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Extent of Pollution Assessment in Drinking Water Supplies of Narayanganj District in Bangladesh

Bikash C. Sarker and [1] M.W. Zaman
Department of Agricultural Chemistry,
Hajee Mohammad Danesh Science and Technology University, Dinajpur 5200, Bangladesh
[1]Department of Agricultural Chemistry,
Bangladesh Agricultural University, Mymensingh, Bangladesh

Abstract: This study examined the chemical quality and suitability of 27 water samples of Narayanganj municipal area in Bangladesh for drinking purposes. The pH, electrical conductivity (EC), total dissolved solid (TDS), Na, K, Ca, Mg, Fe, Mn, Zn, Cu, NO_3-N, SO_4-S, CO_3, HCO_3, Cl and total hardness (H_T) were analyzed. pH of waters were just neutral to alkaline in nature. EC and TDS values varied from 165 to 1770 µS cm^{-1} and 100 to 1020 mg L^{-1}, respectively. Appreciable amount of Ca and Mg were present resulting higher water hardness. The Na concentration was as high as 5.98 to 389.99 mg L^{-1}. Cl was dominant among the ionic constituents. Fe, Mn, Zn, Cu, NO_3-N and SO_4-S concentrations were within the safety limit. Significant amounts of Cl were detected in drinking waters exceeding the level of U.S. Environmental Protection Agency (USEPA). The result of present findings indicated that groundwater contained some chemical parameters that exceeded the upper limit of standard. WASA water was found suitable in all respect while some groundwater samples were unsuitable for drinking and domestic purposes.

Key words: Pollution, drinking water, groundwater, suitability assessment

Introduction

Natural water deterioration is an emerging environmental issue throughout the world. As a consequence of rapidly expanding industrialization and excessive population growth, most of our surface and groundwater are being increasingly polluted. Water is regarded as polluted when it becomes unfit for the given use or changed in its composition largely as a result of human activities and natural contamination. Urban and rural people of Bangladesh mostly depend on conventional shallow tube wells (Hand pressure tube wells) for their drinking and domestic purposes. Drinking water should be free from color, turbidity, odor and microorganisms. It should also preferably be soft, low in dissolved solids and free from toxic constituents. If low quality water is used for drinking, domestic and other beneficial uses, ionic toxicity as well as health hazards may occur. Polluted water has a direct impact on human health and fish and livestock show unusual symptoms and abnormalities. It was reported that NO_3 concentration exceeding the upper limit in drinking water causes methemoglobinemia in babies (Sparks, 1995). Arsenic contamination in groundwater was observed in different parts of Bangladesh viz., Pabna, Jessore, Faridpur, Barishal and Khulna district (Anonymous, 1996).

Narayanganj is an industrially important and over populated area of Bangladesh. There are many point and non-point sources of pollutants liable to contaminate surface and groundwater in this locality. So, analysis of water quality variables is burning issue for the protection of health hazards and the water pollution control program. Considering this importance, a research study on the chemical characteristics of water relating to pollution was undertaken to appraise the suitability of water for public water supplies.

Materials and methods

Samples collection

For the study, 27 water samples were collected from 26 different sampling sites located in the Narayanganj Municipal area (Fig. 1). Detailed sampling programmes were conducted on June 9 and 19, 1997. Out of 27 samples, 25 were groundwater and other 2 were WASA (Water and sewerage authority) water sources. Of 25 groundwater samples, 4 were collected from shallow deep tube wells (Trade name: Pedrollo pump) and 21 were from hand pressure tube well. The remaining two samples of Shitalaxma river that were refined and collected from the WASA water refinery plant situated at Godnail. The collection and record keeping procedures were maintained as per APHA technique (American Public Health Association; Eaton ***et al.*** (1995). Samples were immediately carried to the Laboratory of Agricultural Chemistry of Bangladesh Agricultural University, Mymensingh and filtered and refrigerated prior to chemical analyses especially for atomic absorption and flame photometric analyses.

Analytical methods

The water samples were analyzed for pH, EC, TDS, soluble cations including Na, K, Ca, Mg, Fe, Mn, Cu, Zn, P, B and anions including HCO_3, CO_3, Cl, NO_3 and SO_4-S. The pH and EC (at 25°C) levels were measured electrometrically immediately after collecting the samples as per Tandon (1985). Na, K, Ca, Mg, Cl, NO_3-N, SO_4-S, Fe, Mn, Cu and Zn were quantitatively analyzed following standard methods. CO_3 and HCO_3 levels in the samples were determined by acidimetric method of titration. TDS was obtained by evaporating from measured aliquot. H_T was computed from the estimated Ca and Mg concentration using the formula; H_T (mg L^{-1})=Ca×2.5+Mg×4.1.

The water of a specific area may be classified into different categories based on water quality variables or standards given by the respective authorities. The suitability of a water supply for drinking and domestic uses depends on the type and amounts of some undesirable substances present therein. These undesirable substances are likely to harmfully affect the quality of water for the given use as designated by pollution parameters. In the present study, only the most important chemical parameters including pH, TDS, Ca, Mg, Cl, SO_4, NO_3, Fe, Mn, Cu, Zn and H_T were considered for evaluating the suitability of pubic water supplies. The analyzed waters were categorized as highest desirable and maximum permissible as per standard set by World Health Organization (WHO, 1971) and as suitable and unsuitable according to USEPA, 1975.

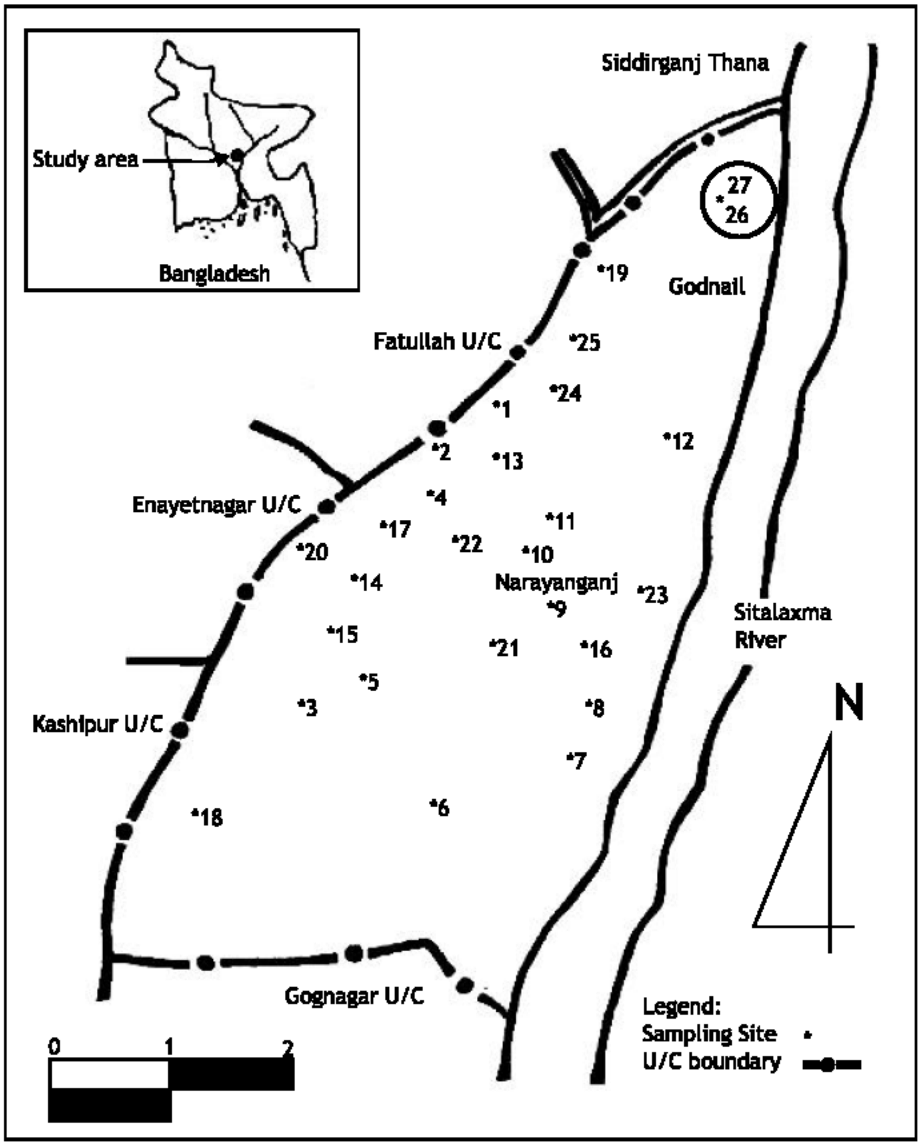

Fig. 1: Map of study area locating sampling sites in Narayanganj along with a map of Bangladesh

A statistical analysis was conducted among the standard parameters using linear correlation regression method. This was performed to know whether any relationship among the parameters existed or not.

Results and Discussion

The concentration of analytes and computed parameter of water samples are depicted in Fig. 2 and Table 1. In Fig. 2, the amount of Ca, Mg, CO_3+HCO_3, Na+K and Cl have been presented with vector diagram. The length of each vector represents the concentration of major ion (s) in milliequivalent per liter (meq L^{-1}). Na and K concentrations were 5.98 to 164.98 mg L^{-1} and 4.49 to 33.15 mg L^{-1}, respectively. The lowest concentration was found in WASA water. The highest value of Na was in sample No. 12 collected from Stadiumpara, where a number of dyeing industries were established many years ago, which discharge a huge amount of effluent containing Na (Fig. 2). Nevertheless, the cause of higher Na was undetermined but it was assumed that the industrial effluent and municipal wastes might be the possible non-point sources of pollutants since most of the test samples of groundwater were collected from nearby the dumping sites. Carliell ***et al.*** (1996) reported that effluents from dyebath containing Na which might be the possible Na donor. The concentrations of K were lower as compared to the Na concentrations in the water samples. Ca and Mg were present abundantly in groundwater and also in WASA water. The values were ranging from 16.04 to 140.28 mg L^{-1} and 1.21 to 71.64 mg L^{-1}, respectively. An appreciable amount of CO_3 and HCO_3 were present in groundwater, though CO_3 was negligible in most cases (Fig. 2). The range of HCO_3 varied in between 6.10 to 317.20 mg L^{-1}. Most of the groundwater contained higher amount of HCO_3 while WASA water demonstrated below average concentration. A substantial variation in Cl levels was found among the samples (Fig. 2). The amount of Cl ranged from 35.5 to 440.2 mg L^{-1}. Lowest concentration was in WASA water than groundwater. Natural water may contain less than 1000 mg L^{-1} in dry regions (Sparks, 1995 based on Durfer and Becker, 1964; Ebens and Schaklette, 1982; Dragun, 1988).

The pH of the samples was neutral to alkaline and the values ranged from 6.97 to 8.6 (Table 1). The alkalinity of water samples is possibly due to the presence of appreciable amounts of Na, K, CO_3 and HCO_3. The EC and TDS were 165 to 1770 µS cm^{-1} and 100 to 1020 mg L^{-1}. The EC values were distinctly dissimilar among the samples. The highest EC value was in the sample No. 18 reflecting the presence of a higher concentration of salt while WASA water showed comparatively lower EC than groundwater. In the present study, groundwater contained higher dissolved solids than surface water. Groundwater usually contain higher TDS than surface water due to appreciable amount of dissolved bicarbonate, chloride and sulfate compound of Ca, Mg, Na and Si (Karanth, 1994) which also confirms the present investigation.

Concentrations of P and B in both WASA water and groundwater were negligible in this study (Data not shown). NO_3 and SO_4-S were also very low but still significant for water pollution parameters regarding drinking quality. Fe and Mn status in waters varied from 0.03 to 0.48 mg L^{-1} and 0.01 to 0.05 mg L^{-1}, respectively. Eight samples contained Mn below the detection limit (Table 1). In the water, NO_3-N was present in very low amount. SO_4-S was 0.32 to 28. 16 mg L^{-1} and some of them were below detection limit. The computed variable, H_T was 60.02 to 539.60 mg L^{-1}. Likely other major ions, H_T of groundwater was higher than WASA water. In respect to $H_{T,}$ the study results were significantly higher than those for the other parts of Bangladesh (Zaman and Mohiuddin, 1995). This is possibly due to presence of higher amount of Ca and Mg ion in waters.

Statistical analysis

A multiple correlation-regression analysis among the variables was performed that was only confined within the groundwater samples. The interrelationships among the parameters in terms

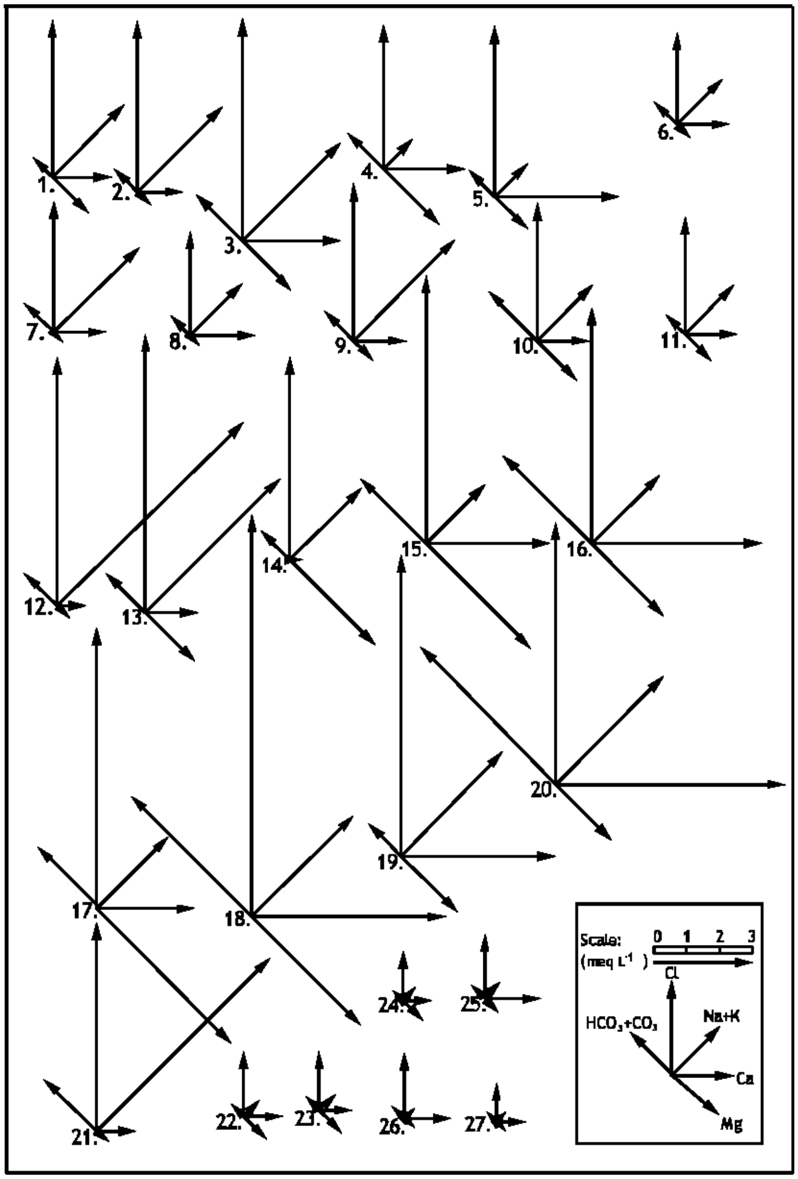

Fig. 2: Vector diagram for representing the chemical analyses of waters. The length of arrow indicates the relative concentration of respective ion (s) shown in the inset

of correlation co-efficient has been presented in Table 2. Significant relationship was observed among the some parameters. pH showed a significant correlation with K which indicated that pH of water increased with the increase in K ion of the water. Both EC and TDS significantly correlated with Na, K, Ca, Mg, HCO_3, Cl and H_T. It indicated that EC and TDS increased with the increase in the major ions of the groundwater. A positive interrelationship was existed among

Table 1: Chemical composition of water collected from Narayanganj municipal area

Sampling location	Depth m	pH	EC μScm^{-1}	TDS	Fe	Mn	Zn	Cu	NO_3	SO_4	H_T
				----	----	----	mg L^{-1}	----	----	----	----
Newpalpara	60	7.8	603	352	0.07	0.02	0.17	0.01	0.36	2.56	169
Nandipara	60	7.7	540	332	0.48	0.02	0.11	0.03	0.43	5.47	90
Paikpara	55	7.9	842	565	0.08	0.02	0.09	0.03	0.15	ND	209
Newpalpara	55	8.1	631	385	0.06	0.01	0.09	0.02	0.29	5.3	240
Paikpara	55	8.2	644	410	0.07	0.01	0.07	0.02	1.85	2.15	260
Paikpara	60	7.8	374	256	0.07	0.02	0.13	0.03	ND	ND	100
BB road	55	7.8	563	362	0.04	0.02	0.07	0.02	ND	0.50	95
Ukilpara	55	8.0	402	260	0.07	ND	0.16	0.04	0.29	1.82	105
Sd para	45	8.1	659	396	0.07	0.01	0.15	0.02	ND	2.00	112
Sd para	45	8.2	539	330	0.03	ND	0.09	0.02	ND	0.32	165
Sd para	45	7.9	464	290	0.05	0.02	0.09	0.02	ND	0.48	135
Sd para	55	8.1	833	574	0.03	0.04	0.4	0.02	ND	ND	61
Newpalpara	55	7.8	977	620	0.07	0.01	0.08	0.01	0.15	ND	205
Newpalpara	45	8.1	840	472	0.05	0.01	0.17	0.02	0.50	15.3	240
Nandipara	60	8.2	1033	640	0.05	0.05	0.08	0.02	1.00	ND	420
Ukilpara	55	7.9	1119	720	0.05	ND	0.09	0.04	0.43	ND	414
Newpalpara	55	8.0	1138	732	0.07	0.02	0.08	0.02	0.43	9.65	444
Nitaiganj	45	7.8	1770	1020	0.09	0.02	0.01	0.02	2.29	ND	540
Ailpara	45	8.0	1176	662	0.08	ND	0.12	0.03	ND	5.30	350
DC road	55	7.8	1440	980	0.05	ND	0.11	0.01	0.15	ND	470
Sd para	45	8.6	930	630	0.07	0.01	0.09	0.01	ND	ND	80
Falpatri	55	7.0	253	164	0.05	ND	0.09	0.01	0.28	5.00	95
Paikpara	45	7.9	245	160	0.08	0.02	0.07	0.03	0.15	2.66	95
Ukilpara	45	7.7	188	120	0.04	0.01	0.09	0.03	0.29	28.7	80
Chasara	35	7.4	265	166	0.04	0.01	0.14	0.03	0.36	1.82	110
Godnail	-	7.8	212	147	0.03	ND	0.16	0.02	0.15	1.47	90
Godnail	-	7.4	165	100	0.03	ND	0.53	0.02	ND	2.00	60
Mean		**7.9**	**698**	**438.7**	**0.07**	**0.018**	**0.13**	**0.02**	**0.53**	**5.14**	**201**
Sd		**0.3**	**407**	**251.9**	**0.083**	**0.011**	**0.11**	**0.009**	**0.6**	**6.96**	144
CV(%)		3.9	58.3	57.42	114.9	57.97	80.04	38.1	112.9	113.3	71

Legend; Sd=Stadium, BB=Bangabandhu, DC=Diamond cinema, ND=Not detected and SD = Standard deviation

Na K, HCO_3 and Cl. Furthermore, Ca and Mg showed a close relationship with HCO_3 and Cl that indicated Ca and Mg might ionized from bicarbonate and chloride compound. In the present analysis, no relation was observed among the minor ions viz., Fe, Mn, Cu and Zn. It was evident that a significant relationship existed among Na, K, Ca, Mg and H_T.

Table 2: Correlation matrix for the relationship among the parameters of collected groundwater samples

	Depth	pH	EC	TDS	Na	K	Ca	Mg	Fe	Mn	Zn	Cu	HCO_3	Cl
pH	-0.03													
EC	0.09	0.31												
TDS	0.14	0.32	0.99**											
Na	0.03	0.37	0.68**	0.70**										
K	0.01	0.43*	0.76**	0.76**	0.72**									
Ca	0.12	0.08	0.81**	0.80**	0.24	0.43*								
Mg	0.08	0.18	0.71**	0.67**	0.13	0.45*	0.62**							
Fe	0.28	-0.12	-0.04	-0.06	0.11	-0.24	-0.08	-0.14						
Mn	0.31	0.19	0.07	0.08	0.22	0.09	-0.17	0.19	0.09					
Zn	0.10	0.10	-0.14	-0.11	0.27	0.11	-0.33	-0.32	-0.08	0.26				
Cu	-0.09	-0.04	-0.24	-0.25	-0.33	-0.35	0.01	-0.13	0.19	-0.09	0.02			
HCO_3	0.03	0.29	0.71**	0.68**	0.46*	0.62**	0.50*	0.68**	-0.15	0.23	-0.29	0.04		
Cl	0.10	0.32	0.95**	0.93**	0.74**	0.76**	0.68**	0.69**	0.03	0.16	-0.05	-0.20	0.71**	
H_T	0.12	0.13	0.85**	0.82**	0.20	0.49*	0.91**	0.88**	-0.12	0.01	-0.37	-0.07	0.65**	0.76**

Significant values of r = 0.396 for P<0.05 and 0.505 for P<0.01 with 23 df. NS, * and ** represented not significant, significant at 5% and 1% level of probability, respectively

Suitability of groundwater and WASA water for drinking and domestic usage

The quality and suitability of waters have mainly been delineated in the light of drinking and domestic usage. The pollution parameters viz., pH, TDS, H_T, Ca and Mg are discussed according to WHO (1971) and Cl, Fe, Mn, Zn, Cu, NO_3 and SO_4 ions are as per standards set by USEPA (1975). The pH values of the collected 27 samples were highest desirable except for two groundwater samples (Sample Nos. 21 and 22). These two samples were out of the highest desirable limit but were within the maximum permissible limit. In respect to TDS, 17 samples were suitable for drinking and mostly desirable. Ten samples were within maximum permissible limit. H_T of water is an important criterion for assessing the suitability of public water supplies. The groundwater collected from Nitaiganj (Sample No. 18) was considered completely unsuitable for drinking and domestic purposes regarding H_T, as because the respective value was beyond the WHO standard (Computed H_T=539.60 mg L^{-1}). A layer of insoluble $CaCO_3$ and $MgCO_3$ would be expected on bathroom fixtures, kettles and other boiling equipment and an additional amount of detergents might be required for washing clothes if this water were regularly used. Seventeen samples were within maximum permissible limit and the remaining samples were highly desirable (Table 3). The Ca concentration of water relates exclusively to the H_T and alkalinity of the water is of the utmost importance for drinking purposes. Six samples of shallow tube well were within maximum permissible limit but the remaining 21 samples were highest desirable (Table 3). All the waters contained Mg at a level that was highly desirable. Considering pH, TDS, H_T, Ca and Mg, WASA water registered suitable for drinking and domestic purposes. As for Cl ion presence in the groundwater, 8 samples (Sample Nos. 12, 13, 15, 16, 17, 18, 19 and 20) were significantly considered unsuitable for drinking and domestic purposes. These waters would produce adverse public health effects. WASA water had Cl ion concentration within safely limit.

Presence of higher content of major ion(s) exceeding standard in the groundwater was the reason for the water pollution. The causes of higher concentration might be the industrial effluents that slowly leached down and mixed to groundwater. Furthermore, the possible reason of higher values of different water quality parameters in the groundwater might be of geological formations of the sediment at depth of the installed tube wells. Several processes may lead to a higher content of dissolved solids in groundwater such as flow through rocks containing soluble mineral matter on concentration by evaporation (Karanth, 1994).

Table 3: Quality classification and suitability of groundwater and WASA water for drinking and domestic usage

pH	TDS	HT	Ca	Mg	Cl	Fe	Mn	Zn	Cu	NO_3	SO_4
WHO, 1971					USEPA, 1975						
HD	HD	MP	HD	HD	ST	ST	ST	ST	ST	ST	ST
HD	HD	HD	HD	HD	ST	UNST	ST	ST	ST	ST	ST
HD	MP	MP	HD	HD	ST	ST	ST	ST	ST	ST	ST
HD	HD	MP	HD	HD	ST	ST	ST	ST	ST	ST	ST
HD	HD	MP	MP	HD	ST	ST	ST	ST	ST	ST	ST
HD	HD	MP	HD	HD	ST	ST	ST	ST	ST	ST	ST
HD	HD	HD	HD	HD	ST	ST	ST	ST	ST	ST	ST
HD	HD	MP	HD	HD	ST	ST	ST	ST	ST	ST	ST
HD	HD	MP	HD	HD	ST	ST	ST	ST	ST	ST	ST
HD	HD	MP	HD	HD	ST	ST	ST	ST	ST	ST	ST
HD	HD	MP	HD	HD	ST	ST	ST	ST	ST	ST	ST
HD	MP	HD	HD	HD	UNST	ST	ST	ST	ST	ST	ST
HD	MP	MP	HD	HD	UNST	ST	ST	ST	ST	ST	ST
HD	HD	MP	HD	HD	ST	ST	ST	ST	ST	ST	ST
HD	MP	MP	MP	HD	UNST	ST	ST	ST	ST	ST	ST
HD	MP	MP	MP	HD	UNST	ST	ST	ST	ST	ST	ST
HD	MP	MP	HD	HD	UNST	ST	ST	ST	ST	ST	ST
HD	MP	UNST	MP	HD	UNST	ST	ST	ST	ST	ST	ST
HD	MP	MP	MP	HD	UNST	ST	ST	ST	ST	ST	ST
HD	MP	MP	MP	HD	UNST	ST	ST	ST	ST	ST	ST
MP	MP	HD	HD	HD	ST	ST	ST	ST	ST	ST	ST
MP	HD	HD	HD	HD	ST	ST	ST	ST	ST	ST	ST
HD	HD	HD	HD	HD	ST	ST	ST	ST	ST	ST	ST
HD	HD	HD	HD	HD	ST	ST	ST	ST	ST	ST	ST
HD	HD	MP	HD	HD	ST	ST	ST	ST	ST	ST	ST
HD	HD	HD	HD	HD	ST	ST	ST	ST	ST	ST	ST
HD	HD	HD	HD	HD	ST	ST	ST	ST	ST	ST	ST

Keys; HD=Highest desirable, MP=Maximum permissible, ST=Suitable and UNST=Unsuitable

Almost all of the waters were suitable for drinking and domestic purposes with concern to Fe concentrations except one (Sample No. 2) that exceeded the USEPA standard. Excessive Fe concentration in waters might be a cause of human health hazard, especially for the stomach. Considering Mn, Zn, Cu and SO_4-S ions, water collected from under ground and surface sources would not be a problem for human health and domestic uses. NO_3-N ion in groundwater is an important point source pollutant threatening the world. In the present study, the NO_3-N concentrations were within the safety limit as per USEPA standards (<10 mg L^{-1}). A consistent result was reported that low NO_3-N was in groundwater collected from different parts of Bangladesh (Zaman and Mohiuddin, 1995). On the contrary, groundwater and surface waters containing NO_3-N levels exceeding the upper limit of USEPA standards for drinking were found in the USA, Canada, Netherland, Germany and many other countries of the world (Fried, 1991; Gillham, 1991 and Spalding, 1991). Lower content of NO_3-N in the groundwater was possibly due to lack of sufficient point source and non-point source in the study area.

In the present study, the waters of the WASA water from water refinery plant was the highest desirable and suitable for drinking and domestic usage considering all respects. Proper treatment before using was the reason for the suitability of drinking and domestic purposes. In some localities of Narayanganj municipal area, groundwaters were polluted to some extent considering the parameters pH, TDS, H_T, Cl and Fe. An adverse human health effect might be appeared after prolonged use of these problematic waters. Although NO_3-N status remained within the safety limit, keen attention should be paid to it along with other variables as stated above. These problematic waters should only be used after proper treatment such as filtration, absorption, adsorption etc. However, future studies should be attempted to assess the relative contribution of different point and non-point sources of pollutants to ground water and surface water contamination. To conclude, while surface water collected from Shitalaxma river which is treated in WASA water refinery plant at Godnail can safely be used for drinking and domestic purposes, simultaneously the polluted waters should be purified to maintain public health safety.

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