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Evaluation of toxic metallic contamination of sewage water for irrigation in some selected industrial areas of Bangladesh

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Abstract: An attempt was made to assess toxic metallic contamination of sewage water for irrigation in some selected industries of Gazipur and Savar areas. Exactly 18 sewage waters were analysed for pH, EC, TDS, Ca, Mg, K, Na, Zn, Cu, Mn, Cd and Pb. All sewage waters were slightly neutral to alkaline (pH=7.07-8.88) and only 4 samples were found unsuitable for irrigation. EC and SAR indicated that sewage waters were under medium salinity (C2), high salinity (C3), low alkalinity (S1) and medium alkalinity (S2) hazard classes expressed as C2S1, C3S1 and C3S2. Sewage waters collected from different industries were graded as good, permissible, doubtful and unsuitable for irrigation purpose as per SSP. The waters were under moderately hard and hard classes. Among the major ionic constituents, Na was dominant followed by Ca, Mg and K. In most waters, Mn ion was considered as toxicant for irrigating soils and crops. Zn and Pb levels were problematic in some samples for long-term irrigation. The contents of Cu and Cd in all the samples were hazardous for irrigation. The relationships between water quality parameters like pH, EC, TDS, SAR, SSP and hardness were computed. Synergistic relationships were observed between EC-TDS, SAR-SSP, EC-Hardness and TDS-Hardness. The correlation between major cationic constituents like Ca, Mg, Na, K, Zn, Cu, Mn, Pb and Cd differed significantly. If sewage water is applied for irrigation, it can contaminate soil due to some toxic ions.
Key words: Sewage water, metallic toxicity, irrigation, soils and crops.

Introduction

Sewage water contains different types of compounds and dissolved ionic constituents that impart an offensive odor. Expansion of industries in many areas of the country and unplanned disposal of industrial sewage water loaded with heavy metals and other chemicals are polluting environmental compartments. This water contained some heavy and trace metals like Cr, Mn, Fe, Cu, Zn, Hg, Cd and Pb (Borghei and Asghari, 2005). Water quality is usually judged by some quality factors like SAR, SSP, TDS and EC (Richards, 1968; Todd, 1980). Sewage water irrigation has long been adopted in the developing and developed countries due to its high fertility as well as due to lack of infrastructure and facilities for disposal of sewage water. It is also considered the best substitute of the freshwater shortages (Monir and Mukhtar, 2003). The use of these waters for irrigation has many fold benefits for farmers due to the availability of excess amount of plant nutrients but prevention from environmental pollution caused by disposing sewage water into drainage and irrigation networks. Industrial sewage waters or wastewaters from different industries were unsuitable for irrigation due to the contamination of heavy metals (Begum, 2006; Rahman, 2006). Before using these waters for irrigation, its quality should be evaluated for better water management. Considering the national importance of water, sewage water needs to be modified or improved in such a way that crop production will not be hampered. Systematic research has not yet been done on sewage water quality of these industrial areas and its impact on crop production and soil health. The present study was designed at the industrial areas of Gazipur and Savar to assess the intensity or degree of ionic toxicity of sewage waters for irrigation usage.

Materials and Methods

Exactly 18 sewage water samples were collected from industrial areas of Gazipur and Savar during February, 2008 following the sampling techniques as outlined by APHA (2005). Sewage water samples were filtered with filter paper (Whatman No. 1) to remove undesirable solid and suspended materials before chemical analysis. pH and EC were determined by pH meter (Model: WTW pH522) and conductivity meter (Model: WTW LF521) according to the technique described by Singh *et al.* (1999). Total dissolved solid (TDS) was measured by evaporating water samples to dryness (Chopra and Kanwar, 1980). Ca and Mg were determined by EDTA titrimetric method (Singh *et al.* 1999). K and Na were determined flame photometrically (Golterman, 1971). Zn, Cu, Mn, Pb and Cd were analyzed by atomic absorption spectrophotometer (APHA, 2005).

The following quality factors were considered in judging sewage water toxicity by the interpretation of obtained analytical results:

i) Sodium adsorption ratio (SAR)

$$= \frac{Na^{+}}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}}$$

ii) Soluble sodium percentage (SSP)

$$= \frac{Na^{+} + K^{+}}{Ca^{++} + Mg^{++} + Na^{+} + K^{+}} \times 100$$

iii) Hardness

$$(H_T) = 2.5 \times Ca^{++} + 4.1 \times Mg^{++}$$

All ionic concentrations were expressed as me L^{-1} but in case of hardness, cationic concentrations were expressed as mg L^{-1}.

Results and Discussion

The ionic constituents such as Ca, Mg, Na, K, Zn, Cu, Mn, Pb and Cd were analyzed. The sampling sites of different industries have been reported in Table 1 and the ionic constituents of sewage water samples have been shown in Table 2. The obtained analytical results have been discussed under the following headings:

pH, EC and TDS: The pH of the waters ranged from 7.07 to 8.88 and were slightly neutral to alkaline (Table 1). Ayers and Westcot (1985) mentioned that the normal pH for irrigation is usually from 6.5 to 8.4. According to this, 14 samples were not problematic for long-term irrigation.

The pH of four sewage waters Sample (Nos: 3, 7, 9 & 18) were above the recommended range for irrigating crops as

Table 1. pH, EC and TDS of sewage water samples

Sample No.	Sapling Sites: Name of the Industry	Sapling Sites: Location	pH	EC µS cm-1	TDS mg L-1
1	Hudson Pharmaceuticals	Telirchala, Gazipur	7.42	742	497
2	Ibna Sina Pharmaceuticals	Safipur Bazar, Gazipur	7.33	823	551
3	Sunipon Pharmaceuticals	Mulaid, Gazipur	8.88	847	567
4	General Pharmaceuticals	Telirchala, Gazipur	8.17	783	525
5	Mita Textiles	Bairigirchala, Gazipur	7.96	464	311
6	Shamim Textiles	Safipur Bazar, Gazipur	8.24	666	446
7	Pride Textiles	Kornopara, Savar	8.61	414	277
8	Rahim Textiles	Safipour Bazar, Gazipur	8.07	634	425
9	Ayman Textiles & Hossiary	Chandra, Gazipur	8.88	810	543
10	Gamoti Textiles	Chandra, Gazipur	7.27	573	384
11	Devine Textiles	Chandra, Gazipur	7.77	592	397
12	Aymen Textiles	Chandra, Gazipur	7.32	580	389
13	Karim Textiles	Noorbag, Gazipur	7.45	492	330
14	Modina Textiles	Safipur Bazar, Gazipur	7.67	485	325
15	Navana Textiles	Ashulia, Savar	7.07	468	314
16	R & R Spinning Mills	Nischintopur, Gazipur	7.60	454	304
17	Winner Knit & Spinning Mills	Chandona, Gazipur	7.51	478	320
18	Motin Spinning Mills	Kashimpur, Gazipur	8.80	504	338
		Range	7.07 - 8.88	414 - 847	277 - 567
		Mean		600.50	402.38
		SD		144.71	96.90
		CV (%)		24.10	24.08

suggested by Ayers and Westcot (1985) and these waters might be harmful for soils and crops. These findings were in agreement the findings of Tiwari *et al.* (1966). The electrical conductivity (EC) of all waters was within the limit of 414 to 847 µS cm^{-1} with an average of 600.50 µS cm^{1} (Table 1). The highest content (847 µS cm^{-1}) was recorded in Sunipon Pharmaceuticals Ltd. and the lowest (414 µS cm^{-1}) was obtained in Taehung packaging. According to Richards (1968), 14 samples were rated as medium salinity (C2, EC= 250-750 µS cm^{-1}) class which might be applied with moderate leaching and only 4 samples (Nos.: 2, 3, 4 & 9) were rated as high salinity (C3, EC = 751-2250 µS cm^{-1}) class which were treated as unsuitable for irrigation. The total dissolved solids (TDS) varied from 277 to 567 mg L^{-1} with mean value of 402.39 mg L^{-1} as shown in Table 1. TDS of 11 samples were less than their respective mean value while the rest 7 samples were higher than the average value. Based on this, all samples were considered as fresh water (TDS <1000 mg L^{-1}) in quality (Freeze and Cherry, 1979). It is clearly demonstrated that irrigating fields by these sewage waters would not affect the osmotic pressure of soil solution and cell sap of the plants.

Ca, Mg, Na and K: The concentrations of Ca and Mg in waters ranged from 1.19 to 3.27 and 1.22 to 2.28 me L^{-1} with mean values of 1.98 me L^{-1} and 1.79 me L^{-1} (Table 2). The contribution of Ca in water was largely dependent on the solubility of $CaCO_3$, $CaSO_4$ and rarely on $CaCl_2$ (Karanth, 1994). A single sample did not exceed the recommended limit (Table 2). According to Ayers and Westcot (1985), irrigation water containing less than 20 me L^{-1} Ca and 5 me L^{-1} Mg was suitable for irrigating crops. On the basis of Ca and Mg content, all sewage water samples could safely be used for irrigation and would not be affected soils. Potassium status of all sewage water samples was within the range of 0.03 to 0.25 me L^{-1} with the mean value of 0.17 me L^{-1} (Table 2). The level of K in all waters had no significant impact on water quality for irrigation (Ayers and Westcot, 1985). The content of Na was recorded within the limit of 3.55 to 20.65 me L^{-1} with an average value of 7.20 me L^{-1} (Table 2). According to Ayers and Westcot (1985), irrigation water containing less than 40 me L^{-1} Na was suitable for irrigating crops. The Na content was far below this specified limit and could safely be applied for long-term irrigation.

Zn, Cu and Mn: Zinc status ranged from 0.34 to 4.76 mg L^{-1} with an average value of 1.97 mg L^{-1} (Table 2). Maximum permissible limit of Zn in irrigation water is 2.00 mg L^{-1} (Ayers and Westcot, 1985). Accordingly, only 11 waters were found within maximum permissible limit for Zn and was found suitable for irrigation. The rest 7 waters were not suitable for irrigation as these samples contained more than 2.00 mg L^{-1} Zn. The concentration of Cu varied from 0.49 to 4.51 mg L^{-1} with mean of 1.09 mg L^{-1}(Table 2) and were not found within the recommended limit (Ayers and Westcot, 1985) because for irrigation, its acceptable limit is 0.20 mg L^{-1}. Cu content in all the waters were found higher than the recommended limit and was considered as toxicant for irrigation. The content of Mn ranged from 0.31 to 2.34 mg L^{-1} with an average value of 1.07 mg L^{-1} (Table 2). According to Ayers and Westcot (1985), maximum recommended content of Mn in water used for irrigation is 0.20 mg L^{-1} and all samples but one were not suitable for irrigation and rated as toxicant.

Table 2. Ionic constituents of sewage water samples

Sample No.	Ca	Mg	K	Na	Zn	Cu	Mn	Pb	Cd
	me L-1				mgL-1				
1	2.73	2.03	0.19	11.05	2.66	4.51	2.18	5.49	5.80
2	2.87	2.25	0.25	20.65	2.82	3.24	2.16	5.55	6.40
3	3.27	2.13	0.22	8.37	3.81	1.27	2.21	4.35	6.05
4	2.87	2.28	0.24	9.42	1.73	1.36	2.34	4.45	5.90
5	1.86	1.30	0.11	9.48	2.97	0.82	0.84	2.29	2.10
6	2.35	2.14	0.23	5.88	1.71	0.85	0.98	2.47	2.60
7	1.88	2.11	0.21	5.49	1.99	0.58	0.85	2.62	2.30
8	2.29	1.95	0.18	5.36	1.59	0.80	0.74	2.70	3.40
9	3.15	2.09	0.17	5.06	4.76	0.81	0.87	2.63	3.50
10	1.76	1.81	0.16	5.95	0.92	0.92	0.67	2.59	0.70
11	1.70	2.11	0.24	5.57	3.55	0.62	0.81	2.41	4.30
12	1.35	2.04	0.11	5.20	0.70	0.58	0.96	2.30	4.60
13	1.19	1.33	0.13	4.08	4.05	0.56	0.71	2.19	1.70
14	1.28	1.30	0.13	3.55	0.57	0.65	0.42	2.66	1.40
15	1.23	1.43	0.13	4.56	0.45	0.54	0.31	2.63	1.60
16	1.28	1.22	0.16	7.93	0.48	0.52	0.61	2.48	1.50
17	1.27	1.28	0.03	5.97	0.45	0.49	0.93	2.34	1.20
18	1.32	1.42	0.21	6.07	0.34	0.60	0.82	2.17	1.70
Range	1.19 - 3.27	1.22 - 2.28	0.03 - 0.25	3.55 - 0.65	0.34 - 4.76	0.49 - 4.51	0.31 - 2.34	2.17 - 5.55	0.70 - 6.40
Mean	1.98	1.79	0.17	7.20	1.97	1.09	1.07	3.01	3.15
SD	0.73	0.39	0.06	3.92	1.42	1.06	0.65	1.11	1.90
CV (%)	36.86	21.78	34.11	54.44	72.08	97.24	60.74	36.87	60.31

Table 3. Quality classification of sewage water for irrigation

Sl. No.	SAR	SSP %	Hardness mg L^{-1}	Water class based on			Alkalinity and salinity hazard class
				SAR	SSP	H_T	
1	7.16	70.25	236.38	Ex	DB	Hard	C2S1
2	12.90	80.32	254.20	Ex	US	Hard	C3S2
3	5.09	61.40	268.30	Ex	DB	Hard	C3S1
4	5.87	65.23	255.68	Ex	DB	Hard	C3S1
5	7.54	75.22	156.96	Ex	DB	Hard	C2S1
6	3.92	57.64	222.79	Ex	Perm	Hard	C2S1
7	3.89	58.82	197.81	Ex	Perm	Hard	C2S1
8	3.68	56.65	210.44	Ex	Perm	Hard	C2S1
9	3.13	49.95	260.33	Ex	Perm	Hard	C3S1
10	4.45	63.12	177.05	Ex	DB	Hard	C2S1
11	4.04	60.40	188.81	Ex	DB	Hard	C2S1
12	3.99	61.03	167.87	Ex	DB	Hard	C2S1
13	3.63	62.56	124.94	Ex	DB	MH	C2S1
14	3.13	58.79	127.96	Ex	Perm	MH	C2S1
15	3.95	63.81	131.86	Ex	DB	MH	C2S1
16	7.09	76.39	124.02	Ex	DB	MH	C2S1
17	5.29	70.18	126.48	Ex	DB	MH	C2S1
18	5.19	69.62	135.86	Ex	DB	MH	C2S1

Pb and Cd: The status of Pb in waters ranged from 2.17 to 5.55 mg L^{-1} with the mean value of 3.01 mg L^{-1} (Table 2). The maximum permissible limit of Pb in irrigation water is 5.00 mg L^{-1} (Ayers and Westcot, 1985) and 16 samples except two (Nos.: 1& 2) were suitable for irrigation. The sewage waters contained Cd ranging from 0.70 to 6.40 mg L^{-1} with an average value of 3.15 mg L^{-1} (Table 2). According to Ayers and Westcot (1985), maximum recommended content of Cd for water used for irrigation is 0.01 mg L^{-1}. The recorded Cd content in all sewage waters was unsuitable for irrigation and Cd was treated as toxicant for irrigating soils and crops.

Water quality determining indices: The results in Table 3 revealed that the SAR and SSP of all the waters ranged from 3.13 to 12.90 and 49.95 to 80.32%, respectively. Sewage waters containing SAR less than 10 were considered as excellent quality reflecting low alkalinity hazard (S1) except one sample (No.: 2) and could be safely used for irrigation but might not be harmful for agricultural crops (Todd, 1980). Considering this value, 17 waters were graded as excellent and only one was graded as good for irrigation purpose. Based on SSP, 5 waters were classified as permissible (SSP=40-60%), 12 were classified as doubtful (SSP=60-80%) and only 1 were rated as unsuitable classes (SSP>80%) according to water classification proposed by Todd (1980). Hardness of all the waters varied from 124.02 to 268.30 mg L^{-1} (Table 3). Out of 18 samples, only 6 were moderately hard (H_T =75-150 mg L^{-1}) and the rest 12 were hard (H_T=151-300 mg L^{-1}) classes following the classification of Sawyer and McCarty (1967). Hardness of waters resulted due to the abundant of divalent cations like Ca^{2+} and Mg^{2+} (Todd, 1980).

Relationship between water quality parameters and ionic constituents: The relationship between six water quality parameters like pH, EC, TDS, SAR, SSP and hardness was established and out of 15 combinations, 4 were differed significantly at 1% level (Table 4). Synergistic relationships were observed between EC-TDS, EC-Hardness, TDS-Hardness and SAR-SSP. The correlation among different ionic constituents like Ca, Mg, Na, K, Zn, Cu, Mn, Pb and Cd were established and out of 36 combinations, 19 were differed significantly at 1% level and 6 were significant at 5% level and rest are not significant (Table 5). Synergistic relationships were also observed between Ca-Mg, Ca-K, Ca-Zn, Ca-Mn, Ca-Pb, Ca-Cd, Mg-K, Mg-Mn, Mg-Cd, Na-Cu, Na-Mn, Na-Pb, Na-Cd, Cu-Mn, Cu-Pb, Cu-Cd, Mn-Pb, Mn-Cd and Pb-Cd. It is evident from the findings that most of the waters were not found suitable for irrigation as these samples contained toxic metals like Cu, Mn and Cd as compared to the recommendation limit. Before irrigating these waters, appropriate sustainable measures should be adopted for the treatment of these samples in the investigated area.

Table 4. Correlation matrix among the quality parameters of sewage water

Parameters	EC	TDS	SAR	SSP	H_T
pH	0.281 NS	0.281NS	-0.246NS	-0.396 NS	0.434 NS
EC		1.000**	0.308 NS	-0.120 NS	0.908**
TDS			0.308 NS	-0.120 NS	0.908**
SAR				0.854**	0.249 NS
SSP					-0.217 NS

**Significant at 1% level; ^{NS}Not significant; Tabulated value of r with 16 df is 0.589 at 1% level of significance.

Table 5. Correlation coefficient (r) among different cationic constituents of sewage water

Ions	Mg	Na	K	Zn	Cu	Mn	Pb	Cd
Ca	0.762**	0.509*	0.596**	0.600**	0.554*	0.766**	0.709**	0.758**
Mg		0.351NS	0.712**	0.409NS	0.411NS	0.622**	0.541*	0.772**
Na			0.406NS	0.206NS	0.737**	0.709**	0.791**	0.616**
K				0.334NS	0.358NS	0.508*	0.494*	0.578*
Zn					0.254NS	0.354NS	0.274NS	0.463NS
Cu						0.733**	0.891**	0.650**
Mn							0.899**	0.869**
Pb								0.804**

**Significant at 1% level; *Significant at 5% level; ^{NS}Not significant, Tabulated values of r with 16 df are 0.469 at 5% and 0.589 at 1% level of significance

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