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GROUND WATER QUALITY STUDIES IN INDUSTRIAL AREAS IN GORAKHPUR DISTRICT, UTTAR PRADESH

Environmental Science

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ABSTRACT

There has been a tremendous increase in the demand for fresh water in the last few decades, due to rapid growth of population, unplanned urbanization, industrialization and too much use of fertilizers. With the growth of industry the ground water is made susceptible for contamination due to addition of waste materials. These waste materials from the factories percolate with rain water and reach aquifer resulting in erosion of ground water quality. Considering the above, study has been taken up in industrial areas of Gorakhpur city, which is located in the Terai belt of eastern Uttar Pradesh. The ground water samples have been collected in 14 locations and were subjected to the analysis of physico-chemical parameters including BOD, COD and Trace metals. The study shows that pH of ground water in the study area ranges from 7.02 to 7.93, EC ranges between 367 to as much as 3833 micro mhos/cm at 250C .Fluoride in water samples are well within the permissible limit of BIS standard. The other chemical parameters are within the normal range. BOD and COD of water samples ranges from ND (not detected) to 1.35 mg/l and ND to 12.3 mg/l respectively which indicates no major ground water pollution due to organic matter in the study area at present, but few areas are vulnerable where COD is more than 10 mg/l at GIDA, Gorakhpur. The heavy metal analysis of water samples are in general within the normal ranges (Copper Cu: ND to 0.008mg/l, Iron Fe:0.08 to 1.23 mg/l, Manganese Mn: 0.01 to 0.482 mg/l, Zinc Zn: 0.015 to 0.221 mg/l and Nickel: ND to 0.014mg/l) except iron and Manganese in few places. The water quality interpretation has been carried out with the help of Wilcox, Hill Piper and USSL diagrams.

The study of hill piper diagram shows that most of the water are Ca-Mg HCO3 type. Percentage Sodium is found to be less than 50% in all the cases. Except in one case all samples have been found under C2S1 or C3S1 as per US Salinity Laboratory diagram. The Water quality is good to within permissible limit in 93% of samples.

KEYWORDS

Industrial Pollution. BOD, COD, Heavy Metals,

INTRODUCTION:

Ground water has an important role in meeting the water requirements of agriculture, industrial and domestic sectors in the state. In the last few decades, there has been a tremendous increase in the demand for fresh water due to rapid growth of population, unplanned urbanization, industrialization and too much use of fertilizers [1]. The increasing dependence on ground water as a reliable source of water has resulted in indiscriminate extraction in various parts of the country [2]. With the growth of industry the ground water is made susceptible for contamination due to addition of waste materials [3]. Thesewaste materials from the factories percolate with rain water and reach aquifer resulting in erosion of ground water quality [4]. Realizing the importance of groundwater quality in urban areas and its deterioration, It has initiated groundwater quality study in industrial pockets of Gorakhpur district, which is one of the fastest growing urban centres in Uttar Pradesh (UP).As the source of water supply in Gorakhpur district is groundwater only, an assessment of Ground water quality has been carried out to assess the physico-chemical parameters of drinking water quality from groundwater sources (India Mark-II and Shallow depth hand-pumps) so that they depict the influence (if any) of the prevailing industrial activity of the area.

AREA OF STUDY:

The Gorakhpur city is located in the Terai belt of eastern UP, 147 sq. km. in area and divided into 70 administrative wards. The topography of the city is largely plain with a marginal slope from North to South. The present study is based on water samples collected from the industrial areas in Gorakhpur to study the ground water quality. The climate is sub-humid to humid and is influenced to some extent by the proximity of the north and the existence of Terai swamps. About 87% of rainfall takes place from June to September. During monsoon surplus water is available for deep percolation to ground water. The normal rainfall is of tune of 1379.20 mm. The most of rainfall in the area occurs from south west monsoon from mid-June to September. During the rest of the year, the rainfall is sporadic and scanty [5].

HYDROGEOLOGY:

The district Gorakhpur is underlain by quaternary alluvium brought by Ghaghra and Rapti river system. At comprises mainly sand of various grades, sandy clay, silt, clay with varying amount of kankar and gravels. The alluvial deposits are broadly classified under two categories (a) older (b) younger alluvium. The older alluvium deposits known as 'Bangar' or high land soils are due to denudation. The Bangar can be further sub divided into three sub categories on the basis of percentage of the sand content vizBalua containing more than 70% silica, Loam containing silica about 50% and Matiar containing less than 40% silica. The younger alluvium deposits known as 'Kachhar' occupy the marginal tract of Rapti and Ghaghra and other third order streams and consists of sandy clay and sand along the river tract and fine silt in the gentle sloping plains. Occurrence of ground water in the area is controlled by Ghaghra and Rapti and their main tributaries. Fine to coarse grained sand, mixed with gravel and kankar form the principal aquifer in the district. Ground water in the area occurs both under confined and water table conditions. It occurs in the zone of saturation within the granular zones encountered below land surface. South and East of Rapti the formation are sandy and suitable for construction of shallow and deep tube wells[5].

METHODOLOGY:

Groundwater samples from 14 locations (Fig. 1) in triplicate were collected in new pre-cleaned polypropylene bottles (1L capacity) in the month of January 2017. Before collecting the water samples, the water was pumped out from tube-wells for about 2-5 min to remove stagnant groundwater. Prior to sampling, water was filtered through 0.45 Millipore membranes. Water samples meant for trace metal estimation were acidified with 2% HNO3 to decrease the pH value to 2. Water samples meant for BOD and COD were kept in ice box (below 5 ^{0}C) and was immediately transported to the Laboratory for its analysis [6], The essential handbook of groundwater sampling, CRC Press, Boca Raton, USA. All samples were analysed on the site for few of the physical parameters and recorded in the field such as temperature, EC (using conductivity meter) and pH (using pH meter). Calcium (Ca^{2+}), magnesium (Mg^{2+}), carbonate (CO_3^{2-}), bicarbonate ($HCO3^-$), total hardness (TH) and chloride (Cl^-) were analyzed by volumetric titration methods, sodium (Na+) and potassium (K^+) were measured using the flame photometer, sulphate (SO_4^{2-}), nitrate (NO_3^-) nd fluoride (F^-) were determined by spectrophotometric technique as per the methods described by the American Public Health Association [7]. Trace metals such as Zinc (Zn), Nickel (Ni), Iron (Fe), Copper (CU) and Manganese (Mn) etc. were analysed by using Atomic Absorption Spectrophotometer.

RESULTS AND DISCUSSIONS:

Water samples have been collected in and around the Industries

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(GIDA) inparts of Gorakhpur district of Uttar Pradesh.The chemical analysis results of basic chemical parameters of the water samples are compared with BIS 2012 [8] and presented in Table-1. The results of heavy metal analysis and BOD, COD of water samples are presented in Table-2 & 3.The study shows that pH of ground water in the study area ranges from 7.02 to 7.93, EC ranges between 367 to as much as 3833 micro mhos/cm at 25 ^{0}C .Fluoride in water samples are well within the permissible limit of BIS standard.The other chemical parameters are within the normal range. BOD and COD of water samples ranges from ND (not detected) to 1.35 mg/l and ND to 12.3 mg/l respectively which indicates no major ground water pollution due to organic matter in the study area at present, but few areas are vulnerable where COD is more than 10 mg/l at GIDA, Gorakhpur.The heavy metal analysis of water samples are in general within the normal ranges (Copper Cu: ND to 0.008mg/l, Iron Fe: 0.08 to 1.23 mg/l, Manganese Mn: 0.01 to 0.482 mg/l, Zinc Zn: 0.015 to 0.221 mg/l and Nickel: ND to 0.014mg/l) except iron and Manganese in few places.

The water quality interpretation have been carried out with the help of Wilcox, Hill Piper and USSL diagrams. The study of hill piper diagram shows that most of the water are Ca-Mg HCO3 type. Percentage Sodium is found to be less than 50% in all the cases. Except in one case all samples are falling under C2S1 or C3S1 as per US Salinity Laboratory diagram.

Wilcox Diagram

Classified groundwater for irrigation purposes based on percent sodium and EC. Diagram is bi-variant %Na versus EC in µS/cm diagram with 5 fold classification of irrigation waters i.e. Excellent to good, Good to permissible, Permissible to doubtful, doubtful to unsuitable and Unsuitable. The nomenclature of category itself explains suitability of ground water for irrigation [9]. The Wilcox diagram of ground water samples collected from Gorakhpur district presented in Fig- 2. The Wilcox diagram revel that only one sample of ChouriChoara fall in unsuitable category and ground water zone of tube well zone is unsuitable for irrigation purpose. In rest all water samples are fall in excellent to good, good to permissible category and ground water is suitable for irrigation.

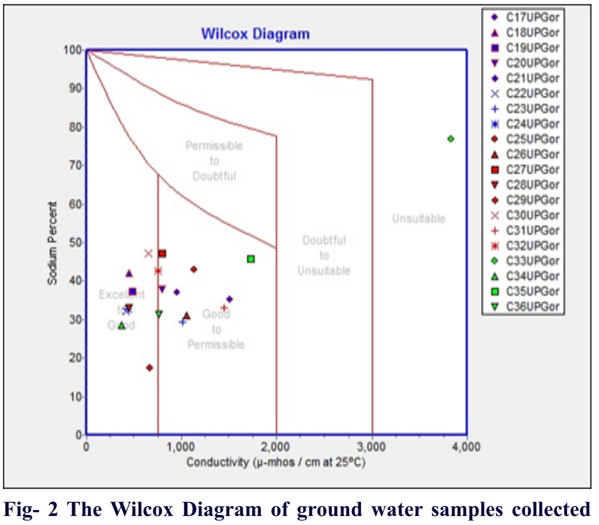

Fig- 2 The Wilcox Diagram of ground water samples collected from Gorakhpur district.

Hill Piper Diagram

The Piper-Hill diagram is used to infer hydro-geochemical facies. These plots include two triangles, one for plotting cations and the other for plotting anions. The cations and anion fields are combined to show a single point in a diamond-shaped field, from which inference is drawn on the basis of hydro-geochemical facies concept. These tri-linear diagrams are useful in bringing out chemical relationships among groundwater samples in more definite terms rather than with other possible plotting methods [10]. Chemical data of representative samples from the study area presented by plotting them on a Piper-tri-linear diagram and has been shown in Fig-3. The concept of hydro-chemical facies has been developed in order to understand and identify the water composition in different classes [11].The diagram reveal the analogies, dissimilarities and different types of waters in the study area, which are identified. It clearly explains the variations or domination of cation and anion concentrations. Ca-Mg-type of water predominated with 92% samples. For anion concentration, HCO3-type of water predominated with 71.4% samples. The study of hill piper diagram shows that most of the water are Ca-Mg-HCO3 type

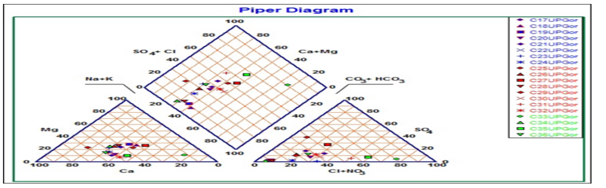

Fig-3Piper-tri-linear diagram of ground water samples collected from Gorakhpur district.

USSL diagram

The most important characteristics of irrigation water in determining its quality are: (i) Total concentration of soluble salts; (ii) Relative proportion of sodium to other principle cations; (iii) Concentration of boron or other elements that may be toxic and (iv) Under some conditions, bicarbonate concentration as related to

the concentration of calcium and magnesium [12].For the purpose of diagnosis and classification, the total concentration of soluble salts (salinity hazard) in irrigation water can be expressed in terms of specific conductance. A better measure of the sodium hazard for irrigation is the SAR, which is used to express reactions with the soil. When SAR and EC of water are known, the classification of the water for irrigation can be determined by graphically plotting these values on the US salinity (USSL) diagrams. Waters have been divided into C1, C2 C3 and C4 types on the basis of salinity hazard and S1, S2, S3, S4 types on the basis of sodium hazard. The significance and interpretations of quality ratings on the USSL diagram can be summarized as follows: (i) Low salinity water (C1) can be used for irrigation with most crops on most soils. Some leaching is required, but this occurs under normal irrigation practices, except in soils of extremely low permeability. (ii) Medium salinity water(C2) can be used if a moderate amount of leaching occurs. Plants with moderate salt tolerance can be grown in most instances without special practices of salinity control. (iii) Medium to high salinity water (C3) is satisfactory for plants having moderate salt tolerance, on soils of moderate permeability with leaching. (iv)High salinity water (C4) cannot be used on soils with restricted drainage. Even with adequate drainage, special management for salinity may be required and plants with good salt tolerance should be selected. (v) Very high salinity water (C5) is not suitable for irrigation under ordinary conditions, but may be used occasionally, under very special circumstances. The soil must be permeable, drainage must be adequate, irrigation water must be in excess to provide considerable leaching and salt tolerant crops should be selected. The classification of irrigation waters with respect to SAR is based primarily on the soil. USSL classification of ground water samples depicts that low sodium water (S1) can be used for irrigation on almost all soils with little danger of the development of harmful levels of exchangeable sodium. Medium sodium water (S2) in fine-textured soils of high cation exchange capacity, especially under low leaching conditions. Very high sodium water (S4) is generally unsatisfactory for irrigation purposes, except at low and perhaps medium salinity[13]. Except in one case all samples are falling under C_2S_1 or C_3S_1 as per US Salinity Laboratory diagram (Fig. 4).

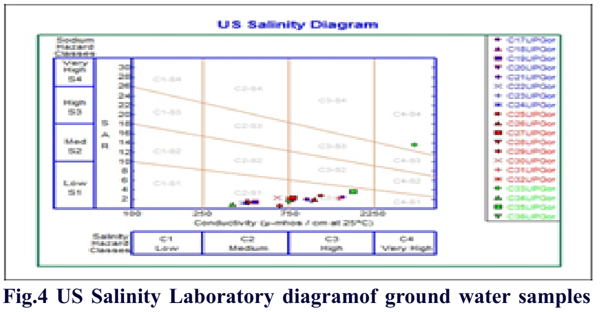

Fig.4 US Salinity Laboratory diagramof ground water samples collected from Gorakhpur district.

Table 1. Basic Analysis of Water Samples around the Study Area

S.No.	Sample No.	Type	pH	E C in µS/cm	TDS	TH	Ca	Mg	Na	K	TA	CO3	HCO3	Cl	SO4	NO3	F	SiO2	PO4
					Concentrationinmg/l														
1	C17	HP	7.37	955	621	305	102	12	77	7.7	310	0	378	71	81	0.8	0.10	13	0
2	C18	HP	7.93	443	288	145	30	16.8	46	2.5	215	0	262	10.6	7	0.1	0.35	29	0
3	C19	HP	7.52	484	315	165	36	18	43	2.4	225	0	275	14.2	7.9	0	0.32	31	0
4	C20	HP	7.36	795	517	250	80	12	66	5.3	270	0	329	78.1	30.9	2.7	0.18	28	0
5	C21	HP	7.16	1504	978	510	128	45.6	125	3.3	450	0	549	185	108	9.5	0.14	20	0
6	C22	HP	7.58	420	273	165	40	15.6	34	2.1	205	0	250	14.2	5.35	0.1	0.18	29	0
7	C23	HP	7.02	1009	656	375	102	28.8	71	0.5	340	0	415	121	3.8	9.4	0.34	19	0.3
8	C30	HP	7.07	652	424	185	62	7.2	75	1.2	210	0	256	49.7	27.8	54	0.17	24	0.2
9	C31	HP	7.13	1440	936	520	164	26.4	115	4.3	320	0	390	263	40.7	1.6	0.08	36	0
10	C32	HP	7.32	755	491	230	80	7.2	78	0.6	235	0	287	56.8	44.5	39	0.04	30	0
11	C33	HP	7.71	3833	2491	415	90	45.6	631	3.2	355	0	433	994	74.6	22	0.04	20	0
12	C34	HP	7.73	367	239	140	36	12	25	1.8	175	0	214	7.1	3.25	0.2	0.23	33	0
13	C35	HP	7.24	1723	1120	465	152	20.4	178	2.9	300	0	366	333.7	66	72	0.06	25	0
14	C36	HP	7.38	757	492	275	86	14.4	55	3.4	235	0	287	49.7	41.9	22	0.12	26	0

Table 2. Heavy Metal Analysis of Water Samples around the Study Area

Sl. No.	Industries Area	Water Sample No	Location	Source	Cu	Fe	Mn	Zn	Ni
					mg/l	mg/l	mg/l	mg/l	mg/l
1	Ambay Industry (cotton dyeing industry)	C17	FL-2, Sector 13, GIDA, SAHJANWA ROAD, GORAKPUR, U.P. In side Factory near entry gat, Hand Pump TW, 60 ft	Hand Pump TW	0.002	0.041	0.461	0.017	nd
2	Ambay Industry (cotton dyeing industry)	C18	FL-2, Sector 13, GIDA, SAHJANWA ROAD, GORAKPUR, U.P. In side Factory , Operating Pump fitted TW, 300 ft	TW	nd	0.08	0.012	0.144	nd
3	Bathwal Industry (cotton dyeing industry)	C19	GIDA, SAHJANWA ROAD, GORAKPUR, U.P. In side Factory , Operating Pump fitted TW, 300 ft	TW	nd	0.054	0.034	0.035	nd
4	Bathwal Industry (cotton dyeing industry)	C20	GIDA, SAHJANWA ROAD, GORAKPUR, U.P. In side Factory , Operating Pump fitted TW, 100 ft	TW	0.002	0.073	0.121	0.015	nd
5	Bathwal Industry (cotton dyeing industry)	C21	Outside factory (Ambay&Bathwal factory) in Village JurianTolaKutolia, near BaidyanathNishad'sHouse, end of factory road, Hand Pump TW, 80 ft	Hand Pump TW	0.004	1.234	0.482	0.018	nd
6	Bathwal Industry (cotton dyeing industry)	C22	Outside factory (Ambay&Bathwal factory), near AMI River in front of RamdasRamkrishanMandir in Village Bharsar, block Sahanaha, Gorakpur district, Hand Pump TW, 60 ft	Hand Pump TW	nd	0.067	0.079	0.016	nd
7	Bathwal Industry (cotton dyeing industry)	C23	Outside factory (Ambay&Bathwal factory),opposite side of factory gate,Juriantola, Gorakpur district, Hand Pump TW, 60 ft	Hand Pump TW	0.002	0.273	0.388	0.034	nd
8	ChouriChoara	C30	Bal Bujurg Village, TahsilChoriChoara, Near house of Misri Yadav, Sardarnagar Block, GOROKPUR DIST.Hand Pump TW , depth 50ft.	Hand Pump TW	nd	0.105	0.016	0.06	nd
9	ChouriChoara	C31	ChoriChoara village, Near Ganga Prasad Memorial Intercollege, Adj to Pond in SE Corner, Mark II Hand Pump TW , depth 140ft.	Hand Pump TW	0.008	1.099	0.032	0.203	nd
10	ChouriChoara	C32	ChoriChoara village, nside of SahidSmarak&adj to old Asok Iron factoryn SE Corner, Hand Pump TW , depth 60ft.	Hand Pump TW	nd	0.118	0.15	0.032	nd
11	ChouriChoara	C33	ChoriChoara village, inside Leather Market (Old) , Hand Pump TW depth 40ft.	Hand Pump TW	0.005	0.151	0.074	0.023	0.014
12	ChouriChoara	C34	ChoriChoara village, inside Masjid, Opposite side of road from Leather Market (Old) , Mark II TW, depth 140ft.	Mark II TW	0.004	0.112	0.021	0.221	nd
13	ChouriChoara	C35	ChoriChoara village, Opposite side of road from Leather Market (Old) towards East nearly 200m, Hand Pump TW of SubanAllahopposite to MaraffarIkbal's house, depth 60ft.	Hand Pump TW	nd	0.047	0.237	0.032	nd
14	ChouriChoara	C36	ChoriChoara village, Road side , in front of Mithai Lal Sweet Shop, Hand Pump TW, depth 60ft.	Hand Pump TW	nd	0.099	0.01	0.026	nd
					nd-	not detectable			

Table 3. BOD & COD Analysis of Water Samples around the Study Area

Sl No	Industries /area	Water Sample No	Location details	COD in mg/l	BOD in mg/l
1	Ambay Industry (cotton dying industry)	C17	FL-2, Sector 13, GIDA, SAHJANWA ROAD, GORAKPUR, U.P. In side Factory near entry gat, Hand Pump TW, 60 ft	0.85	0.25
2	Ambay Industry (cotton dying industry)	C18	FL-2, Sector 13, GIDA, SAHJANWA ROAD, GORAKPUR, U.P. In side Factory , Operating Pump fitted TW, 300 ft	4.66	0.6

3	Bathwal Industry (cotton dying industry)	C19	GIDA, SAHJANWA ROAD, GORAKPUR, U.P. In side Factory , Operating Pump fitted TW, 300 ft	12.3	0.2
4	Bathwal Industry (cotton dying industry)	C20	GIDA, SAHJANWA ROAD, GORAKPUR, U.P. In side Factory , Operating Pump fitted TW, 100 ft	6.8	0.3
5	Bathwal Industry (cotton dying industry)	C21	Outside factory (Ambay&Bathwal factory) in Village JurianTolaKutolia, near BaidyanathNishad's House, end of factory road, Hand Pump TW, 80 ft	7.63	0.6
6	Bathwal Industry (cotton dying industry)	C22	Outside factory (Ambay&Bathwal factory), near AMI River in front of RamdasRamkrishanMandir in Village Bharsar, block Sahanaha, Gorakpur district, Hand Pump TW, 60 ft	4.24	0.2
7	Bathwal Industry (cotton dying industry)	C23	Outside factory (Ambay&Bathwal factory),opposite side of factory gate,Juriantola, Gorakpur district, Hand Pump TW, 60 ft	10.6	0.65
8	ChouriChoara	C30	Bal Bujurg Village, TahsilChoriChoara, Near house of Misri Yadav, Sardarnagar Block, GOROKPUR DIST.Hand Pump TW , depth 50ft.	0.42	ND
9	ChouriChoara	C31	ChoriChoara village, Near Ganga Prasad Memorial Intercollege, Adj to Pond in SE Corner, Mark II Hand Pump TW , depth 140ft.	4.66	0.55
10	ChouriChoara	C32	ChoriChoara village, inside of SahidSmarak&adj to old Asok Iron factoryn SE Corner, Hand Pump TW , depth 60ft.	0.42	0.05
11	ChouriChoara	C33	ChoriChoara village, inside Leather Market (Old) , Hand Pump TW depth 40ft.	5.5	1.35
12	ChouriChoara	C34	ChoriChoara village, inside Masjid, Opposite side of road from Leather Market (Old) , Mark II TW, depth 140ft.	ND	ND
13	ChouriChoara	C35	ChoriChoara village, Opposite side of road from Leather Market (Old) towards East nearly 200m, Hand Pump TW of SubanAllahopposite to MaraffarIkbal's house, depth 60ft.	2.97	0.8

CONCLUSIONS

Ground water samples in Gorakhpur indicated that most of the chemical parameters are within the BIS prescribed drinking water range. Exceptionally high TDS were observed in one sample of ChouriChoara due to some local phenomena. High iron was observed in few well may be due to casing of the well. The ground water is suitable for irrigation for the most part. BOD and COD of water samples also indicates no major ground water pollution due to organic matter in the study area at present, but few areas are vulnerable where COD is more than 10 mg/l at GIDA, Gorakhpur. Hydro-geochemical investigation and mitigation measures may be required in area associated with water quality issue.

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