

Impact of Cadmium Polluted Groundwater on Human Health: Winder, Balochistan

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Farkhunda Burke¹, Salma Hamza², Shahid Naseem¹,
Syed Nawaz-ul-Huda³, Muhammad Azam⁴, and Imran Khan¹

Abstract

A number of serious studies have been conducted to decipher relationships between geological environment, potable/drinking water, and diseases as they were considered to have triggered suffering due to diseases among people. Chronic anemia can be caused by prolonged exposure to drinking water contaminated with cadmium (Cd). Under such circumstances, accumulation of Cd is manifested in the kidney, resulting in cancer and cardiovascular diseases. The aim of this study is to present the impact of Cd-contaminated drinking water on human health among the residents of villages in Winder. Collection of about 48 groundwater samples at an average distance of 1 to 2 km between the sampling sites has enabled a sufficient geological representation of distribution of minerals and elements in the samples. Concentration and comparison of Cd in the study area sample sites reveal highest values (24.2–30.0 ppb) in the northeastern and southeastern sectors, covering parts of all three geological areas of Bela Ophiolite of Cretaceous age. Conducted questionnaire surveys provided relevance between cause and effect nature of Cd bearing diseases among which kidney, joint, and night blindness are more prominent. Due to this phenomena, toxic risk of Cd in drinking water was high as per calculated health hazard indices. The use of this water by the villagers may cause health problems and disorders among the inhabitants of the area.

Keywords

cadmium, groundwater, human health, kidney problem, medical geography and geology

Introduction

Chronic diseases and geologic environment have a close relationship. Geochemical environment has been found to be a significant causative factor of serious health issues. A number of serious studies had been conducted to decipher the relationship between geological environment, potable/drinking water, and diseases as they were considered to have triggered suffering due to diseases among people. Elements are transported in water as either dissolved materials or integral parts of suspended sediments; however, dissolved materials in rivers or streams have the greatest potential of causing the most harmful effects. Subsequently, they may be stored in sediments of the riverbed or percolate into the subterranean water thereby causing contamination of groundwater, especially wells. However, the degree and extent of contamination will depend on the nearness of the well to the geological source (Durube, Ogwuegbu, & Egwurugwu, 2007; Hajalilou & Khaloghi, 2009; Naseem, Hamza, Bashir, Pirzada, & Talpur, 2013).

Water is life; hence, people must be concerned about the safety of their drinking water. With reference to the

classification and evaluation of water quality fit for human consumption, the physical and chemical properties of groundwater play a very significant role (Abou El-Hassan, Mostafa, Fujimaki, & Inoue, 2009; Kacmaz & Nakoman, 2010; Yousef, Salecin, Baraka, & Aglan, 2009). Although, diseases caused by pathogens are responsible for most of the health problems, inorganic elements especially arsenic, cadmium (Cd), and mercury can be causal sources (Pan, Plant, Voulvoulis, Oates, & Ihlenfeld, 2010).

¹University of Karachi, Pakistan

²Department of Earth & Environmental Science, Bahria University Karachi Campus, Pakistan

³Dawn Media Group, Karachi, Pakistan

⁴Federal Urdu University of Arts, Sciences and Technology, Karachi, Pakistan

Corresponding Author:

Syed Nawaz-ul-Huda, GIS Analyst, DAWNGIS, Geospatial and Statistical Research Division, Dawn Media Group, Haroon House, Dr. Ziauddin Ahmed Rd., Saddar, Karachi, 75300, Pakistan.
Email: nawaz_huda@hotmail.com



Winder, a town of district Lasbela, Balochistan, is located about 80 km northwest of Karachi city along the Regional Cooperation for Development (RCD) Highway. Geologically, it lies in the southern part of the western fold belt of Pakistan, which is composed mainly of sedimentary rocks of the Jurassic age (Ferozabad Group) along with igneous rocks (Bela Ophiolites) of the Cretaceous age. Mississippi Valley Type (MVT), Sedimentary Exhalative (Sedex), and vein-type mineralization is common in the rocks of Ferozabad Group of Jurassic age (Naseem, Bashir, & Hussain, 2011). Sulfide mineralization is also confined to the different segments of Bela Ophiolite in the area (Ahmed, 1992). A discrete assemblage of ions in both soils and water emanates due to dissolution of ophiolites (Neal & Shand, 2002).

Cd, a toxic trace element, is found in most rocks, as well as in coal and petroleum, in very low concentrations, often in combination with zinc. Geologic deposits of Cd can serve as their sources to groundwater and surface water, especially when in contact with soft, acidic waters (Ryan, Huet, & MacIntosh, 2000). There is no evidence indicating its essentiality to humans. Cd is toxic, even in extremely low levels, it accumulates especially in the kidney and is a potent cause of cancer and cardiovascular diseases. Cd can cause cough, headaches, and nausea followed by vomiting in low dose intakes, while in large doses, accumulation in the liver and kidneys take place; while its replacement of calcium in bones, culminates in painful bone disorders, renal failure, and implications in human hypertension (Webb, 1979).

Chronic anemia can be caused by prolonged exposure to drinking water contaminated with Cd. The binding of protein, metallothionein, into excess essential metals renders their non-availability to human blood supply. However, it gets bound to copper and zinc when it is induced to activity by Cd (Environmental Protection Agency [EPA], 1999). In their study on Egypt, Salem, Ewieda, and Farag (2000) revealed that drinking of water contaminated with lead and Cd strongly correlated with patients suffering from renal failure.

The present work is the furtherance (Phase II) of Naseem, Hamza, Huda, Bashir, and Haq (2014) study of high Cd bearing water in the study area. According to them, the average range of Cd in selected groundwater samples at Winder Town and its periphery was comparatively high with reference to daily consumption in terms of human health. Their analyzed sample sites contained only 14.58% water safe for human consumption, as per water quality (EPA, 2011), in which Cd value was 1 µg/l, while World Health Organization (WHO; 2011) allowed up to 3 µg/l (29.16% falls under WHO, 2011, range), whereas 60% samples were observed to have higher Cd level (>5 µg/l), among which some had very high content. They also concluded that groundwater of the study area is contaminated with high Cd, alkaline nature of water (pH av. 7.42) and bicarbonate ions providing support as CdCO₃. Due to this phenomenon, toxic risk of Cd in groundwater was high as per calculated health hazard

indices. The use of this water in terms of drinking, vegetable farming, livestock husbandry, and fruits gardening may cause health problems and disorders among the inhabitants of the area.

The current study has been conducted in those areas where the content of Cd in the groundwater was high. For this purpose, a questionnaire based survey was conducted to correlate Cd-borne diseases among the inhabitants of the area. Field survey is a common method for preliminary investigation of ailments based on physical symptoms (Inoue et al., 2014). The present study has created good liaison between medical geography and medical geology for mitigation of health problems among the residents of villages in Winder.

Materials and Method

Sampling and Cd Estimation

Collection of 48 groundwater samples at an average distance of 1 to 2 km between the sampling sites has enabled a sufficient geological representation of distribution of minerals and elements in the samples (Figure 1). Stream and groundwater samples were collected in polyethylene bottles rinsed at least thrice with sampling water prior to water collection. The samples were filtered through 0.45 µm membrane and collected in pre-sterilized polyethylene sampling bottles (1.5 L size). Bottles were completely filled and sealed to prevent oxidation. The bottles were stored under refrigeration at approximately 04°C. Quantitative estimation of Cd was made by using AAS Hitachi-5000.

Questionnaire Survey

During the collection of water samples, it is observed that kidney-related disease is the major problem among inhabitant of the study area. Naseem et al. (2014) reported high accumulation of Cd in groundwater of Winder. Therefore, it was necessary to design field survey to investigate harmful diseases in the study area, because various studies provided evidences with reference to the role of Cd in kidney failure (Inoue et al., 2014). For the perspective of preliminary investigation of Cd-borne disease, a questionnaire was designed for the present study, which was conducted based on random survey method for those settlements (n=32) which were in close proximity to the water samples sites. The questionnaire was comprised of three sections, as follows—basic information, occurrence of diseases based on symptoms, and quality of life. The study focused on the identification of behavior and impact of selected trace elements on human health. Questions were open-ended as well as close-ended and were on the spot sessions. Analysis has been designed, based on age groups. Data were collected through face to face interview of patients during October 2013 to February 2014 through settlement to settlement field survey. The average

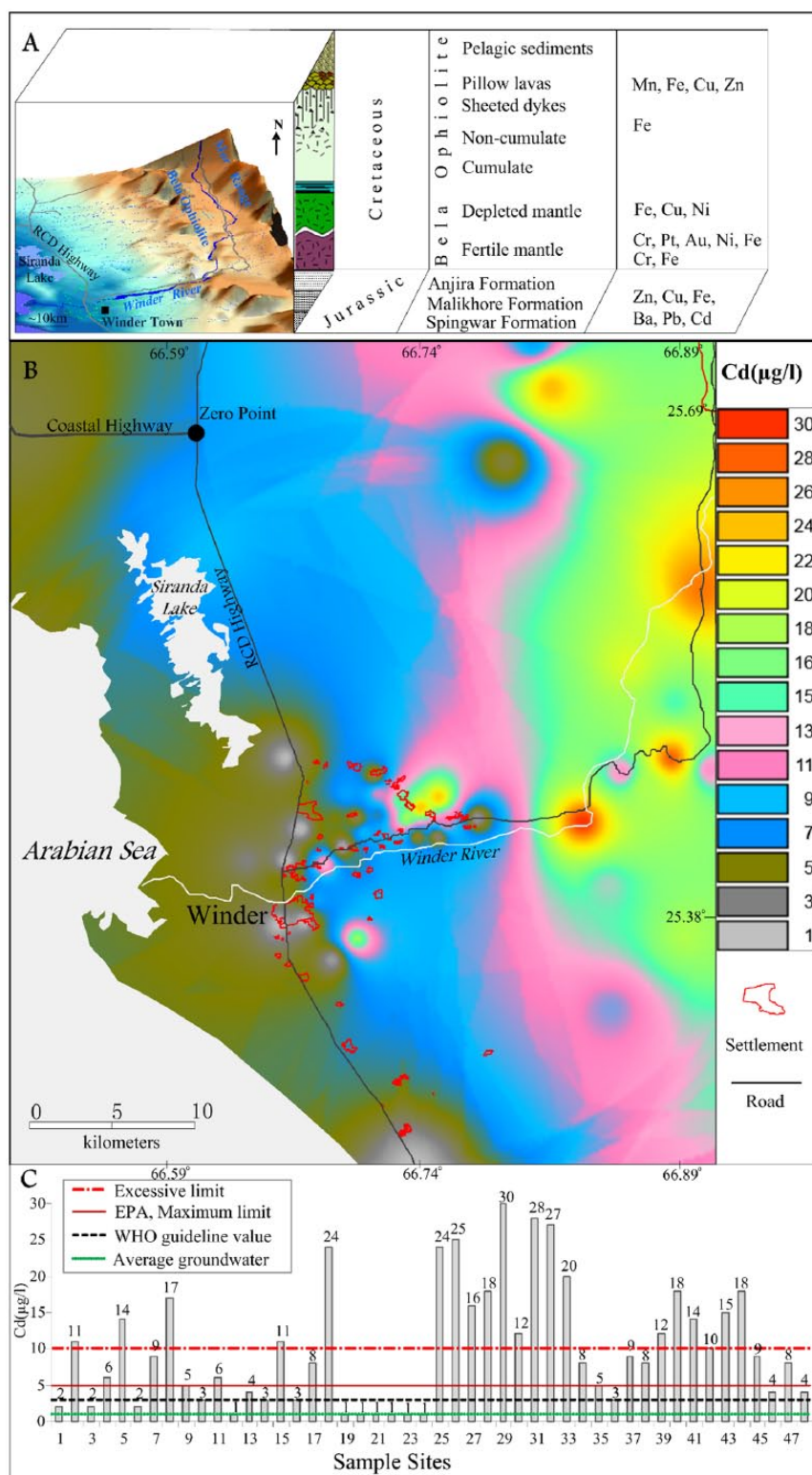


Figure 1. (A) Geology of the study area and source of heavy metals; map (B) shows study area location, sample sites, settlement, and spatial distribution of Cd in the groundwater based on Inverse Distance Weighted (IDW) technique; (C) average Cd in the study area with reference to world average, EPA, and WHO guidelines and statistics of the water.

Source: Naseem, Hamza, Huda, Bashir, and Haq (2014).

Note. EPA = Environmental Protection Agency; WHO = World Health Organization; IDW = Inverse Distance Weighted.

prevalence of patients (p) at a confidence interval (CI) of 95% ($\alpha = .05$) and a deviation (d) of 0.02 was 20%. Acceptable sample size was thus determined to be 284 as per last population census of the study area. Data were entered into a Microsoft Excel spreadsheet and analyzed with Microsoft Excel and SPSS version 20 for analysis. Several research studies were analyzed for assessment of toxicity impacts of trace elements in the human body accumulated over years (D'Ilio et al., 2013; Ogabiela et al., 2011; Vonkatosh & Whole, 1988).

Results and Discussion

Knowledge and information regarding chemical composition, relative abundance, and their mutual relationships are provided through geochemical studies. In the case of Winder town, these connections have been elaborated as an example. Naseem, Hamza, and Bashir (2010) also revealed their insight into water-rock interaction in addition to their sources of ion and relative mobility. Work of Naseem et al. (2014) has been presented (Figure 1), revealing geology, concentration, and comparison of Cd in the study area. Sample sites reveal highest (24.2-30.0 ppb) concentration in the north-eastern and southeastern sector covering parts of all three geological areas of Bela Ophiolite, Sandy Tract Recent as well as Sub-Recent Sandy Tract. Apart from this, the entire area is composed of lowest (1.0-6.8 ppb) and low (8.6-12.6 ppb) concentration of this harmful trace element.

According to Figure 1B, most of the northerly settlements are located around excessive limit zone of Cd in the study area. Therefore, 9% kidney-related diseases patients were reported in these settlements out of 15% to total respondent patients who had kidney problem in the study area.

Rural areas are characterized mainly by agricultural economy and a leisurely way of life. A conservative, illiterate, male dominated society with exploited females, males enjoy their lives in a multiplicity of ways, as a result of which crude birthrates are high, leading to unemployment, low incomes, poverty, and deprivation with several manifestations, including malnutrition and under nutrition (Huda & Burke, 2012). Winder town is one of the cities of Balochistan, the rural areas of which are characterized with backwardness and due to their poor quality of life, inhabitants being unaware of water satisfactory standards are oblivious of diseases caused by heavy metals as Cd, Pb, F, As, and so on and hence keep on suffering.

The study of occupational structure was chosen as an economic indicator because it was considered essential in determining the level of social and economic status as employment provides stability to families (Huda, Burke, & Azam, 2011). Regarding occupational category of respondents within different age groups, 13 categories of respondents have been identified. The highest numbers of respondents within age group 41 to 50 years were laborers, that is, around 16 respondents. The lowest numbers of laborer respondents were in the

age group 11 to 20 and 60 and above as they included the children and elderly. The largest number of housewives who responded to the questionnaire survey was within age group 31 to 40. Agricultural workers of all age groups also responded, but the highest response, that is, from 09 persons, was observable among the age group 21 to 30 years.

Education not only enables people to express themselves with confidence at their workplace but also enhances self-assurance in their community or in their personal relationships (United Nations, 2005). The educational level of respondents reveals that illiterate respondents were highest in all age groups. Some primary, matriculate, and intermediate respondents in age groups 11 to 20, 21 to 30, 31 to 40, and 41 to 50 years were also found. Education is a serious problem in third world countries having a repercussion on all aspects of life. The economic life of any people includes activities of several collars. As a minimum, there are always formalized patterns controlling ownership, production, distribution, and consumption, all having an impact on the economic status. The most direct measures of living standards, however, are income and consumption. There are various sources of Cd accumulation in the human body among the residents of Winder, the most significant being water, while other sources include vegetables and fruits. Studies on fruits with reference to trace metals accumulation in Winder area revealed normal concentration in pulps compared with that in twigs but content was high compared with WHO standard (Hamza, Naseem, Bashir, Rizwani, & Hina, 2013; Hamza, Naseem, Huda, Bashir, Burke, & Sheikh, 2014; Hamza, Naseem, Huda, Burke, & Bashir, 2014). Chang et al. (2014) investigated the extent of heavy metal accumulation in leaf vegetables and associated potential health risks in agricultural areas. The consumption of local vegetables in Winder reveals that respondents of all age categories consume plenty of vegetables (Figure 2A). However, the highest number of respondents, that is, 10 who reported that their vegetable consumption was nil, were in the age category 21 to 30; 02 persons each in age categories 21 to 30 and 31 to 40 responded that they ate vegetables only twice a month. This reveals the dire conditions of impoverishment and subsequent poor health conditions, as vegetables and their seeds are essential for maintaining good health through the provision of vitamins, minerals, and fibers. But the case of Cd polluted groundwater and subsequent soil feeding is responsible for vulnerability in human health (Chang et al., 2014; Haque, Sasaki, Matsuyama, Annaka, & Sasaki, 2014).

In response to the question regarding proper washing of vegetables prior to cooking, the reply of majority of the inhabitants was "no." All respondents except 03 in age groups 21 to 30 and 31 to 40 responded they just cleaned the vegetables by rubbing, which was due to problems of fetching water from great distances or some problems of inability leading to neglect of hygiene. The consumption of fruits reveals that all age groups consume meager amount of fruits, according to their own assessment, which is an uneducated

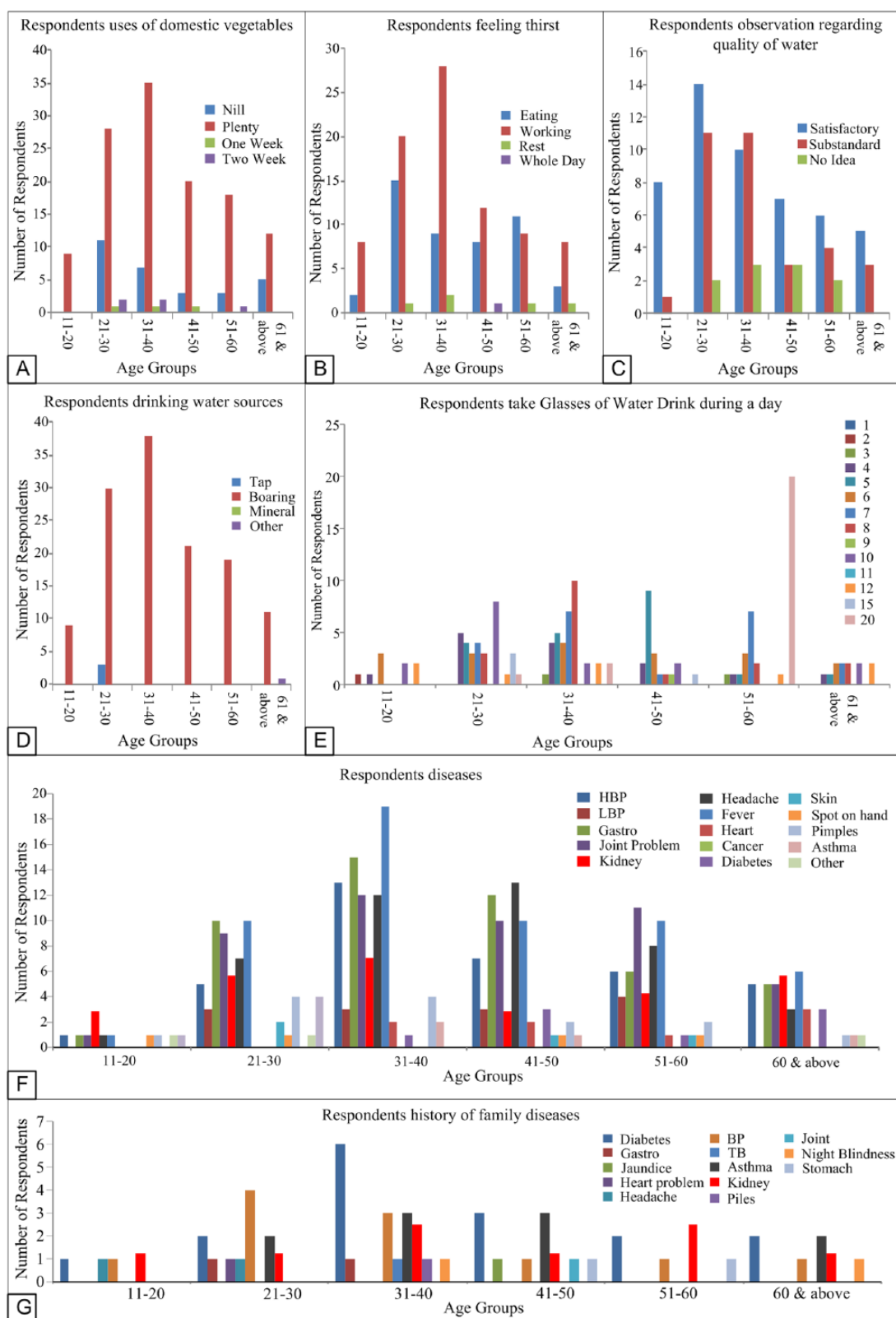


Figure 2. Respondents' replies.

one and not according to official nutritional standards. However, some people in all age categories responded that they consumed much fruits. Figure 2B corroborates with the results of the previous graph as the 60 and above respondents revealed lowest response to feeling of thirst whether it was at work or at rest. All other age groups revealed that they consumed most water while they were at work especially those in the 31 to 40 and 21 to 30 age groups. Habit of drinking water while eating was found to be common among villagers of all ages. Poverty compelled them to swallow their bread with the help of water. Figure 2C, regarding the response to the quality of drinking water, reveals that most respondents in each age group were satisfied. High number of responses, that is, 11 each in age categories 21 to 30 and 31 to 40, found the water to be substandard. Altogether, 10 respondents in age groups 21 to 30, 41 to 50, and 51 to 60 years had no idea about their drinking water quality.

Taste of water revealed that most respondents in all age categories found the water saline except for 01 in age group 11 to 20, who did not. A large number of respondents in all age groups found their drinking water sweet, a few in each age category found it tasteless. Figure 2D, showing the source of drinking water, reveals that all respondents used boring water for drinking. Only 02 and 01 respondents in age groups 21 to 30 and 60 plus, respectively, replied that they used tap water for their families. Figure 2E, showing the number of glasses of water that the villagers of Winder drank, shows that on an average, people consumed 8 to 9 glasses of water, highest response being from among age groups 41 to 50 and 31 to 40. People of 60 and above age group have revealed very little quantity of water consumption because they felt that the more they drank the greater would be the problem of urination and running to the toilet for urinating during old age.

Figure 2F, showing the occurrence of diseases among the village folk, reveals that fever is the complaint of largest number of respondents in all age groups, especially the 31 to 40 age groups. The next most prominent emerging ailment is gastroenteritis, also in the same age category, that is, 31 to 40. Response to headache stands out prominent in the age category 41 to 50. Asthma was reported by a few respondents in the 51 to 60 and 60 plus age category only by one respondent and by 04 respondents in 21 to 30 age category. Joint problem also seems to be a major ailment as respondents of all age categories reported its occurrence. Kidney problems also highlighted impacts of Cd in the study area because respondents were more prominent as kidney patients among various age groups. There were 15% respondents who reported kidney-related diseases among joints, heart, asthma, gastro, and diabetic patients. Figure 2G also showing the occurrence of diseases among the elderly revealed that diabetes is most common as responded by all age groups. The next prominent disease recorded by respondents was blood pressure and asthma. Night blindness was also reported by few respondents of 31 to 40 and 60 plus age groups. Tuberculosis was also reported by a respondent in age group

31 to 40 years. Kidney problem was reported in all age categories, highest in age categories 31 to 40 and 51 to 60 years. This may probably be attributed to the occurrence of Cd, which is widespread in the study area.

Conclusion and Suggestions

The present study has provided significant relevance to toxic risk of Cd in groundwater in the purview of health hazard. Due to poor living standards, the village inhabitants consume the water available from the nearby tanks, tube wells, or directly from the flowing ephemeral river, which is a major cause of their illnesses and ailments. The occurrence of diseases among the village folk reveals that among the most prominently emerging ailments were joint and kidney problems reported by all age categories of respondents. Night blindness was also reported by few respondents of 31 to 40 and 60 plus age groups. According to respondents' opinion regarding poor water quality, they revealed that the locally obtained water did not quench their thirst; hence, less intake saved them from massive intake of Cd and its accumulation in their blood streams. In addition, their emigration from Winder to other parts of the province/country in search of greener pastures to improve their financial position disconnects them from Cd accumulation in their blood streams and body. Reported kidney patients were 15% of the total respondents.

Third phase of the present study will be conducted in the near future, which will include collection of urine and blood samples of kidney patients, like those executed by Inoue et al. (2014) and Wright, Rattray, Lalor, and Hanson (2010) in Jamaica; and Apinan, Satarug, Ruengweerayut, Mahavorasirikul, and Na-Bangchang (2010) in Thailand.

All emergent efforts should be made to provide safe potable water to the inhabitants of Winder. It is deemed necessary for the administrative authority to take serious action to minimize the risk of Cd vulnerability. Various techniques have been used for Cd cleaning from water, most important among which are reverse osmosis, chemical precipitation, foam separation, ion exchange, cementation, and chelating resins (Chou & Okamoto, 1976; Paulson & Balistreri, 1999; Wuana & Okieimen, 2011).

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Declaration of Conflicting Interests

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Author Biographies

Farkhunda Burke is a professor in the department of Geography, University of Karachi, Pakistan. Her publication cover fields of Regional Planning, Geography of Recreation, Medical Geography, Urban Ecology, etc.

Salma Hamza is assistant professor, in the Department of Earth and Environmental Sciences, Bahria University, Karachi Campus. One major focus of her work is environmental geochemistry with special reference of Bela Ophiolites.

Shahid Naseem is a professor in the department of Geology, University of Karachi, Pakistan. He has mainly worked on Economic Geology of southern Balochistan with special emphasize on Bela Ophiolites. Hydro geochemistry, biogeochemistry environmental geochemistry and geochemical exploration are the main interest.

Syed Nawaz-ul-Huda is a GIS analyst in the Dawn Media Group and visiting faculty member, Department of Geography, Federal Urdu University, Karachi, Pakistan. Huda's interests include Regional Planning, Environmental Geochemistry, Electoral Analysis, Research Methods etc.

Muhammad Azam is a assistant professor in the department of Geography, Federal Urdu University. His publications cover fields of Urban Ecology and RS/GIS.

Imran Khan is a PhD candidate with the department of Geography at University of Karachi, Pakistan.