ISSN 2229-5518

Environmental Impacts on Groundwater of Wadi Bani Malik, Jeddah, Saudi Arabia

[1*]Hassan M. Saleem, [2]Ali M. Subyani, [3]Amro Elfeki

Abstract: Groundwater resources are precious everywhere for agriculture and human activities, especiallly where no rivers or surface water. Groundwater may be subject to contamination through the natural impact of the quality of the water bearing formation or human activities. Wadi Bani Malik, located in Jeddah city of Saudi Arabia, is exposed to environmental degradation as a result of the dumping of waste and sewage for more than 20 years. This study aims to detect the contaminants movement and to find the environmental impact of groundwater of the study area. The degree of pollution is recognized from the analysis of the toxic and trace elements of groundwater in the basin. The results show that sulfur, boron, arsenic, lithium, and barium analysis are in high concentration that exceeds the maximum acceptable level due to the disposal of sewage dumping in the basin.

Keywords: Contamination, Groundwater, Environmental Impact, Wadi Bani Malik, Saudi Arabia

1 Introduction

In the broadcast sense, all sources of groundwater contamination and contaminants themselves can be grouped into two categories: naturally occurring and/or artificial (human-made). Although some natural contaminants (trace elements), such as arsenic, fluoride, mercury and radioactivity materials such as uranium and strontium, may have a significant, local or regional impact on groundwater supplies depending on geology and aquifer materials. Numerous human-made sources and contaminants have disproportionately greater negative effects on quality of groundwater resources. Accordingly, almost every human activity has a potential to affect groundwater to some extent. An exponential advancement of analytical organic chemicals is widely distributed in the environment, including in groundwater, and that a considerable number of them can now be found in human tissue and organs of people living in the world. Strongly related to the ever-increasing public awareness of the environmental pollution is a very rapid growth in consumption of water resources [1].

In the arid region, such as Saudi Arabia, groundwater, in shallow or deep aquifers, is the main water resources for different human activities. For instance, irrigation, industrial and bottled drinking [2]. Consequently, it is an important issue to conserve this strategic resource. In Jeddah governate, located in western Saudi Arabia, the rapid expansion in land use and human activity have been taking place since the 1960's. The main factor, which causes the population growth, is the water resource availability. This condition probably drags the attention to increase the commercial growth in Jeddah.
to increase the commercial growth in Jeddah.

[1] Grad St. Hydrogeology Dept., King Abdulaziz University,
E-mail: hassansaleem32@gmail.com
* Corresponding Author
[2] Professor of Hydrogeology, King Abdulaziz University,
E-mail asubyani@kau.edu.sa
[3] Professor of Hydrology and Water Resources,
King Abdulaziz University.
E-mail: elfaki_amr@yahoo.com

Therefore, there are many environmental issues related to not only water pollution but also the air, land and the marine pollutions because of the increase of population. [3].

In late 1990's, due to the absence of sewage network system, most of the households using septic tanks because more than 2/3 of the city area does not have the connection to the central sewage treatment facilities. Sewage is transported by trucks and disposed at pilled lakes to the upstream area or simply in the desert. The main problems are the capacity of the present lake/disposal site has risen to maximum levels and a new location is being installed near Briman (Al-Musk Lake).
In 2011, the lake was dried and no more dumping in the lake. However, this non-point source of contaminations was moved and dispersed in groundwater in unconfined alluvial and fractured aquifer of Wadi Bani Malik (Al-Asla) towards the populated areas and shoreline of the Red Sea. The aim of this study is to detect the contaminants movement and to find the environmental impact of groundwater of the study area.

Groundwater pollution is a global problem. Moreover, it is the most challenging disaster that threatening the human life and the environment.
Internationally, according to [4] nearly 60% of China's underground water is polluted, state media has reported, underscoring the severity of the country's environmental woes. The country's land and resources ministry found that among 4,778 testing spots in 203 cities, 44% had "relatively poor" underground water quality; the groundwater in another 15.7% tested as "very poor". A toxic investigation program conducted by [5] stated that wastewater plume in a pheriatic aquifer in Massachusetts. The contaminant plume is more than 4 km long consists of chlorinated hydrocarbons, detergents, metals, nitrate, and microbes. A test on a large-scale tracer experiments has shows the principle of the heterogeneous nature of contaminant plumes. The observed data are contributed to develop models that allow scientists to develop remediation plans, to understand the the mechanical dispersion of contaminants in groundwater and to estimate the travil time of the plumes in sewage degrade

to less toxic compounds. These methods are being used at other contaminated sites nationwide.

For the local study, in terms of risk analysis, leakage from water supply systems mixed with sewage water, which cause the rises of groundwater. Degradation of water quality becomes a danger for the city infrastructures. Moreover, this condition may lead to high potential flood at the different area in the city [6].

The area of Al Musk Lake has been investigated much time for various studies. Ewea in 2010 [7] investigated the area's flood potential and the associated hazards for several return periods using a conceptual model for estimating the effectiveness associated with AL Musk Lake. He suggested that the integrated management of the Al Musk Lake be applied to reduce the hazards to the environment.

Another investigation was done by [8] using solute transport model to estimate the expected travel time of 50 years for the groundwater contamination plume under the condition of point (continuous) source point of untreated sewage at Al Musk Lake downward to the Red Sea. They suggested two predictive scenarios of the plume distribution, the first scenario was the flow through the confined aquifer and the second was through an unconfined aquifer. The result predicted that the fate of contamination arrives to the Red Sea in less time in the confined aquifer than that in the alluvial aquifer.

Finally, a recent study conducted by [9] in Al-Musk Lake, stated that the high value of electrical conductivity is an indicator to characterize a plume originating at the waste disposal facility. They found boron in high concentration since it is commonly used in detergents. Therefore, they focus on the spatial distribution of boron in the alluvial aquifer, which subjected to sewage waste contamination.

2 Study Area

2.1 Geographical Setting

The study area is located in Wadi Bani Malik, east of the city of Jeddah in the upstream of the mountainous area covers an area of about 519 square kilometers of alluvial (unconfined) aquifer as shown in fig1. This is the main structure in the area in due to the long extending and large basin in the upstream area. The lower part of the wadi consists of a small channel with a lateral streams near joined at the outlet. The middle segment of the wadi also includes small streams branches that contact with the main stream channel of the Wadi . From the main part channel at the middle and mountaneous area all, these small streams flow in the main channel of the Wadi. The catchment area is characterized as mushroom-shaped, with elongated branches formed of straight channels. At the upper-part of the basin, the system shows a a uniforme pattern, a semi-rectangular pattern at the area lying more than 7 km east of the beach and the rest of the basin. The drainage branching ranges between very low at the western zone to moderate at the central zone to low [10]. Al Musk Lake is formed in the upstream part of the area of Wadi Bani Malik (or Wadi AlAsla in some references), this lake is a dumpster area for most of the sewage that disposed of the tankers. The lake is located 30 km away from the red sea coast to the east. Exactly, the lake size is relatively enormous as some and it could cause a massive impact on both the human life and the environment. Roughly, 1200 trailers dump sewage water every day, which makes the lake extend its size dramatically. Over 36000 cubic meters per day of the sewage, water was being disposed of in the lake.

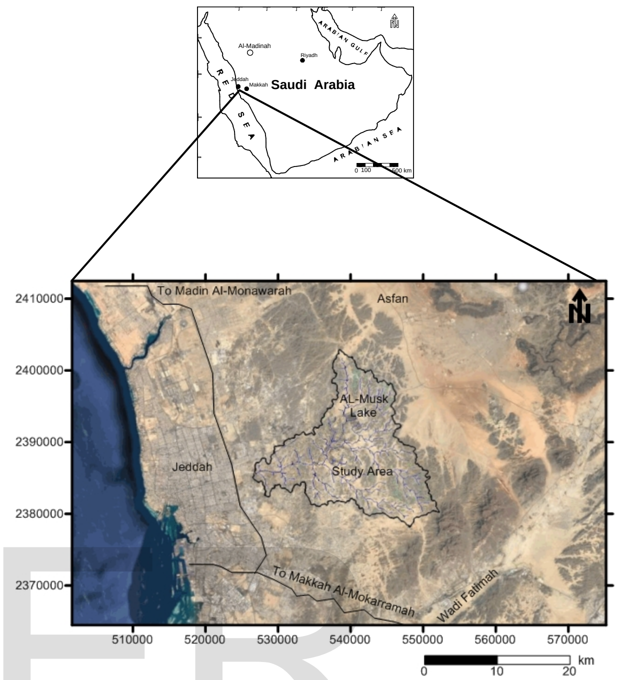

Fig. 1. Location map of study area.

2.2 Geology

Geologically, Wadi Bani Malik basin is occupied by Precambrian Arabian Shield rocks and quaternary deposits fig2. In the study area, there are two major rock complexes:

Dighbij complex characterized by massive to weakly foliated, fine-to coarse-rained.

Hafnah complex is named after Wadi Al-Hafna north of Wadi Al-Asla. There are three types of its rocks in the study areas: Trondhjemite (khtj) with small intrusions of trondhjemite cut tonalite. Hornblend-diorite tonlite (khtt) cavernous and exfoliated outcrops are characteristic of a mainly uniform, medium-grained rock that displays primary igneous, hypidiomorphic-granular textures. Hornblend tonalite (khtn) the tonalite is a generally uniform, medium- to coarse-grained, pink to greenish-gray, equigranular rock with a hypidiomorphic igneous texture. The outcrops have moderate relief.

Finally, Alluvial fan deposits (Qa) the non-terraced alluvial-fan deposits have a similar distribution to the terraced variety and indicate the pluvial period had two separate phases of increased run-off. On the coastal plain north of Jeddah, they consist of moderately sorted gravels with clasts less than 10 cm in size in a sandy matrix. They are overlapped by the flood-plain deposits (included in the map unit (Qu) of the modern drainage system [11].

ISSN 2229-5518

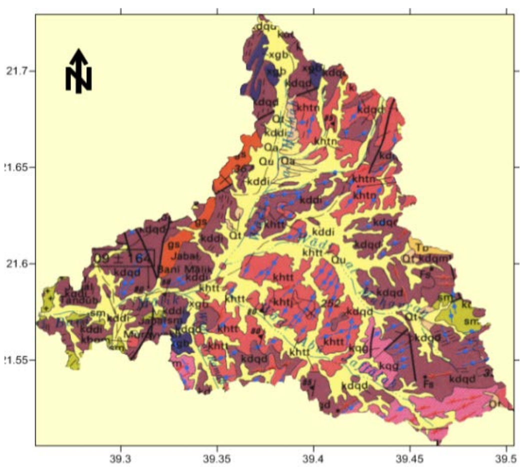

Fig. 2. Geology of the study area.

3 MATERIALS AND METHODS

3.1 MORPHOMETRIC PARAMETERS

The study area geomorphological characteristic was determined from the analysis of Digital Elevation Model data (DEM) of 30 m resolution. This data was run by delineation in Watershed Model System (WMS, v.10). fig 3 shows the most of the morphometric parameters of the basin and streams.

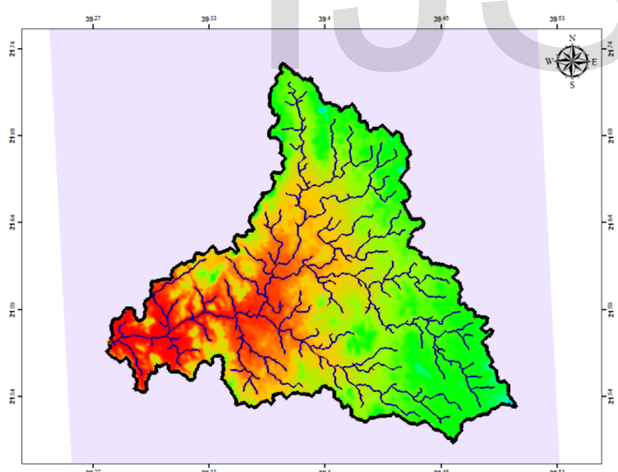

Fig. 3 . Drainage map of study area.

3.2 TOXIC ELEMENTS ANALYSIS

21 groundwater samples were collected from local large diameter wells, at depth ranged from 5 to 15 m. (Fig. 4.) The samples carried to the Water Center at the KAU for analyzing four trace elements and one secondary toxic element. These elements are; Sulfur (S), Boron (B), Barium (Ba), Lithium (Li) and Arsenic (As). The reason for focusing on these elements specifically is that these trace elements are considered as the most toxic component of contamination in the groundwater.

4 RESULTS AND DISCUSSION

The hydrology data of the catchment area was estimated from outdated DEM data since the study area exposed too many changes Table 1. Excavations fig4 and concrete factories were established recently, which take the advantage of the area in terms of drilling and storing supplies for the factories that affect and changes the characteristics of the area. These changes occur on the Wadi channels, the sedimentary bedrock stresses as consequences changing the surface by changing the main streams channels and the groundwater flow directions. The local geological structures and the morphology of the channels have been altered significantly and changed to buildings and roads, which causing floods to occur in the drainages threatening the city. More than 2/3 of the city area does not have a connection to the central sewage treatment facilities. Most of the developments are located in the north districts of the city [12]. Sewage is transported by trucks and disposed at pilled lakes to the upstream area eastern of Jeddah. On-site disposal is done in deep boreholes, as septic tanks which affecting the groundwater system. These disposal practices causing the level of the ground water to rise in north Jeddah and the groundwater is being contaminated due to the activity of supply of wastewater. The problem will continue to increase with population growth. It will cause a hazard on people life in north and east of Jeddah. With increase rises in the groundwater. The rise in groundwater levels will reduce the efficiency of the polar-site septic and leaching facilities. As result, there is a greater potential for the plume (contamination) to move with the groundwater flow direction to the central areas of Jeddah [13]. Al-Musk Lake has been adopted as disposal site for Jeddah city since late 90's up to 2011 Fig. 5. The results of toxic elements are listed in Table 2.

Table 1. Morphometric parameters of Wadi Bani Malik.

Parameter	Value	Unit
Basin area (A)	290	km^2
Basin Slope (BS)	0.06	
North aspect ratio (NF)	0.50	%
Basin Length (Lb)	26.08	km
Basin Perimeter (Pb)	141.83	km
Shape Factor (Ec)	2.36	
Sinuosity Factor (Sin)	1.42	msl/l
Mean Basin Elevation.	144.65	m
Maximum Stream Length (Cm)	37	km
Maximum Stream Slope (MSS)	0.01	
Centroid Stream Distance (CSD)	19.4	km
Centroid Stream Slope (CSS)	0.00	
Total Stream Length (CT)	280.3	km
Relief (Hb)	260.00	m
Drainage density (Dd)	0.97	
Basin elongation (E)	0.65	

Fig. 4. Excavations in the study area.

Fig. 5. Sewage wtare expose in the study area.

Table 2. Toxic elements results in the study area.

Sample Name	B mg/L	Ba mg/L	Li mg/L	As mg/L	S mg/L
B-1	5.73	0.257	0.144	2.19	966
B-2	4.69	0.253	0.237	3.3	680
B-3	9.79	0.144	0.686	7.55	1740
B-4	4.32	0.161	0.579	5.78	729
B-5	19.4	0.287	1	9.64	1780
B-6	8.39	0.0842	0.621	5.76	1300
B-7	7.09	0.086	0.522	4.85	1170
B-8	16.9	0.245	18.15	6.26	1440
B-9	10.1	0.25	1.33	5.46	912
B-10	3.81	0.018	1.29	4.73	649
B-11	11.1	0.377	3.11	7.6	663
B-12	10.5	0.176	2.36	7.16	796
B-13	9.34	0.077	0.73	3.88	1010
B-14	6.11	BDL	0.49	1.92	602
B-15	18.7	0.121	0.981	6.02	2380
B-16	1.53	0.043	0.386	1.66	168
B-17	3.51	BDL	0.423	2.36	589
B-18	6.01	0.02	0.43	2.72	836
B-19	4	0.118	0.591	4.24	985
B-20	2.6	BDL	0.282	1.69	380
LK	1.01	0.149	0.188	0.881	45.1
MAX	**19.4**	**0.377**	**18.15**	**9.64**	**2380**
MIN	**0.559**	**0.018**	**0.094**	**0.098**	**37.9**
MEAN	**6.18**	**0.14**	**1.22**	**3.421**	**749.9**
SDV	**5.15**	**0.097**	**3.21**	**2.65**	**573.9**

Sulfur occurs naturally in soils, rocks, and minerals. In groundwater comes in contact with these solid materials dissolving them, releasing their constituents, including sulfur, to the water. According [13] as a secondary standard, sulfur above the 250 mg/L level, can impart a taste to the water and, depend on the individual, may have a laxative effect. In this study, sulfur found in a high concentration of all elements ranged from 2380 to more than 37 mg/l. This is because sulfur is one of the main components of the sewage water.

The second reason, these elements used as an indicator guide for the constitutes of sewage water especially boron. Boron is interact as an indicator of the sewage waste which is exsisting in a high concentration in untreated sewage water than in the uncontaminated groundwater [12]. That is, boron is much higher than the maximum acceptable range in groundwater or even the natural presence of geochemical process. According to a scientific investigation report from the [8], the concentrations of boron greater than the 900 µg/l need for removal action level (RAL) standard. The RAL only regulates human-affected concentrations of a constituent. In the model, boron reflects high concentration rate of increasing during the period of disposal of the value of by the time of the end of 201. That is the rate of change in Al-Musk Lake for boron was assumed to be 0.007 mg/l/year. This high value can be recognized in sample B-7 with a value of 7.09 mg/l. While it shows decay in concentration as long as moving downstream away from the source point, which sample B-1 with value of 1.7 mg/l.
EPA administration approved the new 10 ppb arsenic standard and it's original in January 2006. Arsenic also shows high concentration. With 0.0045 mg/l/year factor showed decay from B-7 with value of 4.85 mg/l to 1.1 mg/l in B-1.

The fourth toxic element in term of low concentration compared to other measured trace elements is lithium that shows in the model a value ranged from mg/l to mg/l in B-7 and B-1 respectively, with the concentration rate of change of 0.00056 mg/l/year.

Barium is another toxic trace element found in high concentration in the study area. The EPA sets a maximum limit for barium in public drinking water supplies to 2 parts per million (ppm). When people are exposed to barium for short periods at levels above the maximum contaminant level, they may experience gastrointestinal disturbances and muscular weakness [14]. Barium is lower concentration compared to other trace elements. In the model, the rate of change in concentration assumed to be 0.0003 mg/l/year. The Higher value was mg/l and the lower value was mg/l both are in B-7 and B-1 respectively. However, barium is also considered out of the limit of acceptable ranges.

5 CONCLUSION

1. This area subjected to the environmental hazard, and groundwater is the most venerable for the pollution. This pollution can be recognized from the analysis of the toxic and trace elements.

2. The concentration of sulfur recorded the highest concentration in groundwater, with values ranged from 2380 to 38 mg/l.

3. Since boron is the main indicator for a human waist, it showed high concentration in most of the groundwater samples that exceeded the maximum acceptable levels standers.

4. Other toxic elements such as arsenic, lithium, and barium are also exceeding the standard level. This basin needs a comprehensive assessment and sustainable management of groundwater for future development.

REFERENCES

[1] Neven Kresic, "Hydrogeology and Groundwater Modeling," second edition pp. 405-410, 2007

[2] Ministry of Environment, Water & Agriculture 2000

[3] General Department of Environmental Health, 2016

[4] Kaiman, 2014

[5] USGS, "Evaluation of Ground-Water and Boron Sources by Use of Boron Stable-Isotope Ratios, Tritium, and Selected Water-Chemistry Constituents near Beverly Shores, Northwestern Indiana," 2004

[6] Al-Sefry and Şen, "Groundwater rise problem and risk evaluation in major cities of arid lands-Jeddah Case in Kingdom of Saudi Arabia," 2005. DOI: 10.1007/s11269-006-4636-2

[7] Ewea in "INTERPRETATION OF GROUNDWATER CHEMISTRY DATA USING MULTIVARIATE STATISTICAL TECHNIQUES," 2016. Global NEST Journal, Vol 18, No 3, pp 665-673,

[8] Elfeki et.al, "Linking Groundwater Flow and Transport Models, GIS Technology, Satellite Images and Uncertainty Quantification for Decision Maing:Buraiman Lake Case Study Jeddah, Saudi Arabia," 2011. 295-303, 2011 ISSN 2079-7079

[9] Rahman and Cheema, "Effects of sewage waste disposal on the groundwater quality and agricultural potential of a floodplain near Jeddah, Saudi Arabia," 2016, DOI 10.1007/s12517-016-2340-y

[10] H.T Qari, "Geomorphology of Jeddah Governate, with Emphasis onDrainage Systems," Jan 2008

[11] Mooro and Al-Rehaili, " Geological Map of the Makkah Quadrangle, sheet 21D. Kingdom of Saudi Arabia," 1989

[12] General Department Of Environmental Health (GDEH), July 2016, https://seha.alriyadh.gov.sa/Eng/Details.aspx?UGFnZT1hZHMmSUQ9Mzc=

[13] EPA, "Arsenic contamination of groundwater," 2006 & "Drinking Water Advisory: Consumer Acceptability Advice and Health Effects Analysis on Sulfate," 1984

[14] Water Systems Council (WSC), 2011https://www.watersystemscouncil.org/