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Assessment of the Groundwater Quality and Pollution in Kabul City, Afghanistan

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Abstract: Kabul, the Capital of Afghanistan is counting as one of the rapidly growing cities in Asia, one-third of its population have access to the water supply network. In addition to that, the public sanitation system does not exist in the city, which leads to contamination of the groundwater in the city. However, the purpose of this study is to assess the groundwater quality and to analyze the main sources of water pollution in Kabul city. In this relation, more than 450 samples of groundwater which covers the samples from residential houses, water supply wells and public water supply system reservoirs, have been collected and analyzed for physical and biological characteristics, which reveal the existence of Total Coliform bacteria by 12.9% and Fecal Coliform bacteria by 9.6% in the groundwater of the Kabul city. Furthermore, 49 water supply wells were also investigated to find the main sources of water pollution in the city and the result discovered that 13 different sources exist that may affect the groundwater quality of the city to its greater extent.

Key words: *Water Quality, Pollution, Sources of Water Pollution, Groundwater*

INTRODUCTION

Kabul city, the capital of Afghanistan, is situated nearly 1800 meters above the sea level in the northeastern part of the country; the city is surrounded by mountains and having a cluster of basins [1]. Since 2001, Kabul city has experienced rapid population growth which reached about 4.9million people in 2015 from nearly 1.5million people in 2001 [2]. The availability of groundwater in Kabul city is estimated at 44million CuM/year which can cover nearly 2million people with an average of 50 L/day water supply rate. Though the piped water supply network covers about 27.5% of the city population, most of the Kabul people using the shallow well as the main source for the potable water [3].

However, the decline of water level due to global climate change is counting a major problem in many countries, and hence the usage of drinking water from wells will become important [4]. Thus, the groundwater level of the Kabul city has also been decreased by an average of more than 1.7m/year between 2008 and 2016 [3]. Additionally, the contamination of well water can cause serious health problems [4]. A microorganism which causes serious health problem is mainly contaminating the groundwater through concentration of wastewater, the existence of coliform bacteria indicates the presence of the microorganism in the water. Hence the water with having any coliform bacteria is deemed unsafe water for drinking purposes [5]. Meanwhile, the wastewater treatment system also does not exist in Kabul city which can cause the contamination of groundwater [3].

Nonetheless, providing a good quality of water is counting as an essential requirement for the residents. Although the number of authors has analysed the chemical properties of the groundwater quality in the Kabul city, the significance of this study is that it covers the assessment of the bacteriological properties of the Kabul city groundwater, and further discuss the main sources of water pollution. Therefore, to achieve the objective of this study, the physical and biological attribute of the water has been analysed in Kabul city. Further, this study also covers the analysis of major groundwater pollutant sources.

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LITERATURE REVIEW

Water Resources

Water is as one of the essential substances for the livelihood, however among total earth water the ocean water covers nearly 97.6% and the remaining 2.4% as a freshwater, where the liquid water constitutes 13% of the total freshwater and other 87% is in the form of ice and snow, though the surface water cover 3% and groundwater 95% of the total liquid water [5]. Besides, the groundwater and surface water is indeed the main sources for the drinking purpose [6].

Additionally, the Kabul city drinking water mostly depends on the groundwater, which is mainly taking from the aquifer and provide clean water for more than 4million people [7]. The Kabul basin, which is the primary source of the drinking water, is located in the form of the valley and contains a cluster of sub-basins, the Kohi Safi mountains located to its east and the Paghman mountains to its west [8].

The surface water of the Kabul city that stream in the Kabul basin is composed of three main rivers, The first river is the Kabul River which originates from the west side of the Kabul and takes its source from Maidan river, the second river is the Logar river which takes its source from Chak rod of Wardak province entering to the Logar and then streaming to the Kabul city, and the third river is the Paghman river which takes its sources from Paghman mountains [9]. The Paghman river, which is mainly derived from a small stream, is joining the Kabul river in the Dehmazang area, while the Logar river is connecting with the Kabul river near to the Pul Charkhi area [10]. However, the water is flowing in the mentioned river only for a few months which is mainly late winter and spring session, when snow is melting or during the rainfall [9]. Therefore, most of the time the Kabul river within Kabul city has very little water or even dry up [10].

Besides, Kabul city has a continental climate, with hot weather in summer and very cold in the winter session. The meteorological data for recent years is rare. However, the data recorded from 1956 to 1983 by World Meteorological Organization (WMO) shows the mean minimum temperature of -7.1 C^o in January and the mean maximum temperature of 32.1 C^o in July [11], [12]. Besides, the mean annual precipitation during this period was 312mm, furthermore since 1998, Afghanistan has faced drought conditions as many other countries also suffering from it, but the continuity of the drought condition in Afghanistan has reported the worst in a century [11], [12].

Water Quality

Since water is counting as an essential element of the livelihood, therefore the quality of water is significantly important. However, the definition for the word quality of water whether it is good or poor is subject to the usage of water, for instance, high nitrate water is good for irrigation that helps to grow the crops, but the high nitrate water is not safe for drinking and cause serious blood disorder in kids who called "blue baby syndrome," though the high nitrate water for irrigation is good while the high nitrate water for drinking purpose is poor [13]. Therefore, the suitability of water to maintain different types of uses and processes is called the quality of water [14].

Moreover, the quality of water whether it is good or bad depends on its physical, chemical and biological characteristics, the physical properties of water is consisting of its color, odour, and temperature, while the chemical attributes of water are the ingredients melt with the water such as nutrient, metals, gases and other organic materials, but the biological characteristics of water constitute of bacteria, viruses, insect and other tiny animals [13]. The existence of coliform bacteria in the water is counting as unsafe for drinking purposes. However, the total coliform bacteria are the total microorganism living in the digestive system of the human and animal. These microorganisms are found in sewage, soil and vegetable rot. Among these, the fecal coliform bacteria only exist in the wastewater, where the E. Coli is counting as one of the fecal coliform bacteria types; therefore, the existence of coliform bacteria in water shows the presence or melting the sewage with water [15]. Eyes cannot see most of these microorganisms, so the microscope is used by microbiologists to check the existence of microorganisms. To this end, the viruses, bacteria, protozoa, algae, and fungi are the common types of microorganism that can be found in water [16].

The diseases caused by the microorganism to the human health is considering as the serious pollution exist in the drinking water, such as cholera, hepatitis and other bacterial infections that can treat the human health are due to melting of wastewater with drinking water; therefore the quality of water depends on the presence of coliform bacteria in that, and the water having any the coliform bacteria is counting as unsafe water to the human health [5].

Water Pollution

The adverse change to the environment is called the environmental pollution, the environmental pollution or opposite environmental changes are generally occurring due to the human products by change in the form of energy, physical and chemical composition, level of radiation and great amount of bacterium, which in its turn can directly or indirectly impact the human health [17]. So, in the short term, the contamination of water that can impact human health is called water pollution. However, according to Godish [18], the idea of pollution is the decrease in the quality, leaving of pureness and opposite environmental impact.

Moreover, the source, type, and effect of water pollution are usually related to each other, and in general, there are two main types of water pollution based on their impact; First, the water pollution that can affect the human health such as viruses, bacteria, organic and inorganic chemical, and radioactive materials. While the second category of water pollution is the pollutant materials that can impact the ecosystem such as sediment, nutrient, wastage that required oxygen and thermal pollution [5], consequently, in both types of water pollution, the pollutant materials directly or indirectly affect the natural form or pureness of the water, these pollutions can considerably decrease the water quality level and harm the human health and as well as on the ecosystem.

Sources of Water Pollution

As stated above, the contamination of water that can affect human health is called water pollution; usually, several sources can pollute the water bodies such as stormwater, wastewater, agriculture runoff, waste from industries, etc. However, in general, these sources are divided into two main categories; the Point sources and the Nonpoint sources of water pollution, the difference between these two types are based on their effect and identification, so if the water contamination source is identifiable single source such as leakage of pipe then it is called the point source of water pollution, this is while if the water contaminated through large areas such as stormwater and agriculture runoff instead of single point, then it is called the nonpoint source of water pollution [5], [19].

METHODS

The study area (Kabul city) has divided into 22 districts and situated nearly 1800meter above the sea level within the Kabul province in the north eastern part of Afghanistan (Figure-1) [1]. The Kabul city located within the latitude of 34°31´ to the north and longitude of 69°12´ to the east. [2].

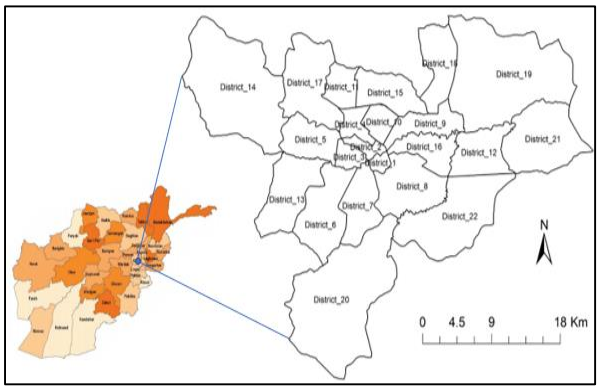

Figure 1 Kabul City Map [2], [25]

Furthermore, to analyze the physical and biological quality of the groundwater in Kabul city, the secondary data has been collected from relevant organizations. The Afghanistan Urban Water Supply and Sewerage Corporation (AUWSSC) has collected more than 450 samples of drinking water during the year 2017, which includes the water samples from wells that provide water to the city water supply network, residential houses that connected to the water supply network and water supply network reservoirs. Subsequently, these samples were tested in the AUWSSC drinking water testing laboratory for some specific physical and biological properties such as Temperature, Color, Odor, pH, Electrical Conductivity (EC), Turbidity, Total Coliform and Fecal Coliform. The results achieved from AUWSSC were further analysed by SPSS software and likewise compared with the World Health Organization (WHO) and Afghan National Standards Authority (ANSA) standards of drinking water for this study.

Additionally, for main sources of water pollution in Kabul city, the Afghanistan National Environmental Protection Agency (NEPA) has investigated 49 different water supply wells during the year 2015, 2017 and 2018 in the Kabul city, the data obtained from NEPA where further analyzed in SPSS software to calculate the major pollutant sources of the groundwater contamination in the Kabul city.

ANALYSIS

Physical and Biological assessment of the Kabul city groundwater

The biological assessment of the groundwater is showing the existence of bacteria or viruses in the water bodies; the presence of the virus in drinking water is counting as a serious threat to human health. These bacteria and viruses are mainly derived through leakage of sewage and waste to the surface and groundwater. However, the physical and biological analysis of the Kabul city groundwater is stipulated in the Table-1 below:

Table 1 Physical and Biological Assessment of the Kabul city Groundwater [15], [20]

Descriptive Statistics

	N	MIN	MAX	Mean	SD	ANSA Standard Limit	WHO
Color	456	1	1	1.00	0.0	< 15TCU	NVS
Odor	456	1	1	1.00	0.0	No Objection/ Agreeable	No Objection/ Agreeable
Temperature (°C)	456	7.40	23.80	13.86	2.98	NVS	NVS
pH	456	7.0	8.4	7.64	0.21	6.5 – 8.5	NVS
EC (µS/cm)	456	90.4	3770.0	802.11	384.89	NVS	NVS
Turbidity (NTU)	456	0.20	1.70	0.47	0.19	5 NTU	NVS
Total coliforms CFU100ml	456	0	250	15.46	47.43	Shall not be detectable in any 100ml water sample. While in case of provision of a great amount of water, where the sufficient number of samples are testing, shall not exist in 95% of the sample taken within 11 months.	Shall not be detectable in any 100ml water sample. While in case of provision of a great amount of water, where the sufficient number of samples are testing, shall not exist in 95% of the sample taken within 11 months.
Fecal coliforms CFU100ml	456	0	150	1.75	8.64		
Valid N (list wise)	456						

Minimum (MIN), Maximum (MAX), Standard Deviation (SD), Afghanistan National Standards Authority (ANSA), No Value Set (NVS), World Health Organization (WHO)

Based on the Table-1 above, the color and odor of the Kabul city groundwater are acceptable, but the coliform bacteria's in the form of Total coliform and Fecal coliforms have exceeded the standard limit set by WHO and ANSA. These standards illustrate the nonexistence of coliform bacteria in any 100ml samples of water. While there is a provision in both the standards, that in case a large amount of water is providing through the distribution system, the coliform bacteria shall not be detectable in 95% of samples for one year. This result means that the existence of coliform bacteria is allowed up to a maximum of 5% of the samples that have been tested during one year from a big water supply network.

Nevertheless, the frequency graph has been checked to determine the percentage of water samples that have coliform bacteria. So, the result shows that the Total coliform bacteria presence in 12.9% and Fecal coliform bacteria in 9.6% of the water samples tested during one year. Moreover, to find the amount of pollutant water in Kabul city, the sum of Total coliform and Fecal coliform has examined, which represents the existence of coliform bacteria in overall 12.9% of the Kabul city groundwater (Figure 2). The presence of any

form of coliform bacteria in the water is unsafe for drinking purposes due to melting the sewage with water. Therefore, it has been revealed that the Kabul city groundwater has been contaminated for about 12.9% by coliform bacteria.

Furthermore, Table-2 below describes that there is a strong positive correlation among the coliform bacteria with the pH and Turbidity. Besides, the EC has strong negative and the temperature has a positive correlation with coliform bacteria. So, it can be expressed that the biological changes in the water quality have a direct relationship with the physical characteristics of the water and any change to the biological property of water can change its physical attribute, besides it is worth to mention that pH in this analysis has nearly touched the maximum limit. Furthermore, the highest temperature of groundwater allows the microorganisms to grow in the water, while the highest EC in water is representing the highest value of the Total dissolved solid [21]. Therefore, any change in the physical characteristics of the water is an alert for identifying the change in other chemical and biological attributes of the water.

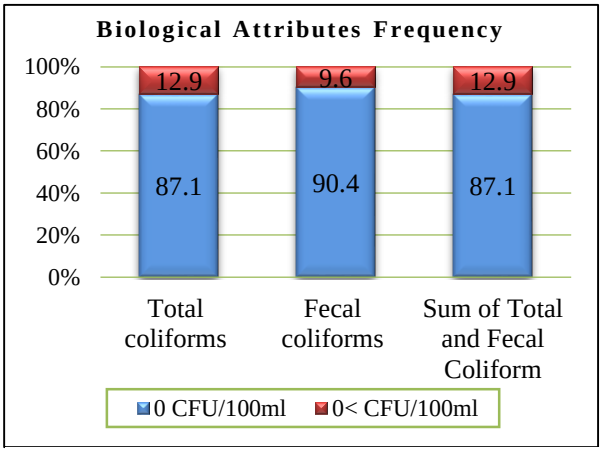

Figure 2 The Frequency of Biological Characteristics [20]

Table 2 Correlation between Physical and Biological attributes [20]

Correlations

		Temperature (°C)	pH	EC (µS/cm)	Turbidity (NTU)	Total coliforms CFU100ml	Fecal coliforms CFU100ml
Temperature (°C)	Pearson Cor	1	-.048	-.108*	.014	-.043	.096*
	Sig. (2-tailed)		.304	.022	.769	.357	.040
	N	456	456	456	456	456	456
pH	Pearson Cor	-.048	1	-.229**	.358**	.219**	.124**
	Sig. (2-tailed)	.304		.000	.000	.000	.008
	N	456	456	456	456	456	456
EC (µS/cm)	Pearson Cor	-.108*	-.229**	1	-.188**	-.241**	-.085
	Sig. (2-tailed)	.022	.000		.000	.000	.071
	N	456	456	456	456	456	456
Turbidity (NTU)	Pearson Cor	.014	.358**	-.188**	1	.531**	.324**
	Sig. (2-tailed)	.769	.000	.000		.000	.000
	N	456	456	456	456	456	456
Total coliforms CFU100ml	Pearson Cor	-.043	.219**	-.241**	.531**	1	.596**
	Sig. (2-tailed)	.357	.000	.000	.000		.000
	N	456	456	456	456	456	456
Fecal coliforms CFU100ml	Pearson Cor	.096*	.124**	-.085	.324**	.596**	1
	Sig. (2-tailed)	.040	.008	.071	.000	.000	
	N	456	456	456	456	456	456

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Pearson Correlation (Pearson Cor)

Sources of Water Pollution in Kabul city

The result achieved from analyzing the data related to main sources of water pollution revealed that 55.1% of the total surveyed wells were active and provides water to the city water supply network, while the remaining

Table 3 Status of Water Wells [22]–[24]

Status

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not Active	22	44.9	44.9	44.9
	Active	27	55.1	55.1	100.0
	Total	49	100.0	100.0	

44.9% were not active at the time of survey or dry up due to the decrease of the groundwater level (Table 3). In addition to that, the data analysis also revealed, that 13 different sources of water pollution contribute to the contamination of groundwater to its highest extent such as; septic tank, irrigation of fertilization in the field, solid waste, filling of ditch with waste, oil from pump station, waste in the river, stagnant, polluted water, pit latrine, irrigation well filled with waste, etc. (Table 4 & Figure 3). These sources of water pollution exist near to the water wells and in general, in the entire city, they can be known as the main pollutant sources for the Kabul city groundwater, which consist of both; Point sources and Non-point sources of water pollution. The nonexistence of the proper sewerage system and its treatment, and the limited water supply network in the city are the main causes for these water pollutant sources that contaminate the groundwater of the Kabul city.

Table 4 Sources of Water Pollution in Kabul city [22]–[24]

Pollution Frequencies				
		Responses		Percent of Cases
		N	Percent	
Main Sources of Water Pollution in Kabul City[a]	Sewage Canal	15	8.1%	30.6%
	Irrigation Well	20	10.8%	40.8%
	Absorbed well/Septic Tank	49	26.3%	100.0%
	Irrigation Field	45	24.2%	91.8%
	Ditch	11	5.9%	22.4%
	Stagnant Water	1	0.5%	2.0%
	Solid Waste	4	2.2%	8.2%
	Pump Station	13	7.0%	26.5%
	Pit Latrine	4	2.2%	8.2%
	Waste in River	12	6.5%	24.5%
	Animal Waste	2	1.1%	4.1%
	Car Wash	1	0.5%	2.0%
	Drainage	9	4.8%	18.4%
Total		186	100.0%	379.6%
a. Dichotomy group tabulated at value 1.				

Based on Table-4 and Figure-3 above, the most serious pollutant sources in the Kabul city are the absorbed well of wastewater or septic tank which exists in all 49 investigated water wells and contributes 26.3% in total water pollution of the Kabul city. Besides, the irrigation of fertilization in the field is counting as the second serious pollutant sources which presence in 45 investigated water wells and have a share of 24.2% of the total water pollution in Kabul city. Additionally, the sewage canal, irrigation well filled with waste, the ditch filled with waste, oil from the pump station, existence of waste in the river and the urban drainage having the

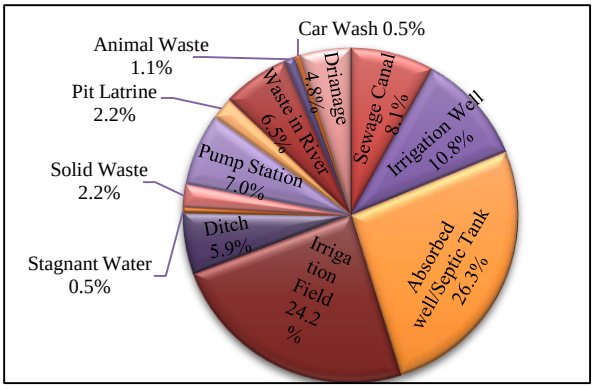

Figure 3 Sources of Water Pollution in Kabul City [22]–[24]

waste are counting as the third serious pollution sources which ranged between 4.8% to 10.8% of total contribution in the water pollution while the influence of stagnant water, solid waste, pit latrine, animal waste, and car wash are very less between 0.5% to 2.2%.

FINDING AND RECOMMENDATIONS

The assessment of the Kabul city groundwater quality shows that the coliform bacteria's in the form of Total and Fecal coliform exist in 12.9% of the total water sample tested. However, the presence of coliform bacteria in the water is mainly due to the melting of wastewater with the water and thus, any water having the coliform bacteria is counting as unsafe for drinking purposes. Further, the analysis of the groundwater pollution sources revealed that 13 different sources contaminate water; among these the major pollutant sources are the absorbed well/septic tank and irrigation field fertilization. Therefore, increasing access to water supply network will help in reducing the usage of shallow well water for drinking purpose. Also, to protect the groundwater from absorption of sewerage its recommended to construct a centralized sewerage system and its treatment or to consider the isolation of septic tank. Besides, public awareness programs are also playing a major role in protecting human health.

CONCLUSION

The analysis of groundwater quality of the Kabul city by assessing more than 450 water samples from the water supply network wells, residential houses and public water supply system reservoirs revealed that the Total coliform bacteria about 12.9% and Fecal coliform bacteria nearly 9.6% have exceeded from the WHO limit set for the drinking water. Both the coliform bacteria collectively contribute to the pollution of the Kabul city groundwater by 12.9%, which is counting as unsafe for

drinking purposes. The presence of coliform bacteria in the water is mainly due to the melting of sewage with water bodies. However, the analysis of 49 water supply wells in Kabul city has been determined that 13 different pollutant sources play a major role in the Kabul city groundwater contamination. The most significance is the septic tank and irrigation field fertilization, whereas the rest other pollutant sources also associate with them. The leakage of wastewater from the septic tank will cause to increase the coliform bacteria in the water, which can cause a serious health threat to the human. Therefore, the construction of the sewerage system and its treatment, increase access to the water supply network and public awareness are required to control the groundwater quality of the Kabul city further.

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