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Evaluation of arsenic and other physico-chemical parameters of surface and ground water of Jamshoro, Pakistan

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ABSTRACT

Arsenic contamination in water has caused severe health problems around the world. The purpose of this study was to evaluate the geological and anthropogenic aspects of As pollution in surface and groundwater resources of Jamshoro Sindh, Pakistan. Hydride generator atomic absorption spectrophotometry (HG-AAS) is employed for the determination of arsenic in water samples, with detection limit of 0.02 $\mu g\,l^{-1}$. Arsenic concentrations in surface and underground water range from 3.0 to 50.0, and 13 to 106 $\mu g\,l^{-1}$, respectively. In most of the water samples As levels exceeded the WHO provisional guideline values 10 $\mu g\,l^{-1}$. The high level of As in under study area may be due to widespread water logging from Indus river irrigation system which causes high saturation of salts in this semi-arid region and lead to enrichment of As in shallow groundwater. Among the physico-chemical parameters, electrical conductivity, Na^+, K^+, and SO_4^{2-} were found to be higher in surface and ground water, while elevated levels of Ca^{2+} and Cl^- were detected only in ground water than WHO permissible limit. The high level of iron was observed in ground water, which is a possible source of As enrichment in the study area. The multivariate technique (cluster analysis) was used for the elucidation of high, medium and low As contaminated areas. It may be concluded that As originate from coal combustion at brick factories and power generation plants, and it was mobilized promotionally by the alkaline nature of the understudy groundwater samples.

1. Introduction

Drinking water, in general, is derived from a variety of sources, depending on availability of surface water (rivers, lakes, reservoirs and ponds) and ground water (aquifers). The arsenic (As) is a toxic metalloid and the 20th most abundant element in the earth's crust. Arsenic is predominantly present in inorganic form (As^{3+} and As^{5+}) in aquatic system with a minor amount of methyl and dimethyl arsenic compounds. Arsenic in the water is a serious natural calamity and a public health hazard, which originates from natural systems including, anthropogenic as well as geological sources [1–8].

The literature studies show that the arsenic in water poses the health hazards to humans, creates non-cancer effects such as hyper- and hypo-pigmentation, keratosis, black foot disease, hypertension, cardiovascular diseases and diabetes, and also typical skin, lung and bladder cancers [9–15]. Inorganic arsenicals belong to group I carcinogens [16,17]. It is reported that about 60–100 million people in India and Bangladesh are currently at risk, due to arsenic-contaminated drinking waters [18–20].

High concentration of As was observed in the surface water and shallow zones of ground water of many countries like Bangladesh, India, Argentina, Mexico, Mongolia, Germany, Thailand, China, Chile, USA, Canada, Hungary, Romania and Vietnam [21–24]. In some regions of Bangladesh, its concentration is as high as 1000 $\mu g\,l^{-1}$ [25]. The surface water resources (river, canal and lake) are less contaminated by As, while relatively higher contents of naturally occurring As may occur in ground water (10–70 $mg\,l^{-1}$), as a result of its input from geothermal sources (e.g. western USA and New Zealand) [26]. The Manchar Lake in Sindh, the largest freshwater lake in Pakistan is the main source of water for domestic and agricultural purposes. Water of lake as well as groundwater, in this vicinity is saline and has high As contamination [27,28].

Like India, Bangladesh and other neighboring countries, Pakistan is also facing serious public health disasters due to arsenic contaminated water and has acknowledged the need of apprizing drinking water quality and As problem. Different areas of our country have

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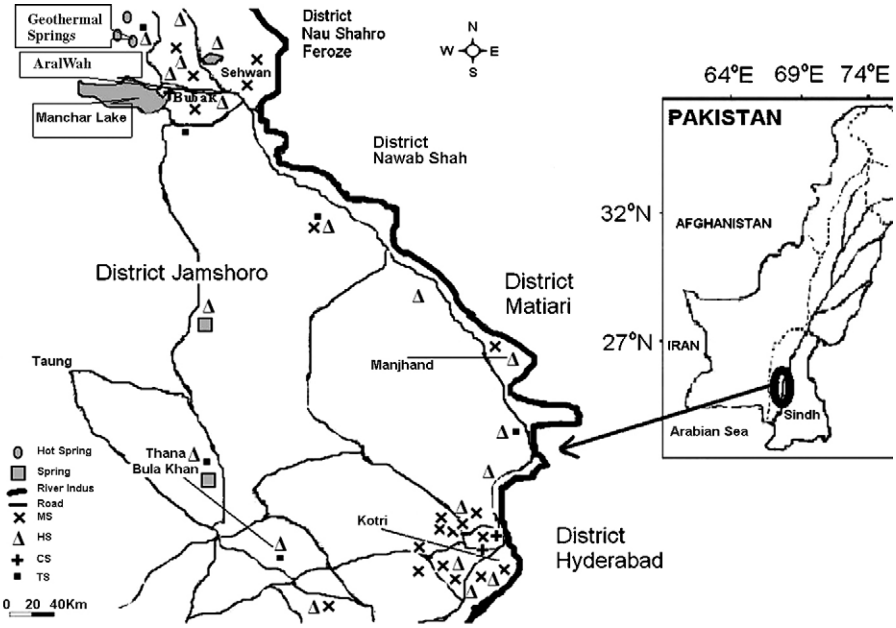

Fig. 1. Sampling map of study area (Jamshoro district).

high As concentration in drinking water (ground and surface water) [29]. On the basis of groundwater quality monitoring program, Pakistan Council of Research in Water Resources (PCRWR) and UNICEF reported that As contaminated groundwater (10–200 $\mu g\,l^{-1}$) was observed in some areas of Punjab province. In Sindh, 16–36% people are exposed to high arsenic (10–50 $\mu g\,l^{-1}$) in groundwater [30].

In study area, the analysis of As concentration in drinking water was not carried out so far, by any government organization or other national laboratories. Thus, the evaluation of arsenic in surface and underground water and its correlation with other physico-chemical parameters in understudy area was the need of the hour. Therefore, the aim of current study was to determine the As contamination in surface and ground water of District Jamshoro, Sindh (Pakistan) and to evaluate the possible contamination sources by characterizing the geochemical data. The water quality parameters (temperature, pH, total dissolved salt, electrical conductivity, sodium, potassium, calcium, magnesium, chloride, bicarbonate, nitrate, nitrite, sulphate, and iron) were also determined. The multivariate technique, cluster analysis (CA) was used, in view to find out the information about similarities and dissimilarities among the different sampling sites, according to As contamination levels.

2. Materials and methods

2.1. Description of study area

The area under study, Jamshoro district is located in southwest edge of the Sindh Pakistan, along with right bank of the river Indus and positioned between 25°19′–26°42′ N and 67°12′–68°02′ E (Fig. 1). The study area has a semi-arid and subtropical continental climate, the temperature ranged from 4 to 46 °C with <200 mm average rainfall [31]. Jamshoro is composed of quaternary alluvial-deltaic sediments derived from Himalayan rocks while most of its area is situated at offshoots of the Kirthar range with quaternary and tertiary volcanic rocks having thermal springs [32,33].

Most of the villages are located on fertile agricultural land in the flood plain of the Indus River. It is observed that, the agricultural/industrial pollution is a possible source of As in surface and underground water [27,34,35].

2.2. Sampling and pretreatment

About 309 surface and ground water samples were collected from 48 sampling points of Jamshoro, Pakistan with the help of Global positioning system (GPS) in 2007 (Fig. 1). Out of total collected samples, 153 groundwater samples were collected from >15 m depth and 156 were surface water samples (canals and municipal water supply). The canal water samples were collected from main stream of five to six different sampling points at a depth of 20–30 cm due to the low-flow conditions [36]. The collection of samples was performed by using Van Dorn plastic bottles (1.5 l capacity) and was kept in well stoppered polyethylene plastic bottles previously soaked in 10% nitric acid for 24 h and rinsed with ultrapure water. In the field, we measured water temperature, pH, electrical conductivity (EC) and total dissolved solids (TDS) by thermometer, pH meter (781-pH meter, Metrohm) and conductivity meter (InoLab conduc. 720, Germany), respectively.

2.3. Water analysis

The collected water samples were stored in an ice box, and delivered on the same day to the laboratory. Five to six water samples from each site were mixed into a washed plastic bucket to make a composite sample and filtered through 0.45 μm filter paper with the help of vacuum pump and stored at 4 °C until processing and analysis.

Standard solutions of understudy elements were prepared by dilution of 1000 $mg\,l^{-1}$ certified standard solutions obtained from Fluka Kamica (Buchs, Switzerland) of corresponding metal ions. To prevent the sample contamination, all the glassware and plastic containers were treated with 5 M HNO_3 and rinsed with distilled water and finally with ultrapure water. The physico-chemical parameters were determined by standard methods [37,38]. Total alkalinity was determined by acid titration using methyl-orange. Total hardness as Ca hardness was measured by EDTA complexometry titration using Erichrome-black-T and Calcon as an indicators at pH 10 and 12, respectively with an analytical error <2% [39]. For As and other metal analyses, water samples were pre-concentrated as reported elsewhere [27,40]. To estimate the equilibrium condition of the minerals possibly controlling the soluble chemical