Chapter 12
Groundwater Quality and Concerns of Kabul River Basin, Afghanistan

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Abstract This study is aimed at assessing water quality in Kabul Basin by integrating several scientific investigations and studies on monitoring and evaluation of water quality conducted so far by different entities. It shows that in Afghanistan lowering of groundwater table is rapidly entering into water-scarce countries. Increase in population density and decrease in water availability have become dual threat to water quality, and impact on public health. It has been estimated that in Afghanistan around 30–40% of all reported diseases and deaths are due to poor water quality. Moreover, the leading cause of deaths in infants and children up to 10 years of age as well as mortality rate of 1,600 per 100,000 live births is reported owing to diarrhea. This situation is rather worst due to being among the backward and poverty-stricken areas. Findings of this research show that the increased population of Kabul city by about 4% per year during 2002–07 affected existing shallow water supply by increased groundwater withdrawals. Increasing water use on groundwater levels indicates that a large percentage of existing shallow water-supply wells in urban areas may contain little or no water by 2057. This research presents a thorough analysis of the groundwater quality and quantity deterioration, which leads to a conclusion and a set of recommendations, which are considered useful to prevent water quality deterioration as well as quantity decrease of the groundwater in Kabul River Basin.

Keywords Kabul River basin · Groundwater quality · Public health
Polluted water

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12.1 Introduction

Kabul River Basin (KRB) is one of the five river basins of Afghanistan (Chap. 1, Fig. 1.1), namely (a) Amu Darya River Basin, (b) Northern River Basin, (c) Harirod-Murghab River Basin, (d) Helmand River Basin, and (e) Kabul River Basin. KRB is the fourth basin in terms of area, while in terms of population and population density, it comes first. It is the basin which shows high consumption of water, while in terms of the water body area, it is the fourth one. It shows high demand for drinking water to meet the requirement. The present article is focused on integrating findings of different studies on water quality of KRB. The review shows Kabul Basin drinking water systems are contaminated by microbial pathogens and anthropogenic contamination and pose a threat to the health of Kabul's inhabitants. Therefore, there is a need to take urgent corrective measures before further deterioration of Kabul Basin drinking water systems.

The lack of potable drinking water provision and sewerage systems to meet the demand of increasing population in the KRB due to massive return of Afghan refugees and presence of international community, the water quality is under a great threat of contamination which will be harmful for the community. It is evident that focus of the study of water quality in the Kabul Basin could be used in adapting effective preventive measures of potable water shortage, contamination of drinking water, and environmental hazards in future.

The organizations/government departments that have studied or are responsible for the study of the water quality in Afghanistan and particularly in Kabul River Basin include the following.

(i) United States Geological Survey (USGS) in cooperation with the Afghanistan Geological Survey
(ii) Danish Committee for Assisting Afghan Refugees (DACAAR)
(iii) United Nations Children Funds (UNICEF)
(iv) Ministry of Public Health of the Islamic Republic of Afghanistan
(v) Ministry of Rural Rehabilitation and Development of the Islamic Republic of Afghanistan
(vi) Drainage Research Centre (DRC), Kabul
(vii) Water Resources Research Centre (WRRC) Kabul

The Kabul River runs from north to south direction and passes through many villages, hospitals, small industries, etc. These agencies dispose their waste directly to the river. Industries include cosmetics industry, garments industry, and soaps industry mainly situated in the city of Kabul. More related information regarding groundwater of South Asia is available in Mukherjee et al. (2018).

12.2 Geomorphology

As stated earlier, KRB is considered to be a geologic valley formed by the Paghman Mountains to the west and the Safi Mountains to the east. The landforms within the Kabul Basin are typical of an arid to semiarid, tectonically active region. All adjacent sub-basins except for the Central Kabul and Logar sub-basins and the Shomali and Panjsher sub-basins are separated by prominent bedrock outcrops. The central plains of the sub-basins are local depositional centers for sediments derived from the surrounding surficial deposits and bedrock outcrops. The central plains gently slope up to the adjacent mountains and hills to form piedmonts. Alluvial fans have developed on the flanks of the mountains surrounding the sub-basins and on the inter-basin ridges. The alluvial fans generally grade from course material near the source to finer material at the distal edges. The study area encompassed about 3,600 km^2 is primarily composed of Tertiary and Quaternary valley-fill sediments filling fault-bounded structural basins.

12.3 Topography

The topography of the Kabul River Basin is strongly influenced by regional and local tectonic activity and by fluvial processes. The basin is bounded by mountain ranges; the highest range, reaching 4,400 m in altitude, is the Paghman Mountains to the west of the study area. The Kohe Safi range to the east of the study area is as high as 3,000 m, and most of the range slopes out of the study area to the east. The inter-basin ridges generally rise about 200–500 m above the adjacent valley floors. The central plains of the sub-basins are generally flat, rising gradually to the surrounding bedrock outcrops. Altitudes of the central plains range from around 1,800 m in the Central Kabul and Logar sub-basins to 2,200 m in the Paghman and Upper Kabul sub-basin. Several ephemeral streams flow from the Paghman Mountains that border the Shomali area. Perennial and ephemeral stream channels have discussed the valley-fill sediments. Active stream channels are generally narrow and shallow, rarely exceeding 10 m in width and 5 m in depth. Some isolated topographic depressions in the Central Kabul and Logar sub-basins act as catchments for surface-water runoff and are the sites of playa lakes or ephemeral marshes.

12.3.1 Geology

The Kabul River Basin is part of the tectonically active Kabul block in the transgressional plate-boundary region of Afghanistan. A generalized geohydrologic section of the Kabul Basin is presented in Chap. 2 to illustrate the general structure and major geologic and hydrologic features. The western edge of the Kabul block is defined by the Paghman fault within the Chaman fault system. The Paghman fault trends north–northeast and is evident in the continuous fault scarp and piedmont alluvium along the western boundary of the Kabul Basin. The Paghman fault marks a transition from primarily left-lateral strike-slip movement on the Chaman fault to apparent left-lateral oblique-thrust faulting and dip-slip displacement on the Paghman fault. The basin can be described as a valley-fill basin-and-range setting where the valleys are filled with Quaternary and Tertiary sediments and rocks, and the ranges are composed of uplifted crystalline and sedimentary rocks. Quaternary sediments are typically less than 80 m thick in the valleys. The underlying Tertiary sediments have been estimated to be as much as 800 m thick in the city of Kabul and may be more than 1,000 m thick in some areas of the valley.

12.4 Hydrology of Kabul River Basin (Precipitation and Runoff in the Basin)

The Kabul Basin study area is within the 25,500 km^2 Kabul River watershed. The number of major rivers flowing into the Kabul Basin undoubtedly contributed to the historical significance of the Kabul area. The Kabul River enters the study area from the south, flows north about 21 km to the city of Kabul, and then flows east, leaving the study area through a steeply cut valley in the Safi Mountains. The Paghman River flows eastward from the Paghman Mountains and enters the Kabul River in the city of Kabul near the point where the Kabul River begins to flow east. The Logar River, a large tributary to the Kabul River, enters the study area from the south through a steeply cut valley and flows northward for about 28 km. The Logar River enters the Kabul River at the eastern edge of the city of Kabul, about 17 km downstream of the mouth of Paghman River. The Chakari River enters the study area from the south, flows northward for about 35 km, and enters the Kabul River about 6 km downstream from the mouth of the Logar River. The Panjsher River enters the study area from the north through a steeply cut valley and flows south for about 24 km, southeast for about 33 km, and finally, following the regional geologic structure, south for about 38 km, joining the Kabul River 15 km east of the study area. The Ghorband River enters the study area from the northwest through a steely cut valley after flowing east for about 54 km through the Paghman Mountains. The Ghorband River enters the Panjsher River at the point where the Panjsher River turns and flows southeast. The Barik Ab River drains the central western flanks of the Paghman Mountains, flows north to the Panjsher River, and enters the Panjsher River about 16 km downstream of the mouth of the Ghorband River. General characteristics of the Kabul, Logar, Ghorband, and Panjsher River Basins are provided by Favre and Kamal (2004). Because of the limited extent of unconsolidated sediments, where the major rivers enter or leave the study area at steeply cut valleys, groundwater inflow or outflow at the margins of the Kabul River Basin occurs/takes place (one of these two terms).

12.5 Water Use in Kabul River Basin

Water use in the Kabul Basin can be grouped into two major categories—combined municipal and domestic use, and agricultural irrigation. The amount of water used for industrial purposes is unknown but is probably much less than that used for other purposes. Water for municipal and domestic use is generally supplied by community or individual wells, which are concentrated in the more populated areas. Water use for agricultural purposes has been estimated to be at least an order of magnitude greater than that for domestic use. Agricultural use is seasonal, generally from May through September and is concentrated in the northern and western areas of the basin. Water is primarily supplied by irrigation canals from streams or karezes, which are a historical type of water-supply system common in the study area and throughout Afghanistan and other arid countries of the Middle East. A kareze consists of a dug underground conduit that intersects the water table near the top of an alluvial fan and directs groundwater discharge laterally out to irrigated land at the base of the fan.

Municipal Water Use

The city of Kabul operates municipal supply and distribution systems in parts of the city; however, limited information on municipal water systems was available for this study. The municipal systems are supplied primarily by groundwater from more than 40 supply wells, and secondarily by surface water obtained from the Qargha Reservoir in the upper Paghman River watershed. In rural areas, domestic water generally is not only supplied by shallow dug or driven wells, but also may be supplied by deeper wells, karezes, springs, or surface-water sources. The per person rate of water use in the study is not known and most likely differs considerably from rural to urban areas. Estimated per person water-use rates reported for Kabul include 40–50 L/day (Niard 2007) and 60 L/day in winter to 110 L/day in summer (Böckh 1971). Estimated per person water use in rural areas is thought to be lower than previous estimates, generally about 20–30 L/day. In 2006, municipal groundwater withdrawals in the city of Kabul were reported to be $\sim$40,000 m^3/day from few pumping centers within the city. Low estimated rates of water use such as 11 L/day by Uhl (2006) may be realistic for domestic use in the more rural areas; however, in rural areas, individuals also provide water to livestock and small gardens, and the total per person use rate for both domestic and livestock uses might be close to rates for more urban areas. With increasing security improving standard of living, future per person water-use rates may be greater than current rates.

If the per person water-use rate is assumed to be 25 L/day (0.025 m^3/day), the Kabul municipal supply system serves about one million people in the city. Shallow wells equipped with hand pumps supply local domestic water needs in many urban and rural areas throughout the Kabul Basin. The Ministry of Urban Development indicates that municipal groundwater withdrawals in the city of Kabul were expected to increase to 120,000 m^3/day in 2009 with the installation of additional planned wells. The total population in the KRB was estimated to be approximately

3.5 million in 2002 (Afghan Information Management System, written communication, 2006) with ~66% of the population (2.3 million) in the Kabul district, which includes the city of Kabul. The population is anticipated to increase by approximately 20% by the year 2012.

Between 1997 and 2005, the Danish Committee for Aid to Afghan Refugees (DACAAR) installed approximately 1,500 shallow wells (with the median depth of 22 m) in the Kabul Basin with about 1,000 of these wells in the three sub-basins of the city of Kabul (Safi and Vijselaar 2007). Of these wells with status reported, about 25% in the city of Kabul were reported as dry or inoperative, whereas about 20% in the larger Kabul Basin were reported as dry or inoperative. Water levels have declined by about 0 m since 1982 in the city of Kabul's intermountain aquifers because of increased water use (Eng. Hassan Safi, DACAAR, Afghanistan, 2005). Increasing water use has reduced groundwater levels, which in turn have led to dry wells.

Agricultural Use of Water

A simplified surface-energy balance (SSEB) method was used to estimate agricultural water use in the Kabul Basin. The method uses agricultural models and remotely sensed images of the land-surface temperature to produce 1-km gridded estimates of evapotranspiration at 8-day intervals during the growing season. Evapotranspiration is the combined transport of water from the land surface to the atmosphere as a consequence of plant transpiration and direct evaporation of surface water and near-surface soil moister. Agricultural water use occurs primarily in three areas of the Kabul Basin, and irrigation is almost entirely supplied by karezes and streamflow diversions. In the northern part of the study area, irrigation is supported by diversions from the Panjsher River and its tributaries. Although many wells have recently been installed in the Kabul Basin, the use of groundwater for irrigation is still likely to be low because of prohibitive fuel costs.

12.6 Water Quality Hazards in Kabul River Basin

Groundwater in the Kabul Basin occurs in the surficial sedimentary (Quaternary) aquifers in the bottom of the basin or sub-basins, the semi-consolidated Neogene aquifer sediments, and, to a lesser extent, the sedimentary and fractured metamorphic and crystalline bedrock of the mountains and inter-basin rides in the Kabul Basin. The primary groundwater resource used in the Kabul Basin is the surficial aquifer consisting of unconsolidated Quaternary sediments. Groundwater in the semi-consolidated Neogene aquifer sediments in 2007 had little use and is presently being investigated for future use. Few wells have been completed in the underlying bedrock aquifers, and, as a result, this aquifer is relatively unused; however, this aquifer contributes water from upland areas to the overlying sedimentary aquifers.

The primary concerns of groundwater quality of Kabul River Basin groundwater include:

i. Progressive increase of microbiological contamination such as coliform bacteria with time
ii. Progressive increase of nitrate concentrations with time
iii. Presence of elevated arsenic and fluoride concentrations

The presence of high rate of fecal coliform bacteria and high concentration level of nitrate indicates that drinking water supply from KRB is contaminated by fecal coliform (microbial pathogens) and nitrate (anthropogenic) contamination. The groundwater resources of the Kabul Basin are generally considered to be the surficial (Quaternary) sediments and consist primarily of loess, river channel sands and gravels, fan alluvium and colluviums, and unconsolidated sand and gravel.

Water quality samples were collected in the Kabul Basin in 2006 and 2007. Water collected from springs and karezes was considered to be more chemically similar to groundwater than surface-water samples collected in streams and rivers. For this reason, samples collected from springs and karezes were grouped with groundwater samples for statistical analyses. The chemical compositions of the samples of surface water and groundwater collected from the different sub-basins and regions were not significantly different from each other with the exception of samples collected from the Central sub-basin. The temperature, specific conductance, and concentrations of total dissolved solids, *Escherichia coli*, and nitrate measured in groundwater collected in the Central Kabul sub-basin were significantly greater than in samples of groundwater and surface water from all other sub-basins with the exception of surface-water samples from the Paghman and Upper Kabul and Shomali sub-basins. The Central Kabul sub-basin may receive most of its recharge from leakage from the Paghman and Kabul Rivers. In the Central Kabul sub-basin alone, there are no upland areas to supply recharge through lateral groundwater inflow.

UNICEF/MRRD did a general screening of 647 wells in July 2003 for arsenic and was found in eight wells in Logar, while in Ghazni, 43% of wells were found contaminated, and large number of wells had arsenic ranging from 10 to 500 μg/L. It puts almost 500,000 people potentially at risk.

USGS (Broshears et al. 2005; Mack et al. 2010, 2014) tested groundwater samples from Kabul Basin for pollution from human excreta. The study shows that total coliform bacteria were detected in almost all samples, *E. coli* was detected in 97% samples, nitrate was found in the range of 3.3–40.2 mg/l, and arsenic was found in few samples.

DACAAR (Safi 2011; Safi and Vihselaar 2007) conducted water quality in some provinces. Excess fluoride concentration beyond WHO limits was found in Badghis, Jawzjan, Faryab, Balkh, Kandahar, Parwan, Maidan Wardak, and Kabul. Arsenic beyond permissible range was found in Ghazni, Punsher, Logar, Paktia, Maidan Wardak, Farah, Kabul, and Faryab.

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