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Heavy metal contamination of drinking water in Kamrup district, Assam, India

Sutapa Chakrabarty · Hari Prasad Sarma

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Abstract This study was undertaken to assess the heavy metal concentration of the drinking water with respect to zinc, copper, cadmium, manganese, lead and arsenic in Kamrup district of Assam, India. Ground water samples were collected from tube wells, deep tube wells and ring wells covering all the major hydrogeological environs. Heavy metals in groundwater are estimated by using Atomic Absorption Spectrometer, Perkin Elmer Analyst 200. Data were assessed statistically to find the distribution pattern and other related information for each metal. The study revealed that a good number of the drinking water sources were contaminated with cadmium, manganese and lead. Arsenic concentrations although did not exceeded WHO limits but was found to be slightly elevated. Copper and zinc concentrations were found to be within the prescribed WHO limits. An attempt has also been made to ascertain the possible source of origin of the metals. Positive and significant correlation existing between manganese with zinc and copper indicates towards their similar source of origin and mobility. In view of the present study and the level of heavy metal contamination, it could be suggested to test the potability of the water sources before using it for drinking purpose.

S. Chakrabarty (✉) · H. P. Sarma
Department of Environmental Science,
Gauhati University, Guwahati 781 014, Assam, India
e-mail: sutapa.chk@gmail.com

H. P. Sarma
e-mail: hp_sarma@sify.com

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Introduction

Water is the most precious natural resource available in the universe and that life without water is impossible. The demand for good quality drinking water has increased with the increasing development in the human community. At the beginning of civilisation non turbidity and free flow were the only parameters of concern but with the growth of population there has been an increase in global attention focused on resolving water quality issues. Thus, with relative industrialisation and urbanisation, the water pollution of heavy metals has become a concerned issue in view of their toxicity to human and other biological systems. The issue has raised widespread concerns in different parts of the world, and results reported by various agencies (WHO/UNEP GEMS 1989; Friberg et al. 1986) have been alarming.

India is currently facing critical water supply and drinking water quality problems. There is evidence of prevailing contamination of water resources in many areas of India. In recent years, due to the increased availability of rapid and advanced testing and monitoring tools, remarkable progress has been made in generating vital data and developing a sound knowledge base in all fields of natural resources. Yet, regions like the north-eastern part of India continue to face the daunting task of creating baseline data for the chronically data-poor water sector. The need for such data is apparent: despite the region's huge water resource potential, it still accounts for some of the most water-starved pockets of the country (Mahanta 2006). The problem of arsenic and other heavy metals in groundwater and related health hazards in Assam is yet to get enough systematic attention due to its recent emergence having few review reports (Singh 2004; SOES 2004; Mukherjee et al. 2006; Nickson et al. 2000; Chetia et al. 2008).

Many researchers (Borah et al. 2009a, b; Das et al. 2009; Sia Su 2007; Singh 2004; Chakraborti et al. 2002) have reported heavy metal pollution of drinking water resources from the different parts of the world. The north-eastern region of India also faces an increasing incidence of ground water pollution with respect to heavy metal contamination.

Borah et al. (2009b) reported that the ground water of the tea garden belt of Darrang district, Assam is contaminated with cadmium and manganese.

Buragohain et al. (2010) studied the seasonal variations of lead, arsenic, cadmium and aluminium concentration of groundwater in Dhemaji district Assam and found the concentrations of aluminium, lead and cadmium in groundwater to be significantly elevated.

Borah et al. (2009a) reported higher concentration of lead and iron beyond the maximum contamination level in groundwater in the tea garden belt of Darrang district, Assam. Singh (2004) reported arsenic contamination in groundwater of North Eastern India. Maximum arsenic content was observed in Jorhat (Titabor, Dhakgorah, Selenghat and Moriani Block), Dhemaji (Sissiborgoan and Dhemaji Block), Golaghat district (Podumani Block) and Lakhimpur (Bogin-odi, Lakhimpur Block) in Assam; Again, a high percentage of iron contamination (77%) in the tubewell waters of the region indicates the severity of the heavy metal pollution in the region. The presence of arsenic in ground water has been identified in 21 districts out of 24 districts of Assam (Chetia et al. 2008).

When the elements necessary for human beings, flora and the environment exceed a certain level, they may have toxic effects. The metals can move with the food chain. For this reason, detection of heavy metal levels in ground water is an important indication for environmental pollution. Consumption of unsafe drinking water especially contaminated with cadmium may bring about diarrheal illness. Lead has no beneficial effect on humans or animals. Chronic exposure occurring over an extended period of time to even low levels of lead can have severe effects since lead is accumulated and stored in the bone. When the concentration is so high that storage in the bone is saturated, blood lead levels begin to affect nerve tissue. Chronic exposure of Arsenic via drinking water causes various types of skin lesions such as melanosis, leucomelanosis and keratosis. Other manifestations include neurological effects, obstetric problems, high blood pressure, diabetes mellitus, diseases of the respiratory system and of blood vessels including cardiovascular and cancers typically involving the skin, lung, and bladder. The skin seems to be quite susceptible to the effects of As. Arsenic-induced skin lesions seem to be the most common and initial symptoms of arsenicosis.

In the North Eastern region of India, natural springs and dug wells are the only cost effective and viable means of fulfilling the needs of freshwater for present population. In hilly areas, most of the drinking water is used to be harnessed from rivers, ponds and natural springs. Many springs are reportedly becoming seasonal. In valleys, most of the domestic water is harnessed from groundwater through shallow tube wells and dug wells. Availability of drinking water in summers is severely marred and the overall quality is questionable (Singh 2004). In Kamrup district, 40% of the urban people have the facility of municipal supply water but the rest of the population use only ground water for domestic and industrial purposes (Fig. 1). It has been found that except a few city dwellers, every house of the district has at least one tube well or ring well, showing their dependency on ground water. Lack of adequate information about the drinking water quality in the Northeastern India has invariably marred the progress of the region. A critical step in assuring the quality of drinking water resources is to identify the cause of current or potential contamination problems. Testing of water quality on a regular basis is, therefore, an important part of maintaining a safe and reliable source (Borah et al. 2009a, b). The present work is an attempt to determine the level of zinc, copper, cadmium, manganese, lead and arsenic in Kamrup district of Assam, India, to generate reliable database for safe future use and to help in implementing remedial policies to improve environmental conditions.

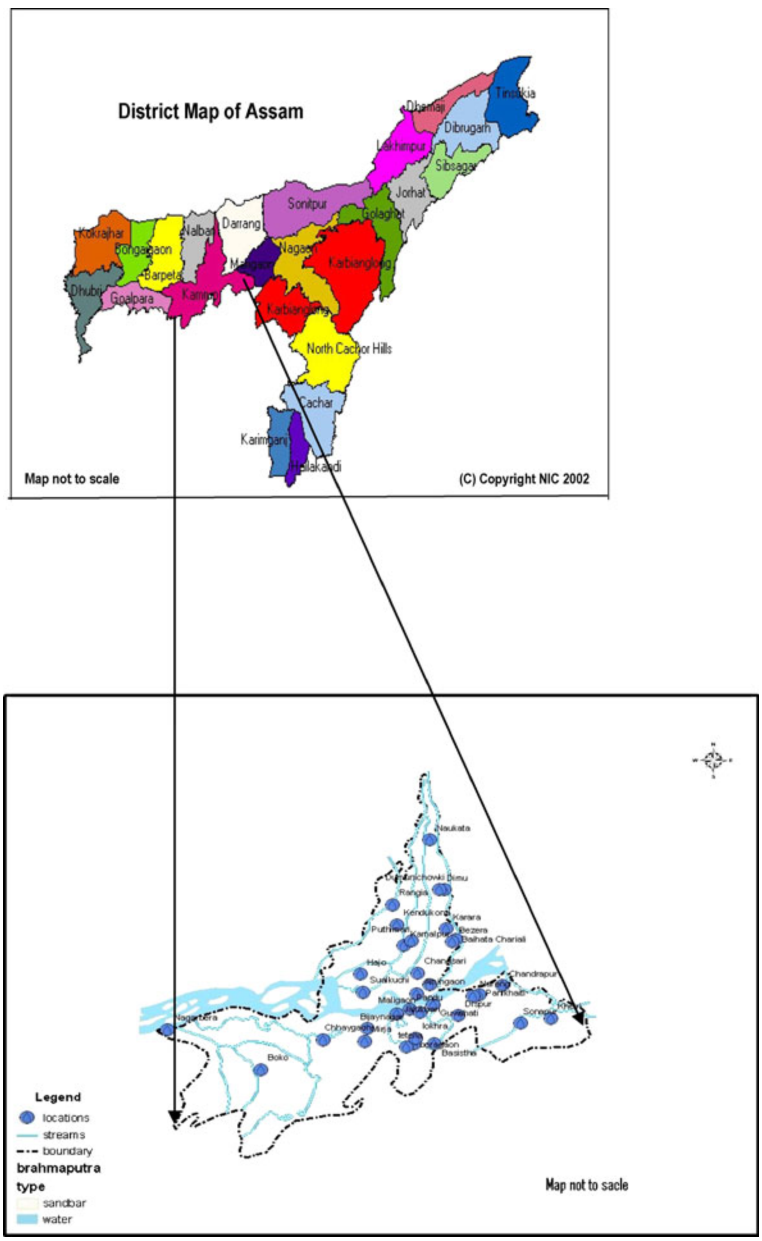

Fig. 1 Map of Kamrup district of Assam showing sampling locations. *Some locations are overlapped

Study area

The district of Kamrup, which is taken as study area is located in the central part of Assam (now Asom). The district is situated over both sides by the river Brahmaputra. Kamrup district is located longitudinally from 90°55′E to 92°10′E and latitudinally from 25°40′N to 26°50′N. It is surrounded by Darrang and Marigaon districts in the east, Nalbari and Goalpara districts in the west, Meghalaya in the south and Bhutan in the north. The river Brahmaputra is passing through the heart of the district. The rainfall is the main mode of recharge for the entire district which is supported by direct rise of water table in response to precipitation.

The major portion of the district is covered by granitic gneisses with lenticular bands of amphibolite, biotite granulite, biotite schist and isolated occurrences of hornblende-diorite, all belonging to the Archaean Gneissic Complex. At the contact of granite, the gneisses are magmatised. Porphyritic granites are exposed mainly along the southern part of the district. All the rock types are traversed by numerous veins and veinlets of quartz, pegmatite and aplites which most probably owe the origin to the porphyritic granite.

Materials and methods

Separate water samples were selected by random selection and compiled together in clean and sterile 1-l polythene cans rinsed with dilute HCl to set a representative sample and stored in an ice box. Samples were protected from direct sun light during transportation to the laboratory. The samples were then filtered and acidified with nitric acid to maintain the pH of the samples less than 2 for metal analysis as per the standard procedures (APHA 1998). Arsenic, lead, cadmium, zinc, copper and manganese were analysed by using an atomic absorption spectrometer (Perkin Elmer Analyst 200) with flow injection analysing mercury hydride generation system (Model FIAS-100) at 189−, 283.3−, 228.8−, 213.86−, 324.75− and 279.48-nm analytical wavelengths, respectively.

The instrument was used in the limit of precised accuracy and chemicals used were of analytical grade. Doubly-distilled water was used for all purposes (APHA 1998). In case of Arsenic to prevent interferences, As (V) was pre-reduced to As (III) prior to determination. Pre-reduction was performed with KI solution (KI+Ascorbic acid) in semi-concentrated (5 mol/L) HCl solution. Time for pre-reduction was 30 min. Ten millilitres of pre-reduced water were analysed using atomic absorption spectrometer at 193.7 analytical wavelengths and 0.7 nm slit width with detection limit of 0.02 μg/L. Radiation source was Electrodeless discharge lamp for As with 50 s pre-reaction purge time and 40 s post-reaction purge time. The Argon gas and Sodium tetraborohydrate were used for hydride generation. The experimental findings have been summarised in Table 1.

Data analysis

Descriptive statistics in the forms of mean, variance, standard deviation, standard error, median, range of variation and percentile at 95%, 75% and 25% (P95%, P75%, P25%) are calculated and summarised in tabular form (Table 2). Univariate statistics were used to test distribution normality for each metal. The confidence interval was calculated at 0.05 level. *T* test is done under null hypothesis (H0) by taking the assumption that the experimental data are consistent with the mean rating given by WHO (Table 4). The correlation analysis was performed for measured parameters to determine the relationship between these variables (Table 3). The significance level reported ($p < 0.05$) is based on the Pearson's coefficients. Statistical analysis is carried out using SPSS 10.0 version.

Result and discussion

Almost all the water samples in the present study meet or fall below the current standard for arsenic, which is 0.05 ppm (WHO 2004). Wide data range and high standard deviation in case of arsenic is likely to bias the normal distribution statistic. This observation is supported by large

Table 1 Metal content of drinking water of Kamrup district at 44 different stations

Sampling stations	Sources	Zinc (ppm)	Copper (ppm)	Manganese (ppm)	Cadmium (ppm)	Lead (ppm)	Arsenic (ppb)
Naukata	TW	0.002	0.001	0.03	BDL	BDL	BDL
Rangia	RW	0.032	BDL	0.04	0.027	BDL	6.271
Karara	TW	0.033	BDL	0.08	0.009	BDL	4.379
Kendukona	TW	0.017	0.001	0.29	0.035	0.08	4.9
Kamalpur	TW	0.022	BDL	0.01	0.018	0.05	BDL
Puthimari	TW	0.001	0.003	BDL	0.026	0.05	5.073
Baihata	TW	0.027	0.021	BDL	0.026	BDL	6.54
Hajo	RW	BDL	BDL	0.03	0.42	0.07	4.57
Changsari	RW	0.033	0.001	0.4	BDL	0.017	BDL
North Guwahati	DTW	0.01	BDL	BDL	BDL	0.1	BDL
Sualkuchi	TW	0.003	BDL	BDL	0.028	0.02	12.544
Palashbari	TW	0.002	0.003	0.02	0.002	0.07	7.054
Chhaygaon	TW	0.044	0.003	0.14	0.012	BDL	BDL
Sonapur	TW	0.118	BDL	0.09	0.029	0.001	0.204
Chandrapur	RW	0.313	BDL	0.16	0.017	BDL	8.115
Khetri	DTW	0.118	BDL	0.09	0.029	0.001	0.559
Narengi	TW	0.118	BDL	0.09	0.029	0.02	28.591
Boko	TW	0.002	0.003	0.02	0.002	0.07	BDL
Dumunichowki	TW	0.003	0.01	0.01	0.015	0.11	17.948
Dimu	RW	0.03	BDL	BDL	0.022	BDL	8.366
Maligaon	TW	0.016	0.01	0.35	0.012	BDL	9.303
Boragaon	DTW	0.022	0	0.03	0.03	0.02	4.553
Tetelia	TW	0.044	0.003	0.14	0.012	BDL	14.149
Lokhra	TW	0.637	0.1	0.18	0.009	BDL	21.184
Bezera	RW	0.033	BDL	0.08	0.009	BDL	2.817
Noonmati	SW	0.15	0.001	0.11	0.01	0.01	BDL
New Guwahati	TW	0.143	0.01	0.16	0.033	BDL	BDL
Pan Bazar	SW	BDL	0.005	0.23	0.005	BDL	BDL
Dispur	SW	0.358	BDL	0.15	0.004	BDL	4.7
Silpukhuri	RW	0.022	BDL	0.03	0.03	0.02	8.281
Bhangagarh	TW	0.044	0.003	0.14	0.012	BDL	BDL
Kamakhya	DTW	0.005	0.04	0.77	0.028	0.001	1.522
Gauhati University	TW	0.017	0.002	0.42	0.011	0.001	BDL
Basistha	DTW	0.01	0.01	0.01	0.005	0.002	33.39
Khanapara	TW	0.118	BDL	0.09	0.029	0.001	5.132
Bhralumukh	DTW	1.328	0.001	1.25	0.005	0.11	8.247
Chandmari	TW	0.027	0.009	0.05	0.007	0.04	6.794
Fancy bazar	SW	0.042	BDL	BDL	0.01	BDL	24.182
Panjabari	RW	0.08	0.18	0.93	0.028	0.03	7.175
Azara	TW	0.002	0.003	0.02	0.002	0.07	6.941
Lankeswar	TW	0.002	0.003	0.04	0.021	0.02	BDL
Satmile	TW	0.045	0.003	0.04	0.022	0.02	22.45
Jalukbari	TW	0.016	0.01	0.35	0.012	0.01	BDL
Satgaon	TW	0.336	0.001	0.16	0.011	0.2	BDL

BDL below detection limit

differences between mean and median. Positive kurtosis and skewness value point toward sharp arsenic distribution with a long right tail in the study area (Table 4).

In about 37 of the 44 sampling stations under investigation, the cadmium contents were much above the guideline value of 0.003 ppm as set by WHO. Cadmium above the permissible limit

Table 2 Descriptive statistics of the metal contents of drinking water in the study area

		Zinc	Copper	Manganese	Cadmium	Lead	Arsenic
Mean		0.101	0.01	0.17	0.025	0.027	6.725
Std. error of mean		0.034	0.005	0.038	0.0093	0.0064	1.252
Median		0.028	0.001	0.085	0.012	0.006	4.800
Mode		0.002	0.000	0.0000	0.0120	0.000	0.000
Std. deviation		0.226	0.031	0.256	0.062	0.043	8.304
Variance		0.051	0.0009	0.065	0.0038	0.0017	68.96
Skewness		4.298	4.717	2.812	6.328	2.129	1.645
Kurtosis		21.204	23.648	8.590	41.252	5.401	2.316
Range		1.328	0.180	1.250	0.420	0.200	33.39
Minimum		.0000	.0000	.0000	.0000	.0000	.0000
Maximum		1.328	0.1800	1.2500	0.4200	0.2000	33.39
Percentiles	25	0.006	0.000	0.020	0.0075	0.000	0.000
	50	0.028	0.001	0.085	0.012	0.006	4.800
	75	0.108	0.0045	0.160	0.028	0.047	8.272

can potentially cause nausea, vomiting, diarrhoea, muscle cramps, salivation, sensory disturbances, liver injury, convulsions, shock and renal failure along with kidney, liver, bone and blood damage from a lifetime exposure. Statistical analysis of the data indicates off normal distribution of cadmium in the study area. This is evident from the difference between mean and median values, significant positive skewness and kurtosis value and the width of the third quartile, which is greater than the first and second quartile. The cadmium contamination of groundwater in the area should be accorded maximum attention.

Lead above the permissible level in water can cause severe health problems among the people in the area. In the present study, as many as 14 sampling stations contain lead above the EPA guideline value of 0.015 ppm. Large differences between mean and median, significant positive skewness, and kurtosis value and the greater width of the third quartile than the first and second quartiles indicate that the distribution of lead in the study area is asymmetric.

The WHO limit for manganese in drinking water is 0.05 ppm Manganese at higher concentrations stains plumbing fixtures and laundry and produces undesirable taste in drinks.

It is observed that 24 of the 44 sampling stations under investigation, which is about 55% samples in the present investigation, contain manganese either at toxic or alert level. Many igneous and metamorphic minerals contain divalent

Table 3 Correlation relationship between the parameters

		Zinc	Copper	Manganese	Cadmium	Lead	Arsenic
Pearson correlation	Zinc	1.000	.131	.577[a]	−.094	.258	.102
Sig. (2-tailed)		.	.396	.000	.542	.091	.509
Pearson correlation	Copper	.131	1.000	.470[a]	−.026	−.068	.136
Sig. (2-tailed)		.396	.	.001	.866	.662	.378
Pearson correlation	Manganese	.577[a]	.470[a]	1.000	−.081	.104	−.126
Sig. (2-tailed)		.000	.001	.	.602	.501	.415
Pearson correlation	Cadmium	−.094	−.026	−.081	1.000	.120	−.032
Sig. (2-tailed)		.542	.866	.602	.	.440	.836
Pearson correlation	Lead	.258	−.068	.104	.120	1.000	−.083
Sig. (2-tailed)		.091	.662	.501	.440	.	.594
Pearson correlation	Arsenic	.102	.136	−.126	−.032	−.083	1.000
Sig. (2-tailed)		.509	.378	.415	.836	.594	.

[a]Correlation is significant at the 0.01 level (2-tailed)

Table 4 One-sample *t* test of the metal contents of drinking water in Kamrup district

	t Test value	95% CL		Comment, 0.05 level
		Lower	Upper	
Zinc	2.958	0.032	0.169	Significant
Copper	2.155	0.0006	0.019	Significant
Manganese	4.263	0.087	0.242	Significant
Cadmium	2.689	0.006	0.044	Significant
Lead	4.322	0.015	0.041	Significant
Arsenic	5.372	4.201	9.250	Non-significant

manganese as a minor constituent. It is a significant constituent of basalt and many olivines and of pyroxene and amphibole. Small amounts commonly are present in dolomite and limestone, substituting for calcium. When divalent manganese is released to aqueous solution during weathering, it is somewhat more stable toward oxidation than is ferrous iron. Detection of manganese in the water samples of the present investigation can be attributed to the presence of amphibole deposits in the study area.

Apart from geological origin, unscientific waste disposal specifically in areas like Bharalumukh, Boragaon etc., where leaching could be a dominant factor for enrichment of manganese in water samples. Thus, manganese contamination of groundwater in the area needs proper attention. A broad third quartile and positive skewness in case of manganese represents a long asymmetric tail on the right of the median. Heaviness of the tail for manganese distribution in the area is evident from very high positive kurtosis value.

The permissible limit for copper in drinking water is 2.0 mg/L. The distribution of copper in groundwater of the study area is found to be within the permissible limit of WHO with an average of 0.01 ppm. Copper may be dissolved from water pipes and plumbing fixtures especially by water whose ph is below 7. Copper salts are sometimes purposely added in small amounts to water supply reservoirs to suppress the growth of algae. Organic and inorganic compounds of copper have been used extensively in agricultural pesticides sprays. The element is therefore likely to be more readily available for solution in surface and ground water than its low average abundance in rocks might have implied. The lower concentrations of copper are readily explainable as a result of co-precipitation by oxides or absorption on mineral surfaces. Asymmetric nature of copper distribution is apparent from the normal distribution statistics with positive skewness and kurtosis values.

Zinc is widely used in metallurgy, principally as a constituent of brass and bronze or for galvanising, in which it is deposited as a coating to inhibit corrosion of steel. Zinc also is used extensively as a white pigment (Zinc oxide) in paint and rubber. These applications tend to disperse the element widely in the environment, and its availability for solution in water has been greatly enhanced by modern industrial civilisation. The drinking water sources of the study area are by and large safe with regard to zinc as evident from Table 1, but its distribution is still not uniform in the area. This observation is supported by positive kurtosis and skewness value, which point towards sharp zinc distribution with a long right tail in the study area. From the correlation of the studied metals as shown in Table 3, significant correlation was found among zinc, copper and manganese indicating their similar source of geogenic origin and mobility. Higher cadmium concentration in more than 70% of the samples indicates towards a grim situation. Although the exact possibility of its origin and source could not be ascertained but the possibility of usage of PVC plastics and electrical batteries to run the electronic gadgets and their unscientific disposal cannot be ruled out. Cadmium can also enter ground water from agricultural drainage if certain specific pesticides are used. Cadmium shares a clear negative correlation with zinc, manganese, copper and arsenic content at the 0.05 level in the area.

By comparing calculated $|t|$ value with tabulated t at 5% probability level of significance, we may either reject or accept our null hypothesis H0. The statistical values show that most of the studied water quality parameters are significant implying that the null hypothesis may be rejected. The calculated confidential limit will give the range within which the unknown value of the parameter is expected to lie.

Conclusion

From the heavy metal analysis, it is inferred that the excess concentration of Cd, Mn and Pb at some locations is the cause of undesirable quality for drinking purposes. Although the possible source of origin of the heavy metals has been ascertained to be geogenic in nature but the possibility of anthropogenic sources cannot be ruled out.

The statistical analysis of the metal content in the study area with respect to arsenic, cadmium, copper, lead, manganese and zinc exhibits an asymmetric distribution of the metals in the study area. Besides presence of cadmium, lead and manganese at an alarmingly higher concentration in most of the samples than the prescribed WHO limits requires immediate attention. The detection of these toxic metals in the drinking water samples is of great danger to the health of people especially in those cases where the water is consumed usually without any form of treatment.

In light of these, it becomes an utmost necessity to test the potability of the water source especially the ground water sources before using for drinking and other aesthetic purposes. Provision of potable water to people in this community by the Local Government Authority and the State water works should be taken as a matter of priority. Thus, from the above study, it can be suggested that there is an immediate necessity of surface water management with people's participation for reduced dependency on ground water.

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