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Prevalent fecal contamination in drinking water resources and potential health risks in Swat, Pakistan

Kifayatullah Khan[1,2], *Yonglong Lu*[2,3,*], *Mian Abdal Saeed*[1], *Hazrat Bilal*[1], *Hassan Sher*[4], *Hizbullah Khan*[5], *Jafar Ali*[3,6], *Pei Wang*[2], *Herman Uwizeyimana*[2,3], *Yvette Baninla*[2,3], *Qifeng Li*[2,3], *Zhaoyang Liu*[2,3], *Javed Nawab*[7], *Yunqiao Zhou*[2,3], *Chao Su*[2,3], *Ruoyu Liang*[2,3]

1. *Department of Environmental and Conservation Sciences, University of Swat, Swat 19130, Pakistan*
2. *State Key Lab of Urban and Regional Ecology, Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing 100085, China*
3. *University of Chinese Academy of Sciences, Beijing 100049, China*
4. *Center for Plant Science and Biodiversity, University of Swat, Swat 19130, Pakistan*
5. *Department of Environmental Sciences, University of Peshawar, Peshawar 25120, Pakistan*
6. *Laboratory of Environmental Nanomaterials, Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing 100085, China*
7. *Department of Environmental Sciences, Abdul Wali Khan University, Mardan, Pakistan*

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ABSTRACT

Fecal bacteria contaminate water resources and result in associated waterborne diseases. This study assessed drinking water quality and evaluated their potential health risks in Swat, Pakistan. Ground and surface drinking water were randomly collected from upstream to downstream in the River Swat watershed and analyzed for fecal contamination using fecal indicator bacteria (*Escherichia coli*) and physiochemical parameters (potential of hydrogen, turbidity, temperature, electrical conductivity, total dissolved solid, color, odor and taste). The physiochemical parameters were within their safe limits except in a few locations, whereas, the fecal contaminations in drinking water resources exceeded the drinking water quality standards of Pakistan Environmental Protection Agency (Pak-EPA), 2008 and World Health Organization (WHO), 2011. Multivariate and univariate analyses revealed that downstream urbanization trend, minimum distance between water sources and pit latrines/sewerage systems, raw sewage deep well injection and amplified urban, pastures and agricultural runoffs having human and animal excreta were the possible sources of contamination. The questionnaire survey revealed that majority of the local people using 10–20 years old drinking water supply scheme at the rate of 73% well supply, 13% hand pump supply, 11% spring supply and 3% river/streams supply, which spreads high prevalence of water borne diseases including hepatitis, intestinal infections and diarrhea, dysentery, cholera, typhoid fever, jaundice, and skin diseases in children followed by older and younger adults.

* *Corresponding author*. E-mail: yllu@rcees.ac.cn (Yonglong Lu).

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Introduction

Drinking water is a vital substance in the environment and a cherished gift of the nature to human beings, particularly to a society where natural water resources are limited (Khan et al., 2013b; Zhang et al., 2016). However, water also acts as a passive carrier for numerous organisms that can cause human illness including viruses, protozoa, and bacteria (Coleman et al., 2013; Ali et al., 2017; Cui et al., 2017). Water quality deterioration with both point sources of pollution (*e.g.*, discharge of wastewater) and non-point sources of pollution (*e.g.*, sewer leakages, overflow discharges, wildlife animal wastes and runoff from urban areas or agricultural fields) resulted from unprecedented population and economic growth, urbanization and industrialization has been a great concern for several decades (Åström et al., 2007; Parajuli et al., 2009; Sánchez et al., 2015; Tran et al., 2015). Drinking water sources in the world where the gastroenteritis diseases are the major contributor to human morbidity are continuously overexploited and polluted with various microbial (bacteria, fungi, parasites, viruses) and physiochemical contaminants (Hussain et al., 2014; Hillebrand et al., 2015).

Drinking water quality based on pathogenic parameters is primarily determined using indicator organisms to indicate the fecal contamination. The availability of indicators organisms is often a key in assessing the pathogenic caused health risks and used worldwide in the drinking water quality regulations and guidelines (Wanda, 2008). In developed countries like United States, the Safe Drinking Water Act requires drinking water systems to be analyzed for pathogens including total coliforms and *Escherichia coli* (*E. coli*) either once a month for the smallest systems or 480 times per month for the largest ones. However, due to limited resources this kind of sampling is not always achievable in developing countries (Kostyla et al., 2015). In developing counties like Pakistan, the microbial contamination of drinking water is regarded the most serious problem; where the situation of fresh water availability is worse due to lack of proper management and poor financial constraints (Muhammad et al., 2010; Azizullah et al., 2011). Normally contamination is caused by biological pollutants from the surrounding sources like toilets, underground damaged sewerage lines, seepage/percolation from drainage system and poor efficiency of the Waste Water Treatment Plants, which ultimately results in severe illness and even deaths (Khalid et al., 2011; Khan et al., 2013b).

To monitor water quality and ensure the provision of safe drinking water, the World Health Organization (WHO) and United States Environmental Protection Agency (US EPA) have proposed to check fecal contamination of drinking water using fecal indicator bacteria (FIB) (Kostyla et al., 2015; Paule-Mercado et al., 2016). *E. coli* is currently recognized as the best FIB for monitoring fecal contamination in drinking water and the key indicator of health risk for both marine and fresh recreational waters (Pettus et al., 2015; Wang et al., 2015). Whereas, the WHO guideline value in drinking water is "none detectable in any 100-mL sample" for human consumption. *E. coli* occurs in high numbers in human and animal feces, whereas water nutrient conditions and other physical, chemical, biochemical and biological parameters existing in drinking-water distribution systems may highly support the growth of these organisms (WHO, 2011). Its high levels in water sources constitute potential infections and frequent waterborne diseases to humans, especially children and old people and thus impair several waters uses (Bachoon et al., 2010; Walker et al., 2013; Gerhard et al., 2017).

Each year in Swat, Khyber Pakhtunkhwa Pakistan, governmental agencies and non-government organizations (NGOs) develop and improve thousands of wells, boreholes, springs and other sources of water supply to provide desperate villages with communal sources of safe drinking water. However, the water quality at the point-of-use is continuously degrading in the area with availability of high fecal and physiochemical contaminants, resulting in serious waterborne diseases including diarrhea, intestinal infections, dysentery, cholera, hepatitis, typhoid fever, vomiting, skin diseases and other related illnesses especially in children and older adults. The objective of the present study was to assess the drinking water quality at the point-of-use based on pathogenic (*E. coli*) and physiochemical (potential of hydrogen (pH), turbidity, temperature, electrical conductivity (EC) and total dissolved solid (TDS)) parameters, and to identify the possible sources of the contaminants and potential human health risks.

1. Materials and methods

1.1. Study area

The study area, District Swat, is comprised of seven tehsils called tehsil Bahrain, Khwazakhela, Matta, Charbagh, Babozai, Kabal and Barikot (Fig. 1). Geographically, the district is located between 34°34′ to 35°55′ north latitude and 72°10′ to 72°50′ east longitude with an altitude ranging from 733 m in the south to approximately 5740 m in the north of Khyber Pakhtunkhwa, Pakistan. Its total population is approximately 1.25 million, with an average density of 248 people per km^2 (Khan et al., 2014). The climate is Mediterranean in the northern parts of the district and Sub-tropical in the southern parts with average temperature ranged from −10 to 25°C (Shah et al., 2010; Khan et al., 2013a), and with average rainfall from 750 to 1350 mm and humidity varied from a minimum of 40% in April to a maximum of 85% in the month of July (Shah et al., 2010). Besides, the area has been gifted with rich fresh water resources. The River Swat is the main source of water in the valley that originates in the Hindukush Mountains and flows at 171.76 m^3/sec downward through the Valley of Kalam in a narrow gorge with a rushing speed up to Madyan, and then gradually spreads in the lower plain areas of Valley up to Chakdara for about 160 km (Ghumman et al., 2010; Khan, 2011). This river plays an important role in the economic development of the valley, where its esthetic value can never be underestimated. It provides water for irrigation, drinking and other domestic uses, and recharges the surrounding groundwater well and spring sources (Khan et al., 2013b). However, the water has been increasingly polluted particularly with biological contaminants. Surface river water may have been significantly contaminated from the direct discharge of municipal sewage and hotel flushes along with surface runoffs from surrounding livestock manure, and the groundwater may have been affected by direct seepages/leakages of surrounding toilets and fragile sewerage lines. Thus, due to lack of proper management and

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