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Quantitative Assessment of Water Contaminants in the Rupsha River of Khulna Region for Irrigation Usage

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Abstract

Water samples were collected from the Rupsha river of Khulna region to determine ionic contamination for irrigation purpose. The chemical analyses included pH, EC, TDS and ions. pH values of water samples were slightly alkaline in nature. Samples were rated as fresh water based on TDS values. Samples were high salinity and low alkalinity hazards expressing C3S1. Regarding SAR and SSP values, samples were excellent and good classes, respectively. Samples were free from RSC and were very hard class. Regarding PI values, samples were under class-II implying 75% maximum soil permeability. Ca, Mg, Na, Cu, Ni, Zn, HCO_3, SO_4 and PO_4 levels in samples were within safe limit. Cd, Cr and Cl ions in water samples were above the permissible limit and were treated as water contaminants for irrigation. From the present findings, it is noted that the detected ions as water contaminants should be considered for irrigation usage toward food safety.

Key words: Food safety, Irrigation, Rupsha River, Water contaminants

Introduction

Rivers are the most important natural water sources used for irrigation but in the developing countries, water is the most poorly managed resources (Islam *et al.,* 2015; Ahmed *et al.,* 2016). River plays an important role in carrying or assimilation of the industrial and municipal wastes and runoff from agricultural fields. Recently water bodies are being used arbitrarily as dumps and water pollution has become dreadful (Samad *et al.,* 2015). Due to the unplanned rapid industrialization, heavy metal contamination has become a serious environmental problem in aquatic environment. The increasing heavy metal pollution have a significant adverse health effects for invertebrates, fish and humans as well as for plants (Yi *et al.,* 2011; Islam *et al.,* 2014; Ahmed *et al.,* 2015; Ali *et al.,* 2016). Daily about 0.4 millions m^3 of untreated industrial waste is being discharged into urban river water in Bangladesh (Arefin *et al.,* 2016). The chemical components of irrigation water can create plant toxicity or deficiency directly, or can affect plants by altering availability of nutrients (Uddin *et al.,* 2014). Irrigation water quality is related to its management and effects on soils and crops. Vegetables and rice may be contaminated with heavy metals and possess a potential health risk if it is grown in contaminated soils (Arefin *et al.,* 2016). For this reason, it is very important to monitor the levels of ionic contamination of its rivers regularly.

Khulna city is situated in the South-West division of Bangladesh. It is the third largest industrial city after the position of Dhaka and Chittagong city. A lot of industries have been built up near the Rupsha river and this region is the most pollution hotspot by the department of environment in Bangladesh. The polluting industries of Khulna region such as chemical complexes, fish processing plants, steel mills, paper mills, rayon mill complexes, cement factories, paint and dye manufacturing plants are directly discharging their untreated toxic effluent into the Rupsha river system. This waste water is ultimately carried out to the Sundarbans through the Rupsha river system (Samad *et al.,* 2015). During the dry season, crop fields are irrigated continuously with contaminated water situated adjacent to the Rupsha river (FAO, 2011; Islam *et al.,* 2016). Due to the availability and cost effectiveness of surface water, this river water is usually applied as a prime source of irrigation purpose by the farmers. Knowledge of river water quality principles helps to determine the potential of water body for irrigation. So, water analysis is usually necessary for measuring the level of ionic contamination in water, which meets standards for irrigating agricultural crops. Keeping these above facts in mind, this study was performed to evaluate the degree of ionic contamination present in the Rupsha river water used for irrigation.

Materials and Methods

Water sampling site

In Khulna region, the Rupsha river was selected on the basis of intensity of water contamination caused by discharge of untreated industrial effluents. Twenty water samples were collected from crop fields irrigated with the contaminated water of the Rupsha river. The exact location of each sampling point was determined using GPS. Accordingly, the entire sampling sites was confined between the longitude 89°34'28.5"and 89°35'15.8" East and the latitude 22°46'56.8"and 22°49'57.7" North. The sampling locations have been shown in Table 1. The detailed sampling sites have been presented in Fig. 1. This sampling was carried out in the month of January, 2017.

Table 1. Sampling locations in the Rupsha River

Sample ID No.	Latitude (N)	Longitude (E)	Sample ID No.	Latitude (N)	Longitude (E)
1	22°49'57.7"	89°34'28.5"	11	22°48'42.8"	89°35'08.3"
2	22°49'54.9"	89°34'35.3"	12	22°48'26.2"	89°35'09.4"
3	22°49'46.0"	89°34'45.7"	13	22°48'12.4"	89°35'11.2"
4	22°49'39.1"	89°34'52.3"	14	22°47'59.0"	89°35'14.0"
5	22°49'35.9"	89°34'57.3"	15	22°47'47.7"	89°35'15.8"
6	22°49'27.3"	89°35'01.1"	16	22°47'40.6"	89°35'13.5"
7	22°49'19.6"	89°35'03.7"	17	22°47'26.7"	89°35'09.3"
8	22°49'11.5"	89°35'07.1"	18	22°47'17.0"	89°35'05.2"
9	22°48'58.3"	89°35'07.6"	19	22°47'06.7"	89°35'03.0"
10	22°48'50.1"	89°35'06.9"	20	22°46'56.8"	89°35'02.3"

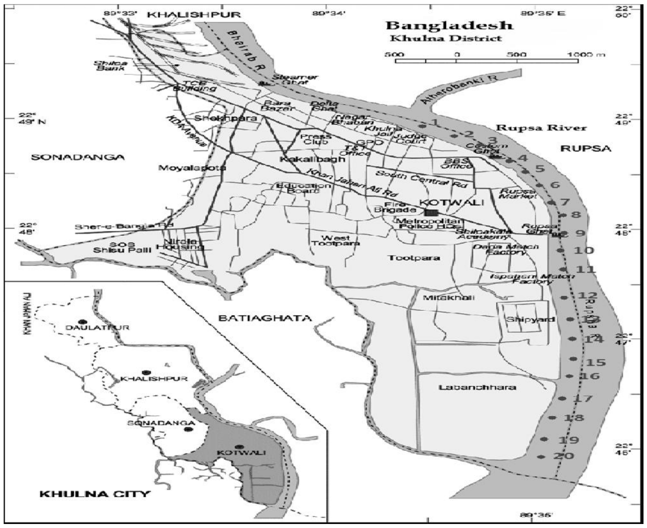

Fig. 1. Geographic location of the study areas in the Rupsha River

Water sampling technique

Water samples were collected from 0.50 m below water surface maintaining a reasonable distance from the river bank. Water samples were collected from each location in 500 mL plastic bottles. Each bottle were previously cleaned with dilute HCl (1:1) and then washed with distilled water. All bottles were rinsed 3 to 4 times before sampling with water to be sampled. For metal analysis, the collected water samples were acidified (pH<2) with HNO_3 to prevent the loss of metal following the sampling technique of APHA (2012). All plastic bottles were sealed tightly and transferred to the Postgraduate Research Laboratory, Department of Agricultural Chemistry, Bangladesh Agricultural University, Mymensingh for chemical analysis. The samples were kept in a clean, cool and dry place. River water samples were filtered through filter papers (Whatman No. 1 and 42) to remove undesirable solids and suspended materials before commencing the chemical analysis.

Water analysis

pH, electrical conductivity (EC) and total dissolved solids (TDS) values of water samples were measured electrometrically as outlined by Gupta (2013). The concentrations of Ca and Mg ions in water samples were estimated by EDTA titrimetric method (Tandon, 2013). The contents of K and Na ions in samples were determined by flame photometric method while the levels of Cd, Cr, Cu, Ni and Zn ions in water samples were analyzed directly by atomic absorption spectrometric method as described by APHA (2012). Titrimetric methods were used to determine the amounts of Cl, CO_3 and HCO_3 ions from water samples (Gupta *et al.*, 2012; Tandon, 2013). The concentration of PO_4 ion in river water samples was determined by spectrophotometric method (APHA,

2012) and SO_4 ion content in samples was determined by turbidimertic method (Tandon, 2013).

Ionic contamination rating

The following chemical quality factors were considered in assessing major ionic contamination of water samples by the interpretation of analytical result:

i) Sodium adsorption ratio (SAR)

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

ii) Soluble sodium percentage (SSP)

$$SSP = \frac{Na^+ + K^+}{Ca^{2+} + Mg^{2+} + Na^+ + K^+} \times 100$$

iii) Residual sodium carbonate (RSC)

$$RSC = (CO_3^{2-} + HCO_3^-) - (Ca^{2+} + Mg^{2+})$$

iv) Hardness (H_T)

$$H_T = 2.5 \times Ca^{2+} + 4.1 \times Mg^{2+}$$

v) Permeability index (PI)

$$PI = [(Na^+ + \sqrt{HCO_3^-}) / (Ca^{2+} + Mg^{2+} + Na^+)] \times 100$$

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

Statistical analysis

According to Gomez and Gomez (1984), statistical analyses of analytical results obtained from river water samples were performed. Excel and Minitab computer programs were used for correlation studies.

Results and Discussion

pH, EC and TDS

pH value of the collected water samples from Rupsha river fluctuated from 7.34 to 7.56 indicating slightly alkaline in nature (Table 2). According to FAO (1992), the recommended pH range for irrigation water is from 6.5 to 8.4. All the samples did not exceed the acceptable range and were not problematic for long-term irrigation. Electrical conductivity (EC) values of all the collected water samples were within the limit of 899.0 to 1409.0 µS cm^{-1} with an average value of 1262.4 µS cm^{-1} (Table 2). According to Wallender and Tanji (2011), all the samples under test were rated in C3 category (EC=750.0-2250.0 εS cm^{-1}) indicating high salinity. High salinity water was treated as unsuitable for irrigation purpose and could not be safely used for sensitive crops. Total dissolved solids (TDS) values of water samples were within the range of 600.0 to 940.0 mg L^{-1} having a mean value of 841.5 mg L^{-1} (Table 2). According to Freeze and Cherry (1979), all the samples were classified as fresh water (TDS<1,000 mg L^{-1}) in quality. These water samples would not affect soil properties and plant growth as irrigation water.

Table 2. pH, EC, TDS and anionic constituents of river water samples

Sample ID No.	pH	EC (µS cm^{-1})	TDS	PO_4	SO_4	Cl	HCO_3
			mg L^{-1}			me L^{-1}	
1	7.34	899.0	600.0	1.47	4.90	16.00	0.09
2	7.56	1159.0	770.0	0.66	5.87	18.71	0.05
3	7.41	1121.0	737.5	0.50	6.35	18.99	0.07
4	7.55	1219.0	815.0	0.91	6.49	19.14	0.06
5	7.52	1160.0	775.0	0.53	6.63	19.99	0.07
6	7.49	1362.0	915.0	0.31	6.73	21.14	0.06
7	7.37	1279.0	855.0	0.72	7.07	20.99	0.06
8	7.54	1292.0	862.5	0.53	6.78	20.71	0.05
9	7.53	1250.0	835.0	0.34	6.11	21.28	0.06
10	7.45	1275.0	852.5	0.97	7.36	20.99	0.06
11	7.41	1230.0	800.0	0.34	9.23	21.42	0.06
12	7.54	1388.0	927.5	0.50	8.99	24.99	0.06
13	7.53	1394.0	935.0	1.31	8.51	24.28	0.06
14	7.38	1399.0	937.5	0.41	8.32	23.85	0.06
15	7.53	1397.0	932.5	1.31	7.84	19.57	0.05
16	7.52	1409.0	940.0	0.41	7.93	22.85	0.05
17	7.43	1215.0	807.5	0.75	7.55	20.42	0.06
18	7.52	1254.0	837.5	0.44	6.54	20.57	0.07
19	7.55	1316.0	877.5	0.38	6.73	19.99	0.07
20	7.47	1229.0	817.5	0.25	6.97	20.57	0.07
Min.	7.34	899.0	600.0	0.25	4.90	16.00	0.05
Max.	7.56	1409.0	940.0	1.47	9.23	24.99	0.09
Mean	-	1262.4	841.5	0.65	7.15	20.82	0.06
SD	-	122.5	83.8	0.36	1.08	2.06	0.01
CV (%)	-	9.7	9.9	55.66	15.14	9.88	15.35
[a]FAO value	6.5-8.4	-	-	2.00	20.00	4.00	1.50

[a] *FAO (1992)*

PO_4, SO_4, Cl, HCO_3 and CO_3 levels

The levels of PO_4 and SO_4 in the collected water samples varied from 0.25 to 1.47 and 4.90 to 9.23 mg L^{-1} having mean values of 0.65 and 7.15 mg L^{-1}, respectively (Table 2). The maximum permissible limits of PO_4 and SO_4 ions in irrigation water are 2.00 and 20.00 mg L^{-1}, respectively (FAO, 1992). As per this limit, all the water samples were suitable for irrigation having no hazard effects on soil properties and crop growth in the study area. Water samples collected from the Rupsha River contained Cl ion within the limit of 16.00 to 24.99 me L^{-1} with an average value of 20.82 me L^{-1} (Table 2). According to FAO (1992), maximum permissible limit of Cl in irrigation water is 4.00 me L^{-1}. On the basis of this limit, all the water samples exceeded the permissible level and this anion was treated as water contaminant for irrigation usage. The concentration of HCO_3 ion in the collected water samples fluctuated from 0.05 to 0.09 me L^{-1} with a mean value of 0.06 me L^{-1} (Table 2). According to FAO (1992), the recommended maximum concentration of HCO_3 ion for irrigation water used continuously on soil is 1.5 me L^{-1}. As per this acceptable range, HCO_3 ionic status of all the collected river water samples was suitable for irrigation. The amount of CO_3 ion was not detected in the collected water samples indicating that river water samples were free from CO_3.

Ca, Mg, K and Na levels

The concentrations of Ca, Mg, K and Na ions in all the samples were found to vary from 2.96 to 3.60, 3.28 to 4.80, 0.10 to 0.16 and 2.33 to 3.23 me L^{-1} with average values of 3.22, 4.02, 0.12 and 2.78 me L^{-1}, respectively (Table 3). Water containing less than 20.0 me L^{-1} Ca, 5.0 me L^{-1} Mg, 0.05 me L^{-1} K and 40.0 me L^{-1} Na ions is suitable for irrigating agricultural crops (FAO, 1992). Considering the limits of these ions, all the water samples of the study area could safely be applied for long-term irrigation without any harmful effect on soil properties and crop growth. But in case of K status, all the collected river water samples might be problematic for irrigation.

Table 3. Cationic constituents of river water samples

Sample ID No.	Ca	Mg	K	Na	Cd	Cr	Cu	Zn	Ni
	é é é é é é é é é me L^{-1}é é é é é é é é é				é é é é é é é é é . mg L^{-1}é é é é é é é é é é é				
1	3.60	3.60	0.10	2.33	0.016	BDL	BDL	BDL	BDL
2	2.96	3.60	0.12	2.55	0.028	BDL	BDL	BDL	BDL
3	3.44	3.28	0.10	2.60	0.031	BDL	BDL	BDL	BDL
4	3.20	3.52	0.13	2.86	0.022	BDL	BDL	BDL	BDL
5	3.12	3.52	0.10	2.60	0.024	BDL	BDL	BDL	BDL
6	3.28	3.84	0.11	2.73	0.023	BDL	BDL	BDL	BDL
7	3.20	4.16	0.12	2.78	0.017	BDL	BDL	BDL	BDL
8	3.28	3.84	0.13	2.78	0.025	BDL	BDL	BDL	BDL
9	3.04	4.00	0.11	2.86	0.025	BDL	BDL	BDL	BDL
10	2.96	4.08	0.14	2.81	0.030	BDL	BDL	BDL	BDL
11	3.12	3.60	0.11	2.78	0.033	BDL	BDL	BDL	BDL
12	3.20	4.64	0.14	3.23	0.028	BDL	BDL	BDL	BDL
13	3.12	4.72	0.16	3.05	0.031	BDL	BDL	BDL	BDL
14	3.04	4.80	0.13	3.02	0.035	0.09	BDL	BDL	BDL
15	3.28	4.40	0.15	2.89	0.032	0.14	BDL	BDL	BDL
16	3.36	4.16	0.13	2.86	0.027	0.30	BDL	BDL	BDL
17	3.28	4.48	0.12	2.89	0.025	0.25	BDL	BDL	BDL
18	3.36	3.92	0.11	2.63	0.031	0.05	BDL	BDL	BDL
19	3.36	4.08	0.12	2.55	0.024	0.25	BDL	BDL	BDL
20	3.28	4.08	0.12	2.71	0.023	0.18	BDL	BDL	BDL
Min.	2.96	3.28	0.10	2.33	0.016	0.05	-	-	-
Max.	3.60	4.80	0.16	3.23	0.035	0.30	-	-	-
Mean	3.22	4.02	0.12	2.78	0.026	0.18	-	-	-
SD	0.16	0.43	0.01	0.20	0.005	0.09	-	-	-
CV (%)	5.03	10.75	11.40	7.30	19.02	51.12	-	-	-
[a] FAO value	20.00	5.00	0.05	40.00	0.01	0.10	0.20	2.00	0.20

[a] FAO (1992); BDL=Below Detection Limit

Cd, Cu, Cr, Zn and Ni levels

The concentration of Cd ion in water samples of Rupsha river varied from 0.016 to 0.035 mg L^{-1} with an average value of 0.026 mg L^{-1} (Table 3). According to FAO (1992), the permissible limit of Cd ion in water used for irrigation is 0.01 mg L^{-1}. Considering this value as standard, all the water samples under investigation exceeded the acceptable limit and this metal ion was considered as water contaminant for long-term irrigation. Out of 20 samples, Cr ion content in only 7 water samples ranged from 0.05 to 0.30 mg L^{-1} with a mean value of 0.18 mg L^{-1} (Table 3). According to FAO (1992), the permissible limit of Cr in irrigation water is 0.10 mg L^{-1}. On the basis of this limit, only 5 water samples under investigation were hazardous for irrigation and the rest samples could safely be used for irrigation without harmful effect on soils and crops grown in the study area. These findings might be due to the disposal of untreated industrial waste containing Cd and Cr ions as water contaminants into the Rupsha river. All the water samples contained below detection limits of Cu, Zn and Ni ions (Table 3). FAO (1992) recommended the respective concentrations of Cu, Zn and Ni ions for irrigation are 0.20, 2.0 and 0.20 mg L^{-1}. On the basis of these recommendation limits, all the collected samples would safely be used for irrigation purpose.

SAR, SSP, RSC, Hardness and PI values

The calculated SAR values of water samples ranged from 1.23 to 1.63 having an average value of 1.46. (Table 4). Water used for irrigation having SAR less than 10 might not be harmful for agricultural crops (Todd and Mays, 2005). Considering this classification, all the samples were rated as low alkalinity hazard (S1) class reflecting excellent for irrigation. The computed SSP values in the collected water samples fluctuated from 25.26 to 30.63% with a mean value of 28.55% (Table 4). According to water classification proposed by Todd and Mays (2005), all the samples were classified as good (SSP=20-40%). In the study area, water samples might be applied safely for irrigating agricultural crops. RSC values of the collected water sample from the study area ranged from -7.78 to -6.51 me L^{-1} with a mean value of -7.18 me L^{-1} (Table 4). As per classification suggested by Schwartz and Zhang (2012), all the water samples were rated as suitable class (RSC<1.25 me L^{-1}). For this reason, all the river water samples might not be problematic for irrigation usage. The obtained results in Table 4 revealed that hardness (H_T) values of the collected water samples varied from 327.67 to 391.51 mg L^{-1} having a mean value of 361.62 mg L^{-1}. Sawyer and McCarty (1967) suggested a classification for irrigation water based on hardness and according to this classification, all the samples were very hard (H_T>300 mg L^{-1}) in quality. The computed PI values were found to vary from 27.55 to 32.42% having a mean value of 30.18% (Table 4). Doneen (1964) had prepared a chart to classify water based on its permeability index (PI). Regarding the obtained PI values, all the water samples were under class-II implying 75% of maximum permeability when applied to soil system as irrigation water.

Table 4. Chemical quality rating of river water samples and its suitability for irrigation

Sample ID No.	SAR		SSP		RSC		Hج		PI	
	Ratio	Class	%	Class	me L^{-1}	Class	mg L^{-1}	Class	%	Class
1	1.23	Ex.	25.26	Good	-7.11	Suit	359.73	VH	27.55	Class-II
2	1.41	Ex.	28.72	Good	-6.51	Suit	327.67	VH	30.48	Class-II
3	1.42	Ex.	28.66	Good	-6.65	Suit	335.77	VH	30.77	Class-II
4	1.56	Ex.	30.63	Good	-6.66	Suit	335.70	VH	32.42	Class-II
5	1.43	Ex.	28.93	Good	-6.57	Suit	331.70	VH	30.9	Class-II
6	1.45	Ex.	28.52	Good	-7.06	Suit	355.66	VH	30.19	Class-II
7	1.45	Ex.	28.25	Good	-7.30	Suit	367.59	VH	29.84	Class-II
8	1.48	Ex.	28.91	Good	-7.07	Suit	355.66	VH	30.43	Class-II
9	1.53	Ex.	29.72	Good	-6.98	Suit	351.61	VH	31.37	Class-II
10	1.5	Ex.	29.35	Good	-6.98	Suit	351.58	VH	31.00	Class-II
11	1.52	Ex.	30.14	Good	-6.66	Suit	335.68	VH	31.85	Class-II
12	1.63	Ex.	30.11	Good	-7.78	Suit	391.51	VH	31.40	Class-II
13	1.54	Ex.	28.9	Good	-7.78	Suit	391.49	VH	30.23	Class-II
14	1.53	Ex.	28.68	Good	-7.78	Suit	391.47	VH	30.06	Class-II
15	1.48	Ex.	28.24	Good	-7.63	Suit	383.56	VH	29.51	Class-II
16	1.48	Ex.	28.51	Good	-7.47	Suit	375.61	VH	29.64	Class-II
17	1.47	Ex.	27.97	Good	-7.70	Suit	387.55	VH	29.42	Class-II
18	1.38	Ex.	27.38	Good	-7.21	Suit	363.65	VH	29.09	Class-II
19	1.32	Ex.	26.4	Good	-7.37	Suit	371.62	VH	28.06	Class-II
20	1.41	Ex.	27.74	Good	-7.29	Suit	367.62	VH	29.42	Class-II
Min.	1.23	-	25.26	-	-7.78	-	327.67	-	27.55	-
Max.	1.63	-	30.63	-	-6.51	-	391.51	-	32.42	-
Mean	1.46	-	28.55	-	-7.18	-	361.62	-	30.18	-
SD	0.09	-	1.25	-	0.43	-	21.20	-	1.19	-
CV (%)	6.04	-	4.38	-	-5.94	-	5.86	-	3.95	-

***Legend**: Ex. = Excellent; Suit = Suitable and VH= Very Hard*

Relationships between chemical quality factors of river water samples

The relationships between chemical quality factors *viz.*, EC, TDS, SAR, SSP, RSC, H_T and PI were studied. Among the combination, significant positive correlations existed between EC vs TDS, EC vs SAR, EC vs H_T, TDS vs SAR, TDS vs H_T, SAR vs SSP, SAR vs PI and SSP vs PI (Table 5). Negative significant correlations existed among the combinations of EC vs RSC, TDS vs RSC and RSC vs H_T. In rest of the combinations, the relationships between quality criteria were insignificant because their respective calculated r values were below the tabulated values of r at both 1 % and 5% levels of significance.

Table 5. Correlation matrix among chemical quality parameters of river water samples

Parameters	TDS	SAR	SSP	RSC	H_T	PI
EC	0.998^{**}	0.641^{**}	0.392^{NS}	-0.584^{**}	0.569^{**}	0.196^{NS}
TDS		0.628^{**}	0.371^{NS}	-0.598^{**}	0.584^{**}	0.176^{NS}
SAR			0.898^{**}	-0.223^{NS}	0.207^{NS}	0.793^{**}
SSP				0.228^{NS}	-0.243^{NS}	0.974^{**}
RSC					-1.000^{**}	0.409^{NS}
H_T						-0.422^{NS}

Legend: *^{NS}Not significant; **Significant at 1% level. Tabulated values of r with 18 df were 0.444 at 5% and 0.561 at 1% levels of significance, respectively*

Conclusions

Considering all the criteria, it is concluded that among the detected ions under investigation, Cd, Cr and Cl ions were above the permissible limit for long-term irrigation and these ions were treated as water contaminants in river water samples leading to create toxicity of soils and crops. From the present findings, it is noted that the detected ions as water contaminants should be considered for long-term irrigation purpose towards food safety.

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