA recorded was 99.31mg/l. Phenolphthalein alkalinity was absent in all the samples analyzed. However, methyl orange alkalinity varied from 74 mg/l to 122 mg/l. This indicates the absence of hydroxyl and carbonate alkalinity and the presence of only bicarbonates. (Prajapati and Mathur 2005) It is generally considered least polluted compared to other inland water resources.

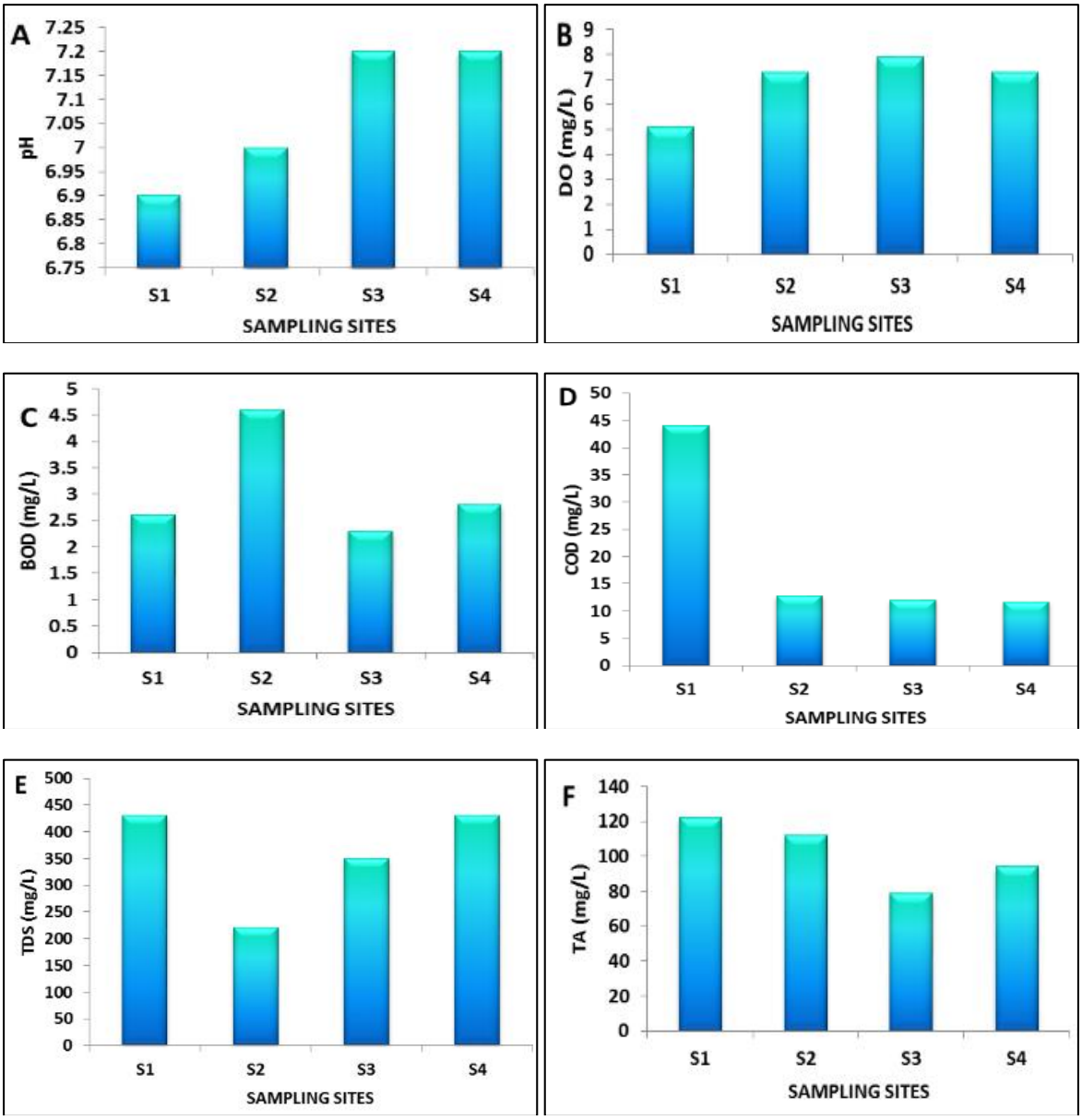

Fig 2: Graphical representation of chemical contaminants estimation: (A) pH (B) DO (C) BOD (D) COD (E) TDS and (F) TA of ground water at four sampling sites of Naini industrial area of Allahabad

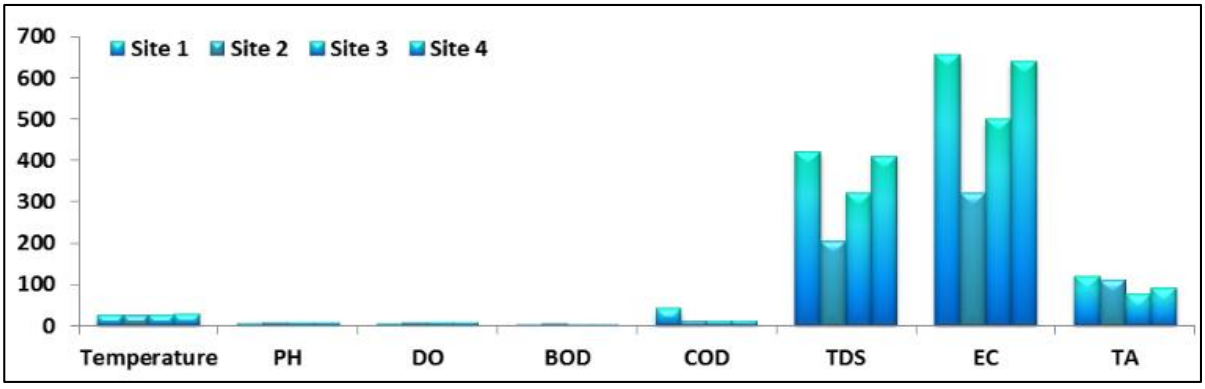

Fig 3: Combined graphical representation of physico-chemical parameters of ground water at four sampling sites of Naini industrial area of Allahabad

Correlation (r) Between Different Parameters

The data from all the four sampling sites was combined to obtain the correlation coefficient matrix is given below-

Table 2: Two-tailed Pearson's Correlation coefficient values among the studied physico-chemical parameters of the ground water of Naini industrial area of Allahabad.

Variable	Temperature	pH	DO	BOD	COD	TDS	EC	TA
Temperature	1							
pH	0.77	1						
DO	0.59	-0.33	1					
BOD	-0.53	-0.05	0.07	1				
COD	-0.54	0.32	-0.98	0.95	1			
TDS	0.39	0.17	-0.52	-0.83	0.51	1		
EC	0.39	0.17	-0.52	-0.83	0.51	1	1	
TA	-0.64	0.23	-0.80	0.5	0.72	0.012	0.012	1

Since the data of all the sites were combined to obtain the correlation coefficient matrix, interpretation has to be given with due caution as they effects simultaneously by spatial and temporal variations. However, a distinct physico-chemical relationship between the variables can be readily established. DO is negatively correlated with COD. This may be attributable to the fact that the solubility of oxygen decreases with the COD. Correlation coefficient between two variables is always 1 or less than 1. The positive value of correlation indicates that, with the increase of variable X (BOD), the value of variable Y (COD) also increases, while the negative value of correlation shows the decrease in variable X associated with Y. The positive correlation found between temperature and pH, temperature and DO, temperature and TDS, pH and COD, TDS and COD, EC and COD. It indicates that these values increase with each other. The negatively correlated parameters are temperature and BOD, temperature and COD, temperature and alkalinity, pH and DO, pH and BOD, DO and TDS, BOD and EC. It indicates that these values decrease with each other, likewise if variable X increase then value of variable Y decreases. A systematic statistical study of correlation and regression coefficient of the quality parameters not only help to assess the overall water quality but also quantify relative concentration of various pollutants in water (Singanan and Rao, 1995) [28].

Conclusion

The present study has been made to evaluate the physico-chemical parameters of ground water sample of Naini industrial area of Allahabad, their suitability for domestic applications. On the basis of above experimental findings it is concluded that all the parameters are within the maximum permissible limit prescribed by WHO and USPHS except dissolved solids and COD which exceeded the limits. The study also revealed that ground water of sampling sites S_1 (Sandwa) is highly polluted followed by S_4 **(**Naini railway station**),** S_2 (Udyog nagar) and S_3 (Labour colony). Correlation coefficient showed highly significant positive and negative relationship (p<0.05 level). Hence, direct consumption of untreated groundwater in Naini industrial area region is at high risk for human health. Water samples varied greatly in quality with respect to different physical-chemical constituents. The results suggests that the present steps, which are being taken, are not adequate, moreover the load of pollutants increasing day by day. Thus to maintain the quality of ground water, preventive measures have to be taken to control the above parameters within the permissible limits.

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