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Physico-chemical parameters of surface and ground water and their environmental impact assessment in the Haripur Basin, Pakistan

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ABSTRACT

The present work is a comprehensive evaluation of surface and ground water quality of Haripur basin (comprising an industrial estate), Pakistan. Heavy metals, trace elements (i.e., Cd, Cr, Cu, Pb, Fe, Ni, Zn, Co, Mn, As and Hg) and physical parameters such as pH, total dissolved solids (TDS) and electrical conductivity (EC) were investigated in 98 sampling points and compared with the WHO guidelines for drinking water. The average metal concentrations in surface and ground water were found in the order of Fe > Mn > Zn > Ni > Pb > Co > Cr > Cu > Cd > As > Hg and Zn > Fe > Pb > Mn > Cr > Cu > Ni > Cd > Co > As > Hg respectively. Furthermore, chronic daily intake (CDI) and hazard quotient (HQ) were also calculated. HQ was found to be <1 for all the heavy metals and trace elements, suggesting no health risk. The multivariate techniques (i.e., correlation, principal component analysis and cluster analysis) for the interpretation of the metal data obtained during the monitoring programme revealed that there is an increase in the concentrations of heavy metals and trace elements in surface water and shallow water relative to deep water. This can be correlated with the discharge of effluents from the existing industries into the stream water in the basin.

1. Introduction

Surface water is most susceptible to pollution due to its easy access to the wastewaters. Both the geogenic, such as erosion, and weathering of crustal materials, as well as the anthropogenic influences like urban, industrial and agricultural activities determine the quality of surface water in a region (Carpenter et al., 1998). Once excessive heavy metals and trace elements (HMTEs) enter the surface and ground water, these may pose hazardous effects on human health because ingestion of contaminated water is one of the main routes through which HMTEs enter the human body (Kavcar et al., 2009; Wanga et al., 2010).

Intake of heavy metals and trace elements through drinking water by the human population has been widely reported throughout the world. Due to its non-degradable and persistent nature, heavy metals are accumulated in vital organs in the human body such as the kidney, bones and liver and are also associated with serious health disorder (Duruibe et al., 2007). For example, elevated Cu and Mn levels in drinking water can create mental diseases such as Alzheimer's and Manganism (Dieter et al., 2005; Wanga et al., 2010). Lead is linked to damage the brain, kidneys, nervous system and blood cells (Gump et al., 2008; Jusko et al., 2008; Kim et al., 2011). However, high intake of Co via consumption of contaminated food and water can cause abnormality of the thyroid artery, polycythemia and over-production of red blood cells (RBCs). High intake of Cd is associated with kidney damage, skeletal damage and itai-itai (ouch-ouch) diseases (Nordberg et al., 2002; Robert and Mari, 2003).

The quality of surface and ground water in the Haripur basin has deteriorated over last two decades, after the establishment of the Hattar Industrial Estate (HIE), and the level of pollution has increased continuously and consistently due to increasing industrialization and poverty. Several researchers have reported the increased concentrations of biological oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solid (TDS), carbonates (CO_3), bicarbonates (HCO_3), sulphates (SO_4) and HMTEs in industrial effluents and surface water (Amin et al., 2010; Rehman et al., 2008; Sial et al., 2006). However, no attempt was made to measure the effects of these effluents on the groundwater quality of the basin. The present study aimed to identify heavy metal distribution in the surface and ground water of the Haripur basin and their health risk assessment.

2. Material and method

2.1. Study area

The Haripur basin is a vast alluvial plain which covers the north western corners of the Potwar Plateau. It is located between longitude

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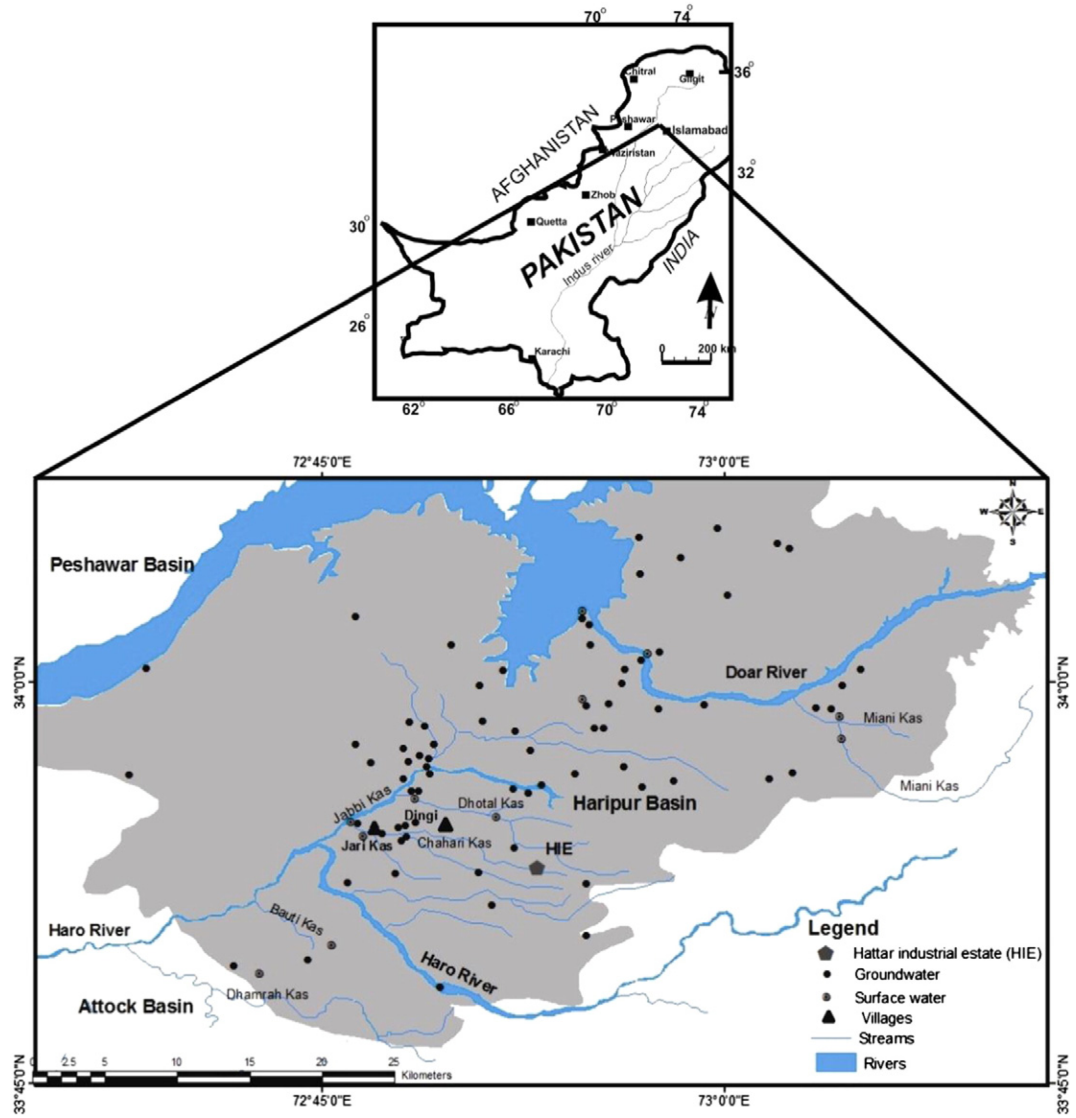

Fig. 1. Map of the Haripur basin and location of the sampling points. The location of the Hattar Industrial Estate (HIE) is also shown.

33°45′ to 34°08′ N and latitude 72°45′ to 73°13′ E (Fig. 1). The Haripur basin is approximately 53 km long, 12 km wide and covers a 644 km^2 area (Jones, 1992). According to the Population Census Organization (PCO) report, 30% of the population of the Haripur basin has tap water facility while the rest of the 70% generally use hand pumps, bore wells, and dug-wells as a source of drinking water. The Hattar Industrial Estate, located in the study area (Fig. 1), has about 300 pharmaceutical, heavy engineering, paint, chemical and paper factories established over the last two decades. The industrial estate has a large number of surface drains and all the industries discharge their effluents directly to the natural hydrological system, which may cause environmental problems in the area. At the Dingi village, all of the natural drains carrying toxic elements in the effluents of different industries ultimately fall into a relatively wider stream called “Chahari Kas”. This stream ultimately falls into the Haro River which is passing through the whole basin.

2.2. Sampling

A total of 98 representative water samples, consisting of 32 from surface water (i.e., streams and rivers), 45 from shallow ground water (<40 m) such as boreholes, dug-well, irrigation pumps and hand pumps and 21 from deep ground water (>80 m) such as tube-wells were collected in triplicates in polyethylene bottles. These bottles were pre-conditioned with 5% nitric acid and rinsed with double de-ionized water (DDW) before use. At each sampling station, temperature, pH, EC and TDS in water sample were measured in the field using the CONSORT C931 instrument. During sampling, each water sample was filtered through a Whatman (0.45 μm) filter paper and five drops of nitric acid (HNO_3) were added to each sample on spot. The bottles were tightly capped to avoid entrance of atmospheric CO_2. All the samples were transported to the Geochemistry laboratory of the National Centre of Excellence in Geology, University of Peshawar and kept in the refrigerator at 4 °C until analysis. The locations of these samples are shown in Fig. 1.

2.3. Analytical methods

All the acidified water samples, collected during field, were analysed for HMTEs (Fe, Mn, Cu, Pb, Zn, Ni, Cr, Co, Cd) using a Perkin Elmer graphite furnace atomic absorption spectrometer (Perkin Elmer AAS-PEA-700) under the standard operating conditions having r > 0.999. In order to keep the accuracy of the technique, each sample was analysed in triplicate and the reproducibility of 95% confidence limit was maintained by analysing blank and three standards after every ten samples. The average value of each sample was used for interpretation purpose. Arsenic (As) and mercury (Hg) in each water sample were analysed by using a Hydride Generation System (HGS-10) fitted with the Perkin