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Impact of Anthropogenic Activities on Drinking Water Quality: A Case Study in Raniganj Coalfield Area (W. B.)

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ABSTRACT

Present study reveals that the quality of groundwater is not safe for drinking in Raniganj coalfield area. The reasons for the deterioration of groundwater quality can be attributed mainly to lack of proper sanitation and intrusion of raw sewage into the groundwaters. The water quality parameters of supply water on the other hand, are within the permissible limits of drinking water standards. As such, it is suggested that use of raw groundwater for drinking purpose should be discouraged.

INTRODUCTION

Rapid increase in population, industrialization, expansion of agriculture and various other anthropogenic activities have escalated the demand of water for various needs. Availability of usable quality of water, on the other hand, is decreasing because freshwater available in surface and sub surface sources has been put under tremendous pressure of pollution resulted from the generation of huge amount of solid and liquid wastes and their incorporation with the water resources.

Industries share considerable amount of pollutants to the aquatic environment. The role of agricultural sector in jeopardizing the water quality also can not be ignored. The farmers use excess of chemical fertilizers and pesticides, which are washed off by the monsoon rains and contaminate the surface and groundwater sources. The contribution of pollution from agriculture is most difficult to assess and control because of its non-point nature (Nandeshwar et al. 1996) and very little information is available which can enable quantification of this contribution (Sawyer & Casagranade 1983). Livestock breeding and animal husbandry is another source of water pollution.

Poor sanitation facilities in our country on one hand and generation of huge volume of sewage containing human, kitchen and cattle wastes on the other hand have aggravated the pollution problem of the water resources. Very few cities are provided with conventional sewerage and sewage treatment facilities and large number of cities and towns are yet to be provided with safe and hygienic wastewater disposal facilities. Overexploitation, improper land use and waste management has led to contamination of groundwater in urban areas (Subba Rao & Subba Rao 1997, Todd 1995, Vishwanath 1997, Kanchan et al. 2001).

Raniganj (23º 36' N and 87º 07'E) coalfield occupies a vast geographical area in Asansol subdivision of West Bengal. The River Damodar flows to the south of Raniganj town. Rapid expansion of coal mining activities and increase in population have led to the expansion of Raniganj town area to a greater extent and consequently to the generation of huge quantity of effluents which are either dumped in the River Damodar or in some cases on open lands. The principal cause of pollution of natural water resources is direct mixing of untreated sewage with the river and its seepage into the sub-surface level.

Table 1: Water quality parameters of dug well.

Months	pH	DO	BOD	TA	Hardness	Nitrate	Ammonia	Phosphate	Sulphate	Chloride	TDS	Total Coliforms
Feb	6.3	5.2	26.4	30.6	216	51.8	3.1	0.08	135	134.9	320	6
Mar	6.5	5.6	24.1	32.1	214	49.2	4.3	0.06	129	135.5	322	4
Apr	5.7	4.9	30.3	28.6	218	56.6	2.9	0.05	133	133.5	330	8
May	6.3	5.1	24.6	33.1	210	53.3	2.6	0.06	135	143.4	328	4
June	6.4	5.2	24.5	30.4	224	52.6	3.1	0.07	80	138.6	331	4
July	6.5	5.3	23.7	19.6	198	50.7	3.6	0.08	95	112.7	315	4
Aug	6.0	4.8	28.5	21.3	180	61.3	2.1	0.05	98	123.2	310	5
Sept	6.2	5.1	22.4	30.2	193	54.3	2.2	0.09	109	121.9	306	4
Oct	6.1	5.3	22.6	29.4	208	53.2	2.9	0.04	121	125.1	321	4
Nov	5.9	4.8	26.1	31.5	221	55.6	2.2	0.06	123	121.6	315	6
Dec	6.4	5.4	24.3	32.3	213	53.2	2.4	0.07	133	132.9	324	4
Jan	5.9	4.9	25.5	31.4	211	59.1	1.9	0.06	131	135.3	321	6

Table 2: Water quality parameters of bore well.

Months	pH	DO	BOD	TA	Hardness	Nitrate	Ammonia	Phosphate	Sulphate	Chloride	TDS	Total Coliforms
Feb	6.1	5.2	25.4	26.8	206	66.8	2.3	0.03	85.9	71.4	420	6
Mar	6.4	5.4	24.6	27.6	202	55.1	2.4	0.02	83.8	69.6	410	5
Apr	5.8	5.0	26.1	32.3	201	67.1	2.1	0.04	81.3	67.8	435	6
May	6.2	5.2	24.8	26.6	204	55.4	2.3	0.05	85.6	69.7	416	5
June	6.4	5.4	23.7	24.0	210	53.7	2.8	0.01	97.6	73.8	388	4
July	6.6	5.6	22.6	18.9	196	52.6	3.9	0.03	87.7	64.0	326	4
Aug	6.1	5.3	24.5	21.8	199	53.7	2.6	0.04	75.8	65.6	410	6
Sept	6.3	5.6	23.1	20.0	202	52.6	3.1	0.02	83.8	74.1	332	5
Oct	6.0	5.1	25.1	24.7	200	63.4	2.3	0.03	78.9	66.0	418	6
Nov	6.2	5.4	24.2	24.0	212	53.4	2.6	0.02	99.7	75.2	406	5
Dec	6.4	5.5	22.3	22.9	209	51.5	4.1	0.06	88.0	73.7	321	5
Jan	6.2	5.0	25.1	25.8	208	62.5	2.3	0.04	87.7	71.9	418	6

Table 3: Water quality parameters of supply water.

Months	pH	DO	BOD	TA	Hardness	Nitrate	Ammonia	Phosphate	Sulphate	Chloride	TDS	Total Coliforms
Feb	7.6	6.2	6.4	12.6	56.7	30.3	NT	NT	NT	24.0	120	NT
Mar	7.5	5.9	7.2	13.8	58.6	32.6	NT	NT	NT	22.4	124	NT
Apr	7.7	6.3	5.3	10.4	56.2	30.2	NT	NT	NT	24.1	119	NT
May	7.6	6.1	6.8	13.4	57.3	30.9	NT	NT	NT	23.5	123	NT
June	7.5	5.8	8.1	15.2	61.4	34.1	NT	NT	NT	21.7	127	NT
July	7.6	6.1	6.6	13.4	56.9	30.4	NT	NT	NT	23.7	121	NT
Aug	7.7	6.5	4.2	13.3	50.3	28.2	NT	NT	NT	24.5	118	NT
Sept	7.5	5.8	7.9	14.4	58.8	33.1	NT	NT	NT	22.0	126	NT
Oct	7.4	5.4	8.3	15.9	63.2	36.1	NT	NT	NT	20.6	130	NT
Nov	7.2	5.4	8.5	16.8	65.4	37.2	NT	NT	NT	18.6	132	NT
Dec	7.5	5.8	7.9	14.4	58.6	32.6	NT	NT	NT	22.4	125	NT
Jan	7.4	5.6	8.3	16.4	62.3	35.3	NT	NT	NT	21.6	129	NT

Units are in mg/L except pH and total coliforms (per 100mL).

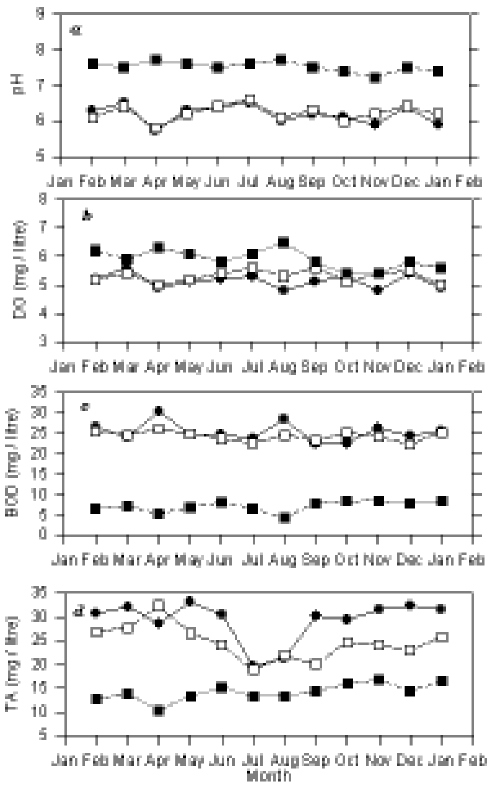

Fig.1: Comparison of water quality parameters [(*a*) pH, (*b*) DO, (*c*) BOD and (*d*) TA] of Dug well (shaded circle), Bore well (open square) and Supply water (shaded square).

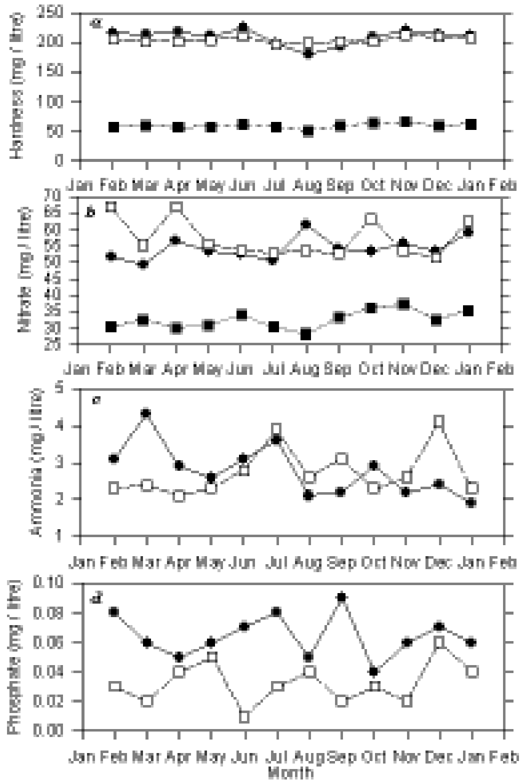

Fig. 2: Comparison of water quality parameters [(*a*) Hardness, (*b*) Nitrate, (*c*) ammonia and (*d*) Phosphate] of Dug well (shaded circle), Bore well (open square) and Supply water (shaded square). Ammonia and phosphate were found to be negligible in Supply water.

Table 4: Mean values of water quality parameters.

Parameters	Standard Permissible Values (Sn)	Dug Wells	Tube Wells	Supply water
pH	6.5	6.23	6.25	7.51
TDS	500	320.25	391.6	124.5
DO	5.0	5.13	5.3	5.9
BOD	5.0	25.25	24.29	7.06
TA	120	29.2	24.6	14.16
Hardness	300	208.0	204.08	58.8
Sulphate	250	118.5	84.65	-
Nitrate	20	54.24	57.3	32.58
Chloride	250	129.89	69.06	22.5
Ammonia	1.5	2.67	3.0	-
Phosphate	0.1	0.064	0.032	NT
Av. tot. coliforms	0.0	4.90	5.25	NT

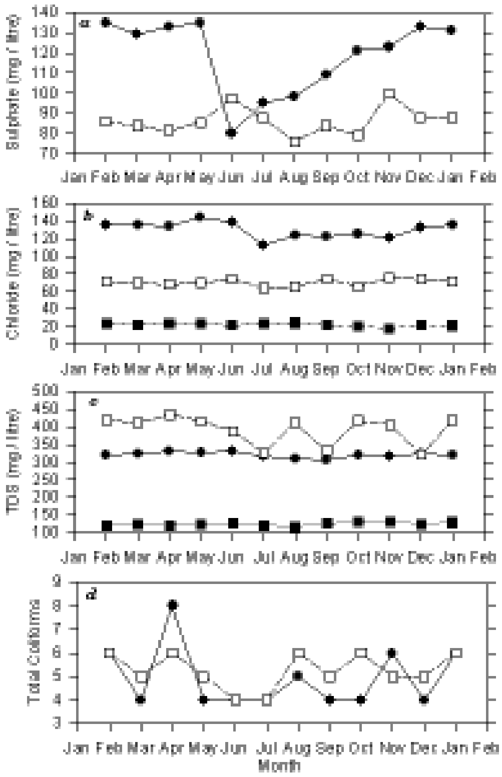

Fig.3. Comparison of water quality parameters [(*a*) Sulphate, (*b*) Chloride, (*c*) TDS and (*d*) Total Coliforms] of Dug well (shaded circle), Bore well (open square) and Supply water (shaded square). Sulphate and Total Coliforms were found to be negligible in Supply water.

The main source of drinking water in Raniganj town is the river Damodar. Groundwater is also extensively used in the summer months when existing municipal supply of water alone can not cope up with the drinking water requirement. Occurrence of gastrointestinal illness is often associated with the quality of water consumed. Frequent incidents of waterborne diseases, particularly among the groundwater users of this area indicated the deterioration of quality of drinking water resources which fuelled the need for conducting the present study to investigate if any contamination has occurred in the drinking water sources of Raniganj town.

MATERIALS AND METHODS

Water samples were collected every month for physico-chemical and bacteriological studies from three dug wells, three bore wells and three municipal supply sources located in different parts of Raniganj town. The studies were conducted from February 2003 to January 2004. pH values were measured at the sampling places using digital pH meter. TDS, DO, BOD, TA, TH, nitrate, ammonia, phosphate, sulphate, chloride and total coliforms were determined by standard methods described in APHA (1980). Pearson's coefficient of correlation (r) was calculated between possible pairs of water quality parameters by using the formula:

$$r = \frac{\sum\left(x-\bar{x}\right)\left(y-\bar{y}\right)}{\sum\sqrt{\left(x-\bar{x}\right)^2\left(y-\bar{y}\right)^2}}$$

In order to determine the overall quality of water for any intended use, Water Quality Index (WQI) was calculated using weighted arithmetic index method (Brown et al. 1972). Ten parameters were selected for calculating WQI using the following formula:

$$WQI = \sum_{n=1}^{n} q_n W_n$$

Where, W = Unit weight for the n^{th} parameter
q = Sub index corresponding to n^{th} parameter
n = number of parameters

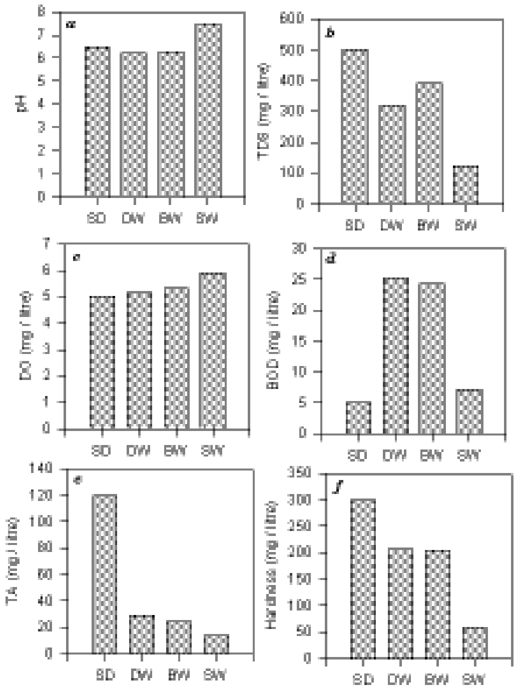

Fig.4. Comparison of mean values of water quality parameters [(*a*) pH, (*b*) TDS, (*c*) DO, (*d*) BOD, (*e*) TA and (*f*) Hardness] from three different sources: Dug well (DW), Bore well (BW) and Supply water (SW). Standard permissible value for each parameter is represented as SD.

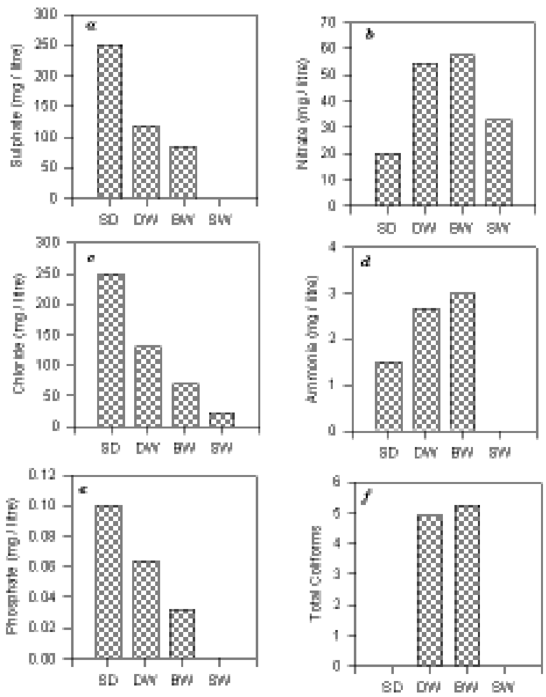

Fig. 5. Comparison of mean values of water quality parameters [(*a*) Sulphate, (b) Nitrate, (*c*) Chloride, (*d*) Ammonia, (*e*) Phosphate and (*f*) Total Coliforms] from three different sources: Dug well (DW), Bore well (BW) and Supply water (SW). Standard permissible value for each parameter is represented as SD. For Total Coliforms SD = 0. Sulphate, Phosphate, Nitrate and Total Coliforms were found to be negligible in Supply water.

RESULTS AND DISCUSSION

The results of the study are given in Tables 1-10 and Figs. 1-5. Both, the dug wells and bore wells, showed acidic pH while the pH of supply water was slightly alkaline. Verma & Thakur (1998) recorded similar observations in Ghatsila. pH of water, however, does not cause any severe health hazard but high pH induce the formation of toxic trihalomethanes. According to Klein (1957), pH between 6.7 and 8.4 is suitable while pH below 5.0 is detrimental. TDS is an important parameter for waters used for drinking and other purposes because pollution has direct relationship with the solids, may be suspended or dissolved (Chandra et al. 2000). High values of TDS give unpleasant taste and make water non-potable. In the present investigation TDS values of all the drinking water sources were noted below WHO permissible limit of 500 mg/L. A good water should have the solubility of oxygen 7.6 mg/L and 7.0 mg/L at 30°C and 35°C respectively (Kudesia 1985). Dissolved oxygen was much higher in supply water compared to that in ground waters. The dissolved oxygen concentrations in dug well and bore well were observed below the standard limit of 6.0 mg/L. In this respect supply water is classified as good quality as oxygen saturated water gives pleasant taste to water. Determination of BOD value is the most useful technique to assess the level of organic pollution in water. Higher BOD values as recorded in the present study indicating seepage of organic wastes into the groundwaters. BOD values in supply water were recorded much lower in the present study. Total

Table 5: Unit weights (Wn), quality rating (Qn) and subindex (WnQn) values.

Parameters	Wn	Dug Well		Tube Well		Supply water	
		Qn	WnQn	Qn	WnQn	Qn	WnQn
pH	0.09374	-51.333	- 4.81198	-50.0	-4.687	34.0	3.1858
TDS	0.00159	64.05	0.101839	78.2	0.1243	24.8	0.0394
DO	0.15936	98.6458	15.7202	96.875	15.438	0.906	0.1442
BOD	0.15936	505.0	80.4768	485.8	77.417	141.2	22.501
TA	0.00664	24.333	0.1615	20.5	0.1361	11.8	0.0783
Hardness	0.00265	69.333	0.1837	68.26	0.1802	19.6	0.0519
Sulphate	0.00318	47.40	0.1507	33.86	0.1076	-	-
Nitrate	0.03984	271.20	10.8046	286.5	11.414	162.9	6.4899
Chloride	0.00318	51.956	0.1652	27.624	0.0878	9.0	0.0286
Ammonia	0.53120	178.0	94.5536	200.0	106.24	-	-
	Σ Wn= 1.00074		Σ WnQn= 197.506		Σ WnQn= 206.42		Σ WnQn= 32.519

Table 6: WQI values of various drinking water sources.

Observed WQI Values		
Dug Well	Tube Well	Supply Water
197.359	206.26	32.494

Table7: Status of water quality based on WQI (Quoted by Mishra & Patel 2001).

WQI	Status
0 - 25	Excellent
26 - 50	Good
51 – 75	Poor
76 – 100	Very poor
Above 100	Unsuitable for drinking

alkalinity itself is not harmful to human beings, still the water supplies with less than 100 mg/L of total alkalinity are desirable for domestic use. Alkalinity value greater than 100 mg/L indicates that water body is nutritionally rich (Philipose 1960). Total alkalinity values were within the permissible limits in all the three sources. The values declined in monsoon months in dug wells might be due to dilution.

Hardness values were within the permissible limits in all three sources. Hardness below 300 mg/L is considered potable but beyond this limit produces gastrointestinal irritation (ICMR 1975). Hardness showed +ve correlation with sulphate and chloride indicating permanent hardness. In the present study, the values of nitrate in the subsurface sources exceeded permissible limit of WHO (1993). The most important source of nitrate is biological oxidation of nitrogenous substances which come in domestic sewage, industrial wastes and agricultural run off. Apart from these, the role of anthropogenic activities in nitrate pollution of water bodies can be well perceived from the fact that terrestrial waters in uninhabited and less polluted regions have negligible nitrate, while world’s average river water contains 1 mg/L of nitrogen (Mason & Moore 1985). Scragg et al. (1982) reported that elevated nitrate in groundwater might be a human teratogen leading to potential death due to congenital malformations in the regions that have more than 45 mg/L of nitrate in drinking water. Intake of high nitrate with water may lead to birth of malformed child (Dorsche et al. 1984). Present findings (Fig. 2b) support the work of Singh et al. (1991) who reported high nitrate in shallow and deep tube wells in Lucknow city. Presence of nitrate was detected much above WHO limit (20 mg/ L) in all the sources of drinking water.

Ammonia was not traced in supply water but its concentration exceeded WHO limit of 1.5 mg/L in groundwater sources. Ammonia concentration exceeding 1 mg/L is indicative of organic pollu-

Table 8: Correlation matrix (Dug well I)

	pH	DO	BOD	TA	Hardness	Nitrate	Ammonia	Phosphate	Sulphate	Chloride	TDS	Total Coliforms
pH	1.00											
DO	+.874	1.00										
BOD	-.592	-.674	1.00									
TA	-.068	+.178	-.220	1.00								
Hardness	-.094	+.198	-.296	+.681	1.00							
Nitrate	-.206	-.807	+.567	-.221	-.539	1.00						
Ammonia	+.206	+.768	-.074	-.184	+.207	-.600	1.00					
Phosphate	+.420	+.263	-.401	-.014	-.047	+.446	+.916	1.00				
Sulphate	-.398	+.116	+.189	+.602	+.338	-.027	-.152	-.216	1.00			
Chloride	+.071	+.138	+.166	+.706	+.584	-.115	+.063	-.242	+.409	1.00		
TDS	+.237	-.056	+.220	+.441	+.746	-.243	+.271	-.483	+.779	+.76	1.00	
Total Coliforms	-.724	-.472	+.916	+.023	+.278	+.454	-.015	-.270	+.380	+.088	+.174	1.00

Table 9: Correlation matrix (Bore well).

	pH	DO	BOD	TA	Hardness	Nitrate	Ammonia	Phosphate	Sulphate	Chloride	TDS	Total Coliforms
pH	1.00											
DO	+.816	1.00										
BOD	-.851	-.888	1.00									
TA	-.674	-.787	+.842	1.00								
Hardness	-.017	-.161	+.0006	+.167	1.00							
Nitrate	-.495	-.758	+.822	+.545	+.028	1.00						
Ammonia	+.863	+.793	-.920	-.763	-.152	-.528	1.00					
Phosphate	-.176	-.300	-.017	+.152	-.064	+.091	+.203	1.00				
Sulphate	+.315	-.038	-.311	-.024	+.762	-.330	+.193	-.464	1.00			
Chloride	+.153	+.211	-.211	+.034	+.889	-.354	+.064	-.191	+.683	1.00		
TDS	-.427	-.547	+.413	+.640	+.400	+.370	-.277	+.588	-.144	+.140	1.00	
Total Coliforms	-.820	-.754	+.731	+.505	-.102	+.724	-.608	+.433	-.534	-.187	+.540	1.00

Table 10: Correlation matrix (Supply water).

	pH	DO	BOD	TA	Hardness	Nitrate	Chloride	TDS
pH	1.00							
DO	+.931	1.00						
BOD	-.848	-.935	1.00					
TA	-.869	-.859	+.804	1.00				
Hardness	-.903	-.950	+.952	+.875	1.00			
Nitrate	-.927	-.968	+.916	+.851	+.966	1.00		
Chloride	+.969	+.931	-.842	+.850	-.913	-.962	1.00	
TDS	-.942	-.980	+.925	+.905	+.940	+.986	-.960	1.00

tion (Reid 1961). Higher concentration of ammonia causes toxicity in Man, which increases with increased pH because at higher pH most of the ammonia remains in toxic gaseous form. The elevated values of ammonia in groundwater might be due to seepage of sewage containing organic matter coupled with ammonification of organic matter. Phosphate occurs in low concentration in natural waters but increases when water bodies receive anthropogenic wastes. The increased application of fertilizers, use of detergents and discharge of domestic wastes greatly contribute to the heavy loading of phosphate in water (Golterman 1975). Phosphate in groundwaters was present below WHO standard of 0.1 mg/L. No phosphate was detected in supply water.

High concentration of sulphate is not desired in drinking water because it produces objectionable taste at 300-500 mg/L. High sulphate may cause diarrhoea. Sulphate in all the water sources was present much below ISI limit of 250 mg/L. In natural freshwaters chlorides remain in low concentration. However, leaching from rocks may cause rise in concentration of chloride in natural waters. The greatest source of chloride in groundwater is seepage of sewage and industrial wastes. Presence of high values of chloride in water indicates contamination by sewage. Klein (1957) found direct correlation between chloride and pollution load. Chloride content of drinking waters observed in the present study was much below permissible limit for drinking water. Total coliforms indicate degree of pollution and its higher density portrays the difference between clean and polluted waters (Rai & Hill 1978). Clark & Pogel (1977) considered coliforms as a reliable indicator of contamination of water. Total coliforms in the present study exceeded permissible limits, both in dug well and bore wells, but no coliforms were detected in supply water. Improper drainage lines might be the largest contributing factor for bacteriological contamination of subsoil water. Presence of coliforms in the groundwater sources indicates possible presence of enteric pathogens (Singh & Kumar 1995). Richariya & Mishra (1998) recorded high values of coliforms in the groundwater at Rewa area, which was attributed to seepage of polluted water from industries, mining and domestic wastes. Bacteriological contamination of underground water at Indore City was studied by Joshi et al. (2000) and recorded coliform counts more than 10/100 mL of water. In order to assess the quality of water in terms of index number, water quality index (WQI) was calculated for the three drinking water sources. Values of unit weight (W_n), quality rating (Q_n) and sub index (W_nQ_n) are presented in Table 5. The values of WQI presented in Table 6 depict a comparative evaluation of water quality of dug well, bore well and municipal supply. It, thus, appears that quality of supply water is good and may be used for drinking purpose but very high WQI values (>100) for subsurface sources indicate that water of these sources is not suitable for drinking.

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