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Occurrence of manganese in groundwater of Bangladesh and its implications on safe water supply

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Abstract

Analysis of data obtained from the national hydrochemical survey show that about 42% of tubewells have manganese concentrations exceeding the WHO health-based guideline value of 0.4 mg/l. High manganese concentrations in groundwater have been found in the central, northern, and western regions of Bangladesh; groundwater in the north-eastern region of Bangladesh contain relatively less manganese. Deeper wells (> 150 m) have been found to contain relatively lower concentrations of manganese. Distributions of arsenic and manganese concentrations are not similar in groundwater of Bangladesh. Areas with low arsenic in groundwater have been found to contain high manganese concentrations, and vice versa. Nationwide about 32% of wells, which contain safe level of arsenic (i.e., < 0.05 mg/l) have been found to contain unsafe level of manganese (i.e., > 0.4 mg/l). This would significantly increase the population exposed to unsafe water, beyond that estimated for arsenic alone. Detection of high concentrations of manganese in groundwater has added a new dimension to the already difficult safe water supply scenario in Bangladesh. However, manganese issue has attracted relatively less attention so far in the water supply sector. Currently iron and arsenic-iron removal plants are being used in many regions of the country. In view of the widespread presence of manganese in groundwater in addition to arsenic and iron, it is important to raise awareness among the stakeholders about the manganese issue. It is also very important to identify areas unacceptable levels of arsenic and/or manganese and to develop water treatment technologies accordingly.

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1. Introduction

In Bangladesh, water extracted from shallow aquifers is the primary source of drinking and cooking water for most of its population of over 140 million. The rural water supply is almost entirely based on groundwater supply through use of hand-pump tube wells; an estimated ten million domestic wells constitute the backbone of rural water supply in the country. The urban water supply is also heavily dependent on groundwater. The discovery of widespread arsenic contamination of groundwater in Bangladesh has led to a re-assessment of water quality. The national hydrochemical quality surveys conducted by the British Geological Survey (BGS) and the Department of Public Health Engineering (DPHE) have shown that in Bangladesh, large numbers of wells also exceed permissible limits for iron (Fe) and manganese (Mn). About half of the wells surveyed exceeded the Bangladesh drinking water standard for iron (1 mg/l), and about three quarters exceeded the permissible limit for Mn (0.1 mg/l) (GoB, 1997). Both of these limits are based on aesthetic concerns; above these levels, people may be unwilling to drink the water, and turn instead to a better-tasting, but microbiologically less safe, water sources. Recently, the World Health Organization (WHO) has introduced a more stringent health-based guideline value of 0.4 mg/l (revised from the previous value of 0.5 mg/l) for manganese (WHO, 2004). Since a significant fraction of wells also exceed health-based standard for manganese, this has added a new dimension to the already difficult safe water supply scenario in Bangladesh. The overall distribution of manganese from the BGS and DPHE (2001) study shows that high concentrations of manganese are found in most areas of the country. The distribution generally does not correspond to that of arsenic (BGS and WaterAid, 2001), which means that groundwater with acceptable concentration of arsenic may not have acceptable concentration of manganese. BGS and DPHE (2001) primarily focus on the arsenic problem and do not provide a detailed analysis of manganese concentration in well water. The distribution of manganese concentration in well water and its implications on the provision of safe water supply therefore need to be assessed in further details.

The primary objectives of this study were to make a detailed analysis of the occurrence of manganese in groundwater of Bangladesh based on the database developed by the BGS and DPHE (2001), and to assess its implications on safe water supply scenario in Bangladesh. Specifically, broader areas suffering from only manganese as well as manganese and arsenic problems have been identified and effect of manganese on currently employed groundwater treatment options have been assessed.

2. Manganese in groundwater of Bangladesh

This study provides a detailed analysis of the distribution of manganese concentration in groundwater based on the database developed by the BGS and DPHE (2001) under the national hydrochemical survey. In this survey, a total of 3534 groundwater samples from throughout Bangladesh, excluding the Chittagong Hill Tracts, were analyzed for arsenic, manganese, iron and a wide range of other water quality parameters. On an average, there were 58 samples from each district and 8 samples from each upazila (sub-district). The analysis in this study was done using the SPSS 12.0 statistical software.

3. Distribution of Manganese in Tubewell Water

Manganese concentration in the 3534 groundwater samples varied from less than 0.001 mg/l to a maximum of 9.98 mg/l. The mean and median concentrations of manganese are

0.554 mg/l and 0.287 mg/l, respectively. Figure 1 shows the number of wells with different ranges of manganese concentrations. It shows that about 27% of the surveyed tubewells have manganese concentrations within the Bangladesh drinking water standard of 0.1 mg/l. About 32% of groundwater samples have manganese concentration between 0.1 and 0.4 mg/l, and about 25% have concentration between 0.4 and 1.0 mg/l. About 17% of samples have manganese concentration exceeding 1.0 mg/l; only 10 samples have concentration exceeding 5 mg/l.

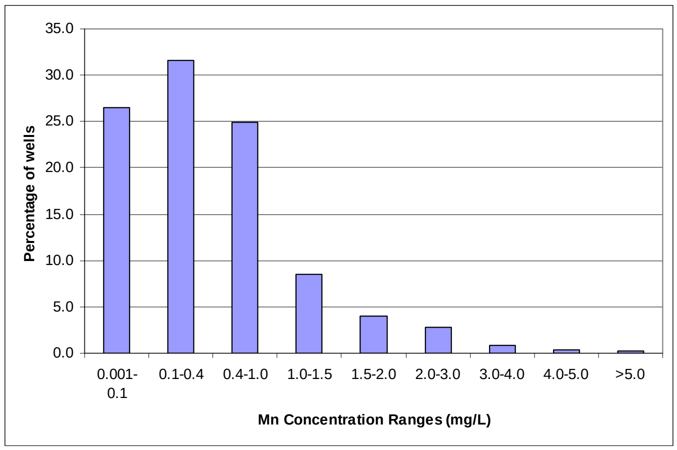

Figure 1. Wells with different ranges of manganese concentrations

Figure 2 shows the frequency distribution of manganese concentrations in all the tubewells surveyed in the BGS-DPHE study. It shows that about 73% of the tubewells surveyed have manganese concentrations exceeding the Bangladesh drinking water standard of 0.1 mg/l, and about 42% of tubewells have manganese concentrations exceeding the WHO health-based guideline value of 0.4 mg/l.

4. Spatial Distribution of Manganese in Groundwater

According to BGS and DPHE (2001), unlike the distribution of arsenic, which has a distinct regional pattern (with highest contamination in the south, south-west, and north-eastern regions of Bangladesh), high concentrations of manganese are found in most areas, but relatively high concentrations are seen in the current Brahmaputra and Ganges floodplains. In other words, high manganese concentrations in groundwater could be found in the central, northern, and western regions of Bangladesh; groundwater in the north-eastern region of Bangladesh contain relatively less manganese. Table 1 shows the division-wise status of manganese concentration in groundwater of Bangladesh. It shows that the Rajshahi division, located on the north-western region has the highest average manganese concentration (0.73 mg/1); this division also has the highest percentage of wells exceeding the Bangladesh drinking water standard (82.9%) and WHO guideline value (55.6%). The lowest average manganese concentration (0.11 mg/l) is found for wells of Barisal division, located in the southern region of the country; this division also has the least number of wells exceeding the Bangladesh standard (19.3%) and WHO guideline value (6.4%). This is followed by the Sylhet division, with an average concentration of 0.29 mg/l, 74.6% wells exceeding the Bangladesh standard and 27.7% exceeding the WHO guideline value. Table 2 shows status of manganese concentration in sixteen districts worst affected by the high manganese concentration, having more than 80% of their wells exceeding the Bangladesh drinking water standard. It shows that

Kurigram district located in northern Bangladesh has the highest average manganese concentration of 1.336 mg/l; 96% and 82% of wells of this district exceed the Bangladesh standard and WHO guideline value for manganese, respectively. Other worst affected districts include Narayanganj, Narsingdi, Tangail, Faridpur and Rajbari in central region; Sirajganj and Jamalpur in north-central region; Jaipurhat, Sherpur and Gaibandha in northern region; Pabna, Magura and Meherpur in western region; and Rajshahi and Natore in north-western region of the country.

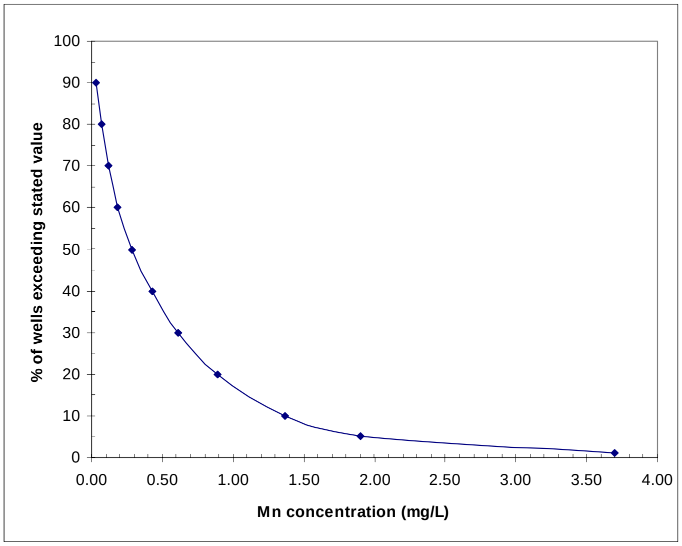

Figure 2. Frequency distribution of manganese in well water

Table 1
Division-wise status of manganese concentration in tubewell water

Division	No. of wells surveyed	Mean conc. (mg/L)	% exceeding Bangladesh standard (0.1 mg/l)	% exceeding WHO guideline value (0.4 mg/l)
Barisal	295	0.11	19.3	6.4
Chittagong	445	0.46	78.9	38.0
Dhaka	988	0.65	77.4	44.6
Khulna	474	0.46	73.8	38.4
Rajshahi	1072	0.73	82.9	55.6
Sylhet	260	0.29	74.6	27.7
Total	3534	0.55	73.7	41.9

5. Manganese Concentration versus Well Depth

Among the 3534 wells surveyed in the BGS and DPHE (2001) study, 3207 were shallow wells (< 150 m) and the rest 327 were deep wells (> 150 m). From analysis of manganese concentrations of these wells, it appears that the deeper wells contain much less manganese compared to the shallower wells. Among the shallow wells, 79% exceed the Bangladesh drinking water standard and about 46% exceed the WHO guideline value. On the other hand, about 22% of deep wells exceed the Bangladesh standard and only about 3.4% exceed the WHO guideline value. It should be noted that the BGS-DPHE survey found also the deeper wells to be relatively free from arsenic contamination, with only 5% exceeding the WHO guideline value of 0.01 mg/l and 1%

exceeding the Bangladesh standard of 0.05 mg/l. However, as noted in BGS and DPHE (2001), it must be kept in mind that most of deep wells surveyed in the study were from southern coastal region where shallow groundwaters are affected by salinity and therefore may not be typical of those from elsewhere in Bangladesh.

Table 2
Manganese statistics for the 17 most contaminated districts

District	No. of wells surveyed	Average Mn concentration (mg/l)	Maximum Mn concentration (mg/l)	% Exceeding Bangladesh standard (0.1 mg/l)	% Exceeding WHO guideline value (0.4 mg/l)
Kurigram	77	77	1.336	5.23	96
Narayanganj	30	30	1.276	8.39	93
Sirajganj	89	89	1.249	3.77	96
Rajbari	34	34	1.195	3.87	97
Pabna	78	78	1.083	5.54	100
Narsingdi	56	56	0.979	4.03	82
Magura	32	32	0.971	3.14	97
Tangail	91	91	0.922	3.8	88
Jaipurhat	40	40	0.907	9.98	98
Rajshahi	78	78	0.859	3.82	87
Natore	51	51	0.841	2.13	100
Sherpur	51	51	0.814	7.83	98
Faridpur	63	63	0.806	3.83	87
Gaibandha	71	71	0.787	4.59	92
Jamalpur	63	63	0.771	4.6	90
Meherpur	77	77	1.336	5.23	96

Figure 3 shows distribution of arsenic concentration in tubewells of different depths. It shows that with respect to Bangladesh standard of 0.1 mg/l, the shallow wells (< 150 m) do not show any strong trend with depth. But when the WHO guideline value of 0.4 mg/l is considered, a decreasing manganese concentration with increasing depth becomes apparent. As shown in Fig. 3, the trend is particularly strong for well depths exceeding 60 m.

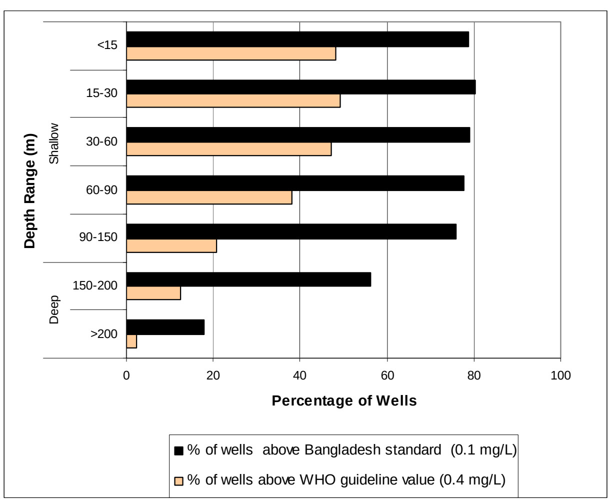

Figure 3. Distribution of manganese concentration water according to depth of w

6. Manganese Concentration versus Year of Well Construction

Table 3 shows status of manganese concentrations in wells as a function of year of well construction. Deep wells (> 150 m) have been excluded from this table. This table shows no clear trend between the age of tubewell and manganese concentration.

Table 3
Status of manganese concentrations in well water as a function of year of well construction

Year of well construction	% wells exceeding Bangladesh standard (0.1 mg/l)	% wells exceeding WHO guideline value (0.4 mg/l)
Before 1970	75.0	50.0
1970-74	85.5	47.0
1975-79	76.6	39.0
1980-84	76.9	41.0
1985-89	79.7	44.1
1990-95	78.2	45.5
1995 and later	80.2	48.4
All Wells	79.0	45.8

7. Arsenic Versus Manganese Concentrations

As noted earlier, the distribution manganese generally does not correspond to that of arsenic, which means that groundwater with acceptable concentration of arsenic may not have acceptable concentration of manganese. In this study, available data were analyzed to determine acceptability of well water with respect to both arsenic and manganese. Figure 4 shows distribution of arsenic and manganese in well water. It shows that about 32% of surveyed wells which are safe with respect to arsenic (i.e., with arsenic less than 0.05 mg/l) are in fact unsafe with respect with manganese concentration (i.e., with manganese concentration exceeding 0.4 mg/l). Figure 4 shows that about 10% of wells have both arsenic and manganese concentrations exceeding the Bangladesh standard and WHO health-based guideline value, respectively. Table 4 shows division-wise status of wells with respect to both arsenic and manganese concentrations. It shows that there are areas which are relatively safe from arsenic contamination, but are at the risk of contamination by manganese. For example, in Rajshahi division, about 50 % of sampled wells are safe with respect to arsenic, but contaminated with manganese about the WHO health-based guideline value.

8. Implications on Safe Water Supply

Widespread presence of manganese in well water exceeding the WHO health-based guideline value of 0.4 mg/l has added a new dimension to the already complicated safe water supply scenario of the country. According to BGS and DPHE (2001), about 35 million people of Bangladesh are exposed to arsenic concentrations exceeding the Bangladesh standard of 0.05 mg/l and about 57 million people are exposed to arsenic concentration exceeding the WHO guideline value of 0.01 mg/l. Thus, if wells with unsafe manganese concentrations are considered, then population exposed to unsafe water would increase significantly.

The iron problem has long been recognized in Bangladesh, and many technologies have been developed for iron removal at municipal, community and household levels (Azim, 1991; Mahmud, 1999). After the detection of arsenic in groundwater, many municipal IRPs are now being used for removal of both iron and arsenic; but none have specifically addressed the manganese issue. With the discovery of widespread arsenic contamination of groundwater in early 1990s, community- and household-level groundwater treatment units generated renewed attention. Since many arsenic-affected areas also suffer from high iron concentration, most community and household arsenic removal units have been developed as arsenic-iron removal plants (AIRPs). However, none of the community or household treatment units have been designed for specifically removing manganese from water. A recent study (BUET and UNICEF, 2006) showed that the currently operational municipal and community AIRPs are not very effective in removing manganese from groundwater. Thus, new water treatment technologies are needed for simultaneous removal of iron, arsenic and manganese from well water in many regions of the country. Low-cost manganese (or manganese and iron) removal technologies also need to be developed for areas which are suffering from manganese, but are fee from arsenic contamination.

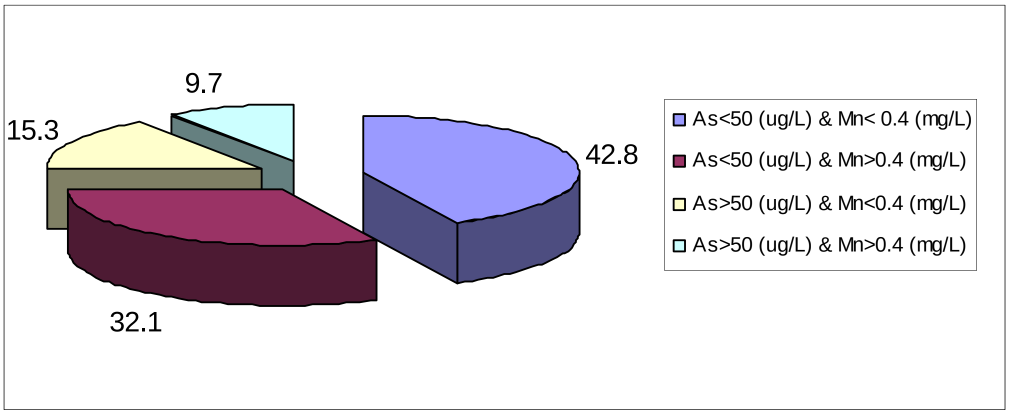

Figure 4. Status of wells with respect to arsenic and manganese concentrations

Table 4
Division-wise status of wells with respect to arsenic and manganese concentrations

Division	% of well with			
	As<50 (μg/L) Mn< 0.4 (mg/L)	As<50 (μg/L) Mn>0.4 (mg/L)	As>50 (μg/L) Mn<0.4 (mg/L)	As>50 (μg/L) Mn>0.4 (mg/L)
Barisal	84.4	2.0	9.2	4.4
Chittagong	27.9	21.8	34.2	16.2
Dhaka	39.0	30.4	16.4	14.3
Khulna	31.9	27.0	29.7	11.4
Rajshahi	43.6	50.3	0.8	5.3
Sylhet	53.1	25.4	19.2	2.3

9. CONCLUSIONS

Widespread presence of manganese in groundwater has added a new dimension to the already difficult safe water supply scenario in Bangladesh. Analysis of data obtained from the national hydrochemical survey (BGS and DPHE, 2001) show that about 42% of tubewells have manganese concentrations exceeding the WHO health-based guideline value of 0.4 mg/l. High manganese concentrations in groundwater could be found in the central, northern, and western regions of Bangladesh; groundwater in the north-eastern region of Bangladesh contain relatively less manganese. Deeper wells (> 150 m) have been found to contain relatively lower concentrations of manganese. It has been found that in many areas, groundwater with acceptable concentration of arsenic do not have acceptable concentration of manganese. Nationwide about 32% of wells, which are safe with respect to arsenic (i.e., arsenic < 0.05 mg/l), are in fact unsafe with respect with manganese concentration (i.e., manganese > 0.4 mg/l). If wells with unsafe manganese concentrations are considered, then population exposed to unsafe water would increase significantly beyond that estimated for arsenic alone. However, manganese issue has attracted relatively less attention so far in the water supply sector. In view of the widespread presence of manganese in groundwater, it is important to raise awareness among the stakeholders about the manganese issue.

Since many arsenic-affected areas also suffer from high iron concentration, many municipal IRPs are now being used for removal of both iron and arsenic, and most community and household arsenic removal units have been developed as arsenic-iron removal plants (AIRPs). However, these IRPs/AIRPs need to be designed or modified for removal of manganese in areas with from high manganese concentrations. It is very important to identify areas suffering from arsenic and/or manganese problems and to develop water treatment technologies accordingly.

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