Groundwater Contamination: A Brief Review for Pakistan and Saudi Arabia

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Abstract

This study presents a brief review on groundwater contamination, its causes and effects. The groundwater is contaminated by various sources. However two major sources, domestic sewage and industrial waste are discussed. The improper management of domestic wastewater and industrial effluents is responsible for deterioration of groundwater quality and human health hazards. The status of groundwater contamination in major cities of two countries Pakistan and Saudi Arabia is discussed. Both countries are suffering from groundwater contamination issues. In Pakistan most of population is deprived of clean drinking water because of contamination of groundwater water reserves. There are close similarities between Saudi Arabia and Pakistan as far as the contamination and the constantly declining quality of groundwater is concerned. The colossal amalgamation of wastewater from domestic and industrial sources with groundwater resources is causing a concentration of hazardous substances, like heavy metals, which eventually leads to poor human health Issues. It's the dire need of the hour that the water reserves left underground should be saved from being contaminated.

Keywords

Groundwater, pollutants, domestic affluent, industrial waste

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Introduction

Water is the most inevitable of the essentials responsible for the continuity of human life and nature grants the right to safe and clean drinking water to every human being on earth (Meride and Ayenew, 2016). Unfortunately, a considerably large number of population is deprived of this right and the developing countries crowd the list. As a matter of fact, the impure unclean drinking water and poor sanitation system is hosting multitudinous diseases in these countries. Moreover, 946 million individuals are unable to approach clean drinking water (WWDR, 2009). The growing population, environmental changes and an unplanned urbanization will further result into the scarcity of water in the coming years. In the developing countries, especially in Sub-Sharan African countries, nearly 884 million individuals fail to access safe drinking water (Renaud et al., 2010). Though water is inevitable to life on planet earth yet, the mankind is faced up with the horrendous issues of water scarcity and contamination and sadly enough, despite the global scientific and technological advancement these issues are expanding beyond the control of human beings. To substantiate, for instance, nitrate contamination, an offspring of agribusiness is the biggest source to pollute the groundwater (Li et al., 2016).

For a large number of people, groundwater is the most precious water asset for drinking and other needs, especially for the dry areas with low precipitation and surface water (Li et al. 2014). There are various factors responsible for diminishing groundwater and destroying its quality, including the global climatic changes, anthropogenic exercises, and poor groundwater administration, that has risked the life in general and human well being in particular (Han et al., 2016; Wu and Sun 2016). The ecological transitions coupled with the human activities are the major factors to ruin water sources. In a pursuit to speedy improvement in economy and a robust human development, the actions taken are actually having a more negative impact on water reserves. The groundwater which is actually a dynamically great asset of nature is awfully affected by rapid industrialization, urbanization and advances in water system. Thus, it’s now inescapable that this phenomenon of water scarcity and deterioration of this asset should be observed and moderated respectively (Du et al. 2016).

It's obvious that the public health, environment would face a great setback and the future economic development will undergo a halt if the quality of water is not managed appropriately. Ultimately this poses an irreversible harm to society in terms of poor health and life threatening diseases (Pius et al. 2012). Long term use of contaminated water is detrimental to human health and it is backed up by several studies. The aforementioned factor makes it even more critical to improve the quality of water. The access to clean drinking water is greatly significant to achieve many of the millennium goals set by UN, despite the fact that only one of these goals (related to ecological sustainability) aims at resolving water related issues (Li et al., 2017).

Causes and Effects of Groundwater Contamination

Water, combination of hydrogen and oxygen has transformed into a giant issue of present day's human world. It's a most valuable resource, ruined by people irrationally. The issue of non-accessibility of safe drinking water has accumulated so much weight that it appears to go past the forces of human beings. These circumstances keep on becoming disturbing. In excess of 800 million individuals don't have the nourishment and water to satisfy their requirement. Consistently the total population is expanding around 80 million every year and approximately 64 billion cubic meters freshwater is required for this growth annually. The amount of untreated contaminated water disposed off to fresh waters is approximately two million ton which dirties the water assets (WWDR, 2009).

The groundwater has its existence in the fractures of soil/rocks, within the subsurface or it is generated from the ground. The human activities, largely, are to be held responsible for groundwater contamination. The natural processes like recharging waters, rocks in subsurface through which water flows, groundwater flow rate and water interaction with subsurface rocks are important to determine the quality of groundwater (Helena et al. 2000). The groundwater sources are easy prey to contamination in densely populated areas. The chemical and biological composition of water contaminants determines the extent of their absorption into the environment (Sharma et al., 2014).

The sewage "vital contaminants", fatal to human health are the common material in the sewerage system. These substances known as TDS (totally dissolved substances) include different metals like mercury nickel, zinc, lead, copper, arsenic, and cadmium. The micronutrients absorbed by plants, which include chromium, zinc, and copper, are preserved by their roots. The excess of these metals turn into toxins in plants. TDS get very harmful as they are related to electric conductivity and hence entirely dissolved in water. The socioeconomic attitude of the population determines the quantity and quality of the wastewater from household. However, chemical, biological and physical configuration of water is helpful to categorize the wastewater. On physical basis, there are two categories of waste water i.e., the grey water that is drained from bath, laundry and kitchen sinks, and the black water (from toilets). Analyzing chemically, waste water contains organic and inorganic substances. The domestic wastewater is dependent upon socioeconomic attitude of the population (Tjandraatmadja & Diaper, 2006).

Every year, disposal of untreated sewage water into lakes, coastal areas and streams, results in various harmful diseases in individuals. In developing nations around 90% of sewage water released in the surface water without any treatment contaminates the fresh water resources. Approximately wastewater generation globally is around 1500km^3. Approximately one liter of wastewater is contaminating eight liter of freshwater. Around 50% of the developing nations exposed to dirtied water. The poor people are mostly affected by this contaminated water, which is the most widely recognized reason for waterborne diseases and deaths (WWDR, 2009).

The death toll ranges from 1.6 to 2.5 million people every year because of waterborne diseases (WWDR, 2006). The death rate can be decreased by one-tenth worldwide by improving the water quality (WWDR, 2009). Each year swimming in contaminated waters causes around 1.8 to 3.5 million people groups turn out to be sick (Dorfman et al., 2004). Historically United States faced this issue. In 1993 around 403,000 turned out to be sick in Milwaukee city because of contaminated water. China likewise USA, faced contaminated wastewater issue. In few months around 1,547 individuals were sick and around 468 passed on in Hongkong and Shanghai. The entire world is confronting an issue of water contamination and water is turning into a basic crucial issue (Rehman & Rehman 2014).

Domestic Wastewater

Water is a standout amongst the most basic factor for presence of life and most indispensable common asset. Around 2 million tons of waste water originates from various agricultural, industrial and domestic sources every day. It is estimated that around 80% sewage wastewater is released specifically into the streams, lakes, and surface waters without any treatment in developing nations. This phenomenon results in primary driver of waterborne death in these nations (WWDR, 2009). Domestic wastewater is classified as grey and dark water. Water which is contaminated with excrements and originates from the toilets is termed as dark water. The wastewater from kitchens, washrooms, or laundries is called grey water (Tarasenko, 2009). The wastewater from households is related with the substances employed by the householder. The stuff utilized by the householders can generate contaminants comprised of different metals like lead, antimony, zinc, chloride, molybdenum, cobalt and nickel while alternate activities, for example, dishwashing can generate boron, selenium arsenic, cadmium, chromium, tin and sodium contaminates. The iron and fluoride contaminates normally originates from tap water (Tjandraatmadja and Diaper, 2006).

The contaminants in domestic wastewater can be classified into three classes: organic contaminants, inorganic supplements and suspended solids. The organic and inorganic substances may be incorporated as suspended and dissolved solids. Organic part of wastewater comprises of fats and oils 10%, carbohydrates 40%, protein 50% and traces of other pollutants. Approximately 103 to 104 fecal streptococci, 105 to 108 colony forming units, 101 to 102 virus particles and 101 to 103 protozoan cyst contributes to the biological composition. The primary sources of contamination of groundwater are comprised of landfills leachate, industrial and agrarian contamination and Human or animal sewage (Rehman and Rehman 2014).

Typically household sewage comprise of around 0.1-0.2% TDS and 99.8-99.9% water, however this little measure of contaminants make very large alterations in utilization of water. Municipal wastewater characteristic includes physical properties, biological and chemical constituents. The Physical characteristics include odour, colour, temperature and solids. The chemical constituents consist of inorganic/organic contaminants and gases. Microorganisms, viruses, protozoa and plants fragments constitute biological components. The basic contaminants are comprised of heavy metals, suspended solids and pathogens (Harris et al., 1996).

The organic contaminants in household sewage water weight approximately 45-58% of total weight of contaminated water and comprise of fats, carbohydrates, and proteins (Tarasenko 2009). The dissolved fractions and suspended solids may incorporate both organic and inorganic material. The organic contaminants comprised of domestic pesticides, detergents, animal steroids and food additives. The physical or physiochemical wastewater treatments methods can be used effectively to remove suspended fractions (Rehman and Rehman 2014).

The domestic sewage water contains bacteria, helminths, viruses, protozoa, which are among common types of organisms causing different diseases. Biological constituents comprised of roughly 10^3 to 10^4 fecal streptococci, 10^1 to 10^2 virus particles, 10^1 to 10^3 protozoan cyst and 10^5 to 10^8 colony forming units (Shon et al., 2006). The major sources of biological contamination consist of agricultural pollutants, leachate from sanitary landfills and human or animal sewage (Al-Harthi, 2001). The viruses and bacteria responsible for diseases are probably transferred from animal to animals and from animal to human and often expelled in faeces and urine (Pal et al., 2010). The total suspended solids in sewage wastewater comprises of suspended inorganic or organic fragments. The sunlight is blocked due to these suspended solids when they are in high concentration to aquatic vegetation. The phosphorous and nitrogen, common surface water contaminants, originates from detergents chemical conditioners, and human wastes (Wang et al., 2007). The eutrophication condition occurs when large amounts of nutrients released in the water which results in reduced sunlight penetration all oxygen amount in water (Harris et al., 1996).

The human activities identified for discharge of heavy metal to bio sphere includes pesticides farming, sewage, burning of hydrocarbons, mining wastes, industrial productions and transport. Though the municipal waste water contains a little amount of metals ,yet the toxic metals like cadmium and lead, which are a gigantic hazard to human health are still present in it, eventually making this water lethal for living beings as these toxins rapidly mount up in the body but their removal from the body is not fast paced. The main source of the intake of these metals into body is breathing ingestion and skin absorption. A high concentration of these metals in human body is believed to cause the diseases commonly identified with kidney, bones and cardio. Animals suffer from genes mutation, and production of tumors in their bodies because of excessive amount of these substances (Khan et al., 2015).

Industrial Waste

Accelerated developments in modern technology and industrialization are major contributing factor of groundwater contamination. Highly toxic metals are present in industrial wastes, which are extremely harmful to humans. Different industries discharge different types of pollutants, which include organic, inorganic substances and heavy metals. The electroplating industries are most important distributor of heavy metals pollutants. The heavy metals discharge by metal working industries includes zinc, lead, titanium, nickel, iron and chromium. The paper manufacturing related industries discharge dioxins, organic, and suspended solids. Mineral oils and phenols are mainly discharged by petrochemical industries. Food processing plants effluents include organic material and suspended solids (Yi, 2009).

Rapid industrialization is responsible for high levels of trace metals in groundwater. There are many extremely harmful elements discharged into soil and water bodies without any treatment which result in serious effects on human health (Rehman and Rehman, 2014). The elements include mercury, arsenic, Cd, lead, copper, and chromium. Small amounts of some of these metals are necessary for life some have no biological effect. However, large doses of all are highly toxic (Jaishankar et al., 2014). The semi-solid waste and effluents disposal in nearby site and water bodies by industries into has ruined groundwater resources (Kataria et al., 2017).

These polluting industries include electroplating facilities, printing and dyeing industry and paper manufacturing industry, which are responsible for organic and inorganic compounds containing pesticides, pathogens, textiles dyes, and toxic heavy metals pollutants discharge. (Zang and Chen, 2015). The Chromium metal (Cr) and its salts are used in various industries. The major industrial processes include ceramic and glass manufacturing, manufacture of catalysts, paints, leather tanning, fungicides, pigments, chrome plating, and chrome alloy and metal production. As a result, Cr has become a major factory runoff pollutant and the chromium content of surface waters reflects the extent of industrial activity in general. Nickle (Ni), a hard, silvery white metal, which combines with other metals to form alloys, is used mainly in the production of stainless steels, nonferrous alloys and super alloys. Iron (Fe), which is the second most abundant metal in the earth's crust, is a common constituent in soil and groundwater. Iron oxides (Fe_2O_3) are used as pigments in paints and plastics and as coagulants in water treatment. The primary anthropogenic sources of Zinc (Zn) in the environment are metal smelters and mining activities. The production and use of Zn in brass, bronze, die-casting metal, alloys, rubbers and paints may also lead to its release to the environment through various waste streams (Bhutiani et al., 2016)

Pakistan

Water contamination is a worldwide issue. Therefore, in excess of 14,000 individuals kick the bucket because of water related sicknesses daily. Pakistan's one of most alarming issue is groundwater contamination, its utilization and associated hazards. Around 70% of surface water and groundwater are contaminated in Pakistan. The 26% population in Pakistan have access to clean water supply according to the international standards (Shahid et al., 2014). In Pakistan groundwater contamination happens because of the untreated local, industrial and rural spillover. In the majority of zones water is influenced with fluorides nitrates, arsenic and microbial (Ali et al., 2013). An investigation led by Pakistan Council of Research in Water Resources (PCRWR) in 2007 inferred that around of 84– 89% of the water sources throughout the nation have a water quality beneath the recommended standards for human utilization. Many studies reported by individuals indicated higher amounts of anion, cation, heavy metal and organic contaminants in groundwater and considered to be responsible for major health issues. A costly option for safe drinking water is accessible as bottled /filtered water, which is additionally not reliable. It has been reported by PCRWR in 2017, that about 11 out of 109 filtered water brands accessible in Pakistan, contains microbial and bacterial contaminations (Raza et al., 2017).

The groundwater in Pakistan is mainly contaminated by sewerage water mixing with drinking water and considered as primary source of contamination because of poor sewerage and sanitation system. The chemical pollution is considered as second source of contamination, which includes toxic substances from pesticides, textile dyes, industrial effluents, arsenic, nitrogenous fertilizers and other chemicals (Daud, et al., 2017). The groundwater contamination by arsenic is an alarming issue, in addition to industrial and municipal effluents in Pakistan. The 36% and 16% of Punjab and Sindh province population are exposed to a level of contamination higher than 10 ppb and 50 ppb respectively (Ali et al., 2013). In Pakistan the biological contaminants include fecal coliforms and total coliforms in drinking water and beyond the WHO standards. The major sources of microbial contaminants includes lack of water disinfection and filtration practices, improper disposal of municipal wastes and industrial, poor water supply and sanitary systems (Nabeela et al., 2014).

The groundwater in most areas of Karachi has been deteriorated as compared to the other cities of Pakistan due to improper management system of the sewerage waters seepage, industrial waste waters, and sea water intrusions. The water wells contain alarmingly excess amounts different chemical and biological constituents, which are unfit for human as well as industrial utilization (Khattak & Khattak 2013). The study carried out for municipal solid waste management, concluded that improper solid wastes management is destroying groundwater quality. The concentration of metals like Nickel, Lead, cadmium, and Chromium were found beyond the permissible limits of the groundwater in analyzed samples (Shahid et al., 2014). The high concentration of lead was found in many sources of drinking water in Karachi city. In the groundwater sources the mean lead quality was greater than 150 ppb in half districts of Karachi (Ul Haq et al., 2011). The sewage water from urban areas Rawalpindi and Islamabad cities contained Hepatitis E infection (Ahmad et al., 2010).

A high grouping of pesticides dominates the analytical results of groundwater collected during spring and fall seasons. The contamination of groundwater in the vicinity of Lahore is believed to be caused by the waste water that is untreated, sites for dumping waste and over the top an overuse of pesticides. The quality of ground, soil, and river water in Lahore is marred by the waste dumped into water as three fourth portion of this waste is dumped without any treatment (Akhtar and Tang, 2013). Furthermore Bacteria oriented contamination of water in Pakistan is aggravated by the worn out pipelines, passing through the sites of waste (Anwar et al., 2010). Samples collected from Mughalpura and Islampura (Lahore) carried the microbial (Sulehria et al., 2011) and the similar results were found in the samples collected from the northern parts as well (Baig et al., 2012). Haydar et al., (2014) carried out of study on groundwater quality and found microbiological contamination in water samples.

Landfill sites are additionally genuine ecological issues in Pakistan, high convergence of aggregate broke down solids, conductivity, turbidity, bacterial tainting was found in the water tests from close landfill of Lahore city. Likewise a noteworthy danger for the human wellbeing is the nearness of fecal coliform and E.coli (Butt and Ghaffar, 2012).

Water contaminations is a primary driver of medical issues and as per report of UNICEF the healing centres of the Pakistan are around 20-40% loaded with patients that are contaminated with the water related infections. Around 1.3 million individuals are influenced by contaminated water and the high convergence of arsenic was found in the checking water wells of Kasur (Mohsin et al., 2013) and over 20% populace of Punjab area is presented to arsenic. Kasur is one of the most established modern city of Pakistan, where dirtied water is utilized for the water system in excess of five thousand hectares zone which influences the health condition of 76.07% of population of the city (Ashraf et al., 2010).

In excess of 2 million individuals are specifically presented to arsenic and fluoride in 17 towns of east Punjab like Kalalan town. The convergence of arsenic and fluoride is high in water tests taken from these villages. Pakistan board of research in water assets led an exploration program in which the water tests were examined from 21 noteworthy urban communities of every one of the four areas, considers demonstrated that examples from all territories are contaminated microbiologically (Memon et al., 2011).

Saudi Arabia

Saudi Arabia is extended over a vast territory, covering an area of 2.15 million square kilometer in Arabian Peninsula. In terms of regular sustainable water asset, Saudi Arabia is the most impoverished one as for most of its water utilization, about 80 to 90%, it depends on groundwater. In general groundwater sources fall within a normal range of 2259 billion cubic meters (Aly et al., 2013). Until 1970, the dependence for fresh water was mainly on groundwater in Saudi Arabia., yet the accessible points for groundwater in Saudi Arabia are few (Al-Hasawi and Hussein, 2012). The yearly populace development is 3.4 % but within last 40 years the growth of population rose from seven million to twenty seven million which eventually raised the utilization of water up to 7 billion cubic meter and 60 % of every portion of water drawn out, is the desalinated one (Ouda, 2013). A record expansion in the utilization of water has been noted in Saudi Arabia, almost eight million cubic meter per day, implying that each individual uses 250 to 265 liters as a matter of routine and it exceeds the normal universal water utilization by 91%. The use of water for farming has increased by 85% from the total water consumption. The population expansion by 2020—2025 is expected to touch 40.426 million which will in turn increase the domestic usage upto 6450 million cubic meters (Rehman & Rehman 2014).

The three inexhaustible sources of water on which Saudi Arabia relies include groundwater, sustainable and desalinated water from the sea. A small part of people get an access to an adequate supply of water from inexhaustible assets. Because of cost factor, the desalination source of ocean water zone is constricted to front zone only. Thus most part of the country relies on the same old non-sustainable assets revived years before (Al-Saud et al., 2011).

One of the thickly populated urban area of Saudi Arabia, Jeddah, has a populace of 300,000, which is on a constant increase by 2.35% a year. Groundwater sources are insufficient to meet the needs of the individuals. So, desalinated water is provided as an alternate. A careful summation indicates that 200 liters of water is consumed per capita everyday and 80% of the water consumed is returned to ground as waste water. Jeddah remains the worst hit of sewage squander water in Saudi Arabia as 70% area of the city is not connected to sewerage pipelines. Sewage water gets stored in underground pools and then transported to dumpsites or channel plants in tanker trucks. Four main sources are responsible to contaminate Jeddah beach front water, i-e untreated sewage water from the surrounding areas, contaminants of oil refineries, angle wastes and plants installed for desalination of water. All these gather together to replete the place with harmful metallic substances. Jeddah beachfront was found to be terribly infected with nitrogen and phosphorus etc. The south sea zone is polluted with household sewage and northern section is contaminated with local sewage along with petrol spilled in it (Rehman and Rehman 2014).

In the Jeddah waterfront territory water quality was inspected and ponders demonstrated that the Jeddah beach front region is greatly dirtied with nitrogen, phosphorous and substance oxygen request (COD). Though the south seaside zone is primarily dirtied by household sewage and northern part is contaminated with local sewage and also with the spilled petrol. Because of fast increment in populace and industrialization the beach front region of Jeddah winds up dirtied with overwhelming metals and because of these tainting the soundness of fish likewise influenced in light of the fact that these defilements harm the marine organism (Montaser et al., 2010). Likewise Almisk lake region posed a horrible ecological danger for Jeddah as the sewage water from all around Jeddah was dumped into it without any treatment for more than 10 years. The underground sullying was always there. According to an estimation, 40,000 cubic meter of waste water was dumped onto the lake on regular basis by 800 tankers and the indeed there has been an increase in this amount ever since. The toxic waste that has tainted the Al Misk lake water, includes chemical as well as mechanical substances. A portion of the wells nearby is also affected (Elfeki et al., 2010). In 2009-2010 the noro virus was detected in the Al Misk lake water, which could be easily transmitted through the vaporized course, ultimately causing sickness among human beings (Redwan and Bagatadah, 2012). Rehman and Cheema (2016) carried out hydrogeological investigations in Al-Misk area and concluded that groundwater quality is deteriorated. High concentration of boron was found in waste dumping site near Jeddah City (Rehman and Cheema, 2017).

Makkah Al- Mukaramah the most crowded city, is, likely exposed to the dangers of contaminated water. The sewage water of Makkah, though treated and dumped into the aqueduct of Uranah, was also not found free of risks. The investigations substantiated the traces of microbial substances in the stream water because of high concentration of salts. With the passage of time, the water will be unsuitable for agricultural use (Al-Harthi, 2001). According to Khdary and Gassim (2014) selenium, barium, arsenic copper, chromium, mercury, cadmium cobalt and lead were found in water samples from different wells in Makkah Al Mukarramah area. However the heavy metals were found in permissible limits according to International slandered. Similarly Sharaf (2011) conducted a study for hydrochemistry of aquifer system of Wadi An Numan, Makkah Al Mukarramah. The groundwater in Wadi is suitable for irrigation process.

The water from savouring water wells from Ha’il (northern Saudi Arabia) were detected with the presence of disintegrated solids, a raised level of nitrogen and solid existence of coliform microorganisms. This colossal contamination of water makes it inappropriate for any kind of use without proper treatment. The groundwater samples collected from

Rabigh also showed tainting of water because of coliform microorganisms (Al-Hasawi and Hussein, 2012).

Discussion and Conclusion

The research presents a brief review on groundwater contamination and its current status in Pakistan and Saudi Arabia. The two major sources of groundwater contamination are domestic wastewater and industrial effluents. There are close similarities between Saudi Arabia and Pakistan as far as the contamination and the constantly declining quality of groundwater is concerned. The factors leading to this phenomenon are the seepage of sewage water into ground, old flawed water drainage system and the dumping of domestic waste into the resources of fresh water. The colossal amalgamation of waste water with the underground fresh water reservoirs is causing a concentration of lethal substances like heavy metals. The excess presence of these substances eventually is leading to poor human health and onset of complex ailments.

It's the dire need of the hour that the water reserves left underground should be saved from being contaminated. For this purpose, the society and the governments will have to work on missionary basis. The waste water must not be dumped into the fresh water reservoirs like lakes and rivers unless it is treated properly. The sewerage pipelines for the drainage of the domestic waste should be fixed with a careful consideration so that there is no chance of drinking water getting mixed with the sewerage water. The old and worn out approach of dumping domestic waste should be altered with the modern approach of not letting any harmful substance getting combined with water used for any living organisms. The best measure to avoid that is to treat any kind of waste water before making it a part of recycling process. The elimination of contaminants will ensure better health for living beings. To achieve this target, wide research should be carried out by collecting samples from most endangered areas and solutions and recommendations should be heeded seriously.

References

Ahmad, T., Waheed, Y., Tahir, S., Safi, S. Z., Fatima, K., Afzal, M. S., & Qadri, I. (2010). Frequency of HEV contamination in sewerage waters in Pakistan. The Journal of Infection in Developing Countries, 4(12), 842-845.

Akhtar, M. M., & Tang, Z. (2013).Identification of contamination sources and TDS concentration in groundwater of second biggest city of Pakistan. International Journal of Environmental Science and Development, 4(3), 341.

Al-Harthi, A. A. (2001). Preliminary environmental assessment of the pollution of soil and water at Wadi Uranah, Makkah Al-Mukarramah, Saudi Arabia. Earth Sciences, 13(1).

Al-Hasawi, Z., & Hussein, K. (2012). Groundwater investigation in Rabigh Governorate, West of Saudi Arabia. Global Advanced Research Journal of Environmental Science and Toxicology, 1(4), 072-079.

Al-Hasawi, Z., & Hussein, K. (2012). Groundwater investigation in Rabigh Governorate, West of Saudi Arabia. Global Advanced Research Journal of Environmental Science and Toxicology, 1(4), 072-079.

Al-Saud, M., Teutsch, G., Schüth, C., & Rausch, R. (2011).Challenges for an integrated groundwater management in the Kingdom of Saudi Arabia. International Journal of Water Resources and Arid Environments, 1(1), 65-70.

Ali, S. S., Karim, N., Munshi, A. B., Siddqui, I., & Khan, F. A. (2013). Health hazards among coastal villagers of Pakistan due to arsenic contaminated drinking water. Journal of Water Resource and Protection, 5(12), 1235.

Aly, A., Alomran, A., Alwabel, M., Almahaini, A., & Alamari, M. (2013). Hydrochemical and quality of water resources in Saudi Arabia groundwater: a comparative study of Riyadh and Al-Ahsa Regions. Proceedings of the International Academy of Ecology and Environmental Sciences, 3(1), 42.

Ashraf, M. A., Maah, M. J., Yusoff, I., & Mehmood, K. (2010). Effects of polluted water irrigation on environment and health of people in Jamber, District Kasur, Pakistan. International Journal of Basic & Applied Sciences, 10(3), 37-57.

Baig, S. A., Akhter, N. A., Ashfaq, M., Asi, M. R., & Ashfaq, U. (2012). Imidacloprid residues in vegetables, soil and water in the southern Punjab, Pakistan. Journal of Agricultural Technology, 8(3), 903-916.

Bhutiani, R., Khanna, D. R., Kulkarni, D. B., & Ruhela, M. (2016).Assessment of Ganga river ecosystem at Haridwar, Uttarakhand, India with reference to water quality indices.Applied Water Science, 6(2), 107-113.

Butt, I., & Ghaffar, A. (2012).Groundwater quality assessment near MehmoodBoti landfill, Lahore, Pakistan.Aslan journal of social sciences and humanities, 1(2).

Daud, M. K., Nafees, M., Ali, S., Rizwan, M., Bajwa, R. A., Shakoor, M. B., ...& Malook, I. (2017). Drinking water quality status and contamination in Pakistan.BioMed research international, 2017.

Dorfman, M., Stoner, N., & Merkel, M. (2004).Swimming in sewage. Natural Resources Defense Council and the Environmental Integrity Project, New York, NY [Online.] http://www. nrdc. org/water/pollution/sewage/sewage. pdf.

Elfeki, A. M. (2010). Estimation of Uncertainty in the Flow Field around Underground Ains (Qanats) Using Monte-Carlo Method. Meteorology, Environment and Arid Land Agriculture Sciences, 21(2).

Han, Z., Ma, H., Shi, G., He, L., Wei, L., & Shi, Q. (2016). A review of groundwater contamination near municipal solid waste landfill sites in China. Science of the Total Environment, 569, 1255-1264.

Harris, J. A., Birch, P., & Palmer, J. P. (1996). Land restoration and reclamation: principles and practice. Addison Wesley Longman Ltd.

Haydar, S., Haider, H., Nadeem, O., Hussain, G., Jalees, I., & Qadeer, A. (2014). Effect of Hudiara drain on the quality of groundwater in the housing schemes of Lahore. Journal of Faculty of Engineering & Technology, 21(2), 119-134.

Helena, B., Pardo, R., Vega, M., Barrado, E., Fernandez, J. M., & Fernandez, L. (2000). Temporal evolution of groundwater composition in an alluvial aquifer (Pisuerga River, Spain) by principal component analysis.Water research, 34(3), 807-816.

Jaishankar, M., Tseten, T., Anbalagan, N., Mathew, B. B., & Beeregowda, K. N. (2014). Toxicity, mechanism and health effects of some heavy metals. Interdisciplinary toxicology, 7(2), 60-72.

Kataria, H. C., Gupta, M., Kumar, M., Kushwaha, S., & Kashyap, S. (2017).Study of physico-chemical parameters of drinking water of Bhopal city with reference to health impacts. Current World Environment, 6(1).

Khan, M. A., Khan, S., Khan, A., & Alam, M. (2017).Soil contamination with cadmium, consequences and remediation using organic amendments. Science of the Total Environment, 601, 1591-1605.

Khattak, M. I., & Khattak, M. I. (2013).Groundwater analysis of Karachi with reference to adverse effect on human health and its comparison with other cities of Pakistan. Journal of Environmental Science and Water Resources, 2(11), 410-418.

Khdary, N. H., & Gassim, A. E. (2014). The distribution and accretion of some heavy metals in Makkah Wells. Journal of Water Resource and Protection, 6(11), 998.

Li, P., Tian, R., Xue, C., & Wu, J. (2017). Progress, opportunities, and key fields for groundwater quality research under the impacts of human activities in China with a special focus on western China. Environmental Science and Pollution Research, 24(15), 13224-13234.

Li, P., Wu, J., Qian, H., Lyu, X., & Liu, H. (2014). Origin and assessment of groundwater pollution and associated health risk: a case study in an industrial park, northwest China. Environmental geochemistry and health, 36(4), 693-712.

Li, P., Wu, J., Qian, H., Zhang, Y., Yang, N., Jing, L., & Yu, P. (2016). Hydrogeochemical characterization of groundwater in and around a wastewater irrigated forest in the southeastern edge of the Tengger Desert, Northwest China. Exposure and Health, 8(3), 331-348.

Memon, M., Soomro, M. S., Akhtar, M. S., & Memon, K. S. (2011). Drinking water quality assessment in Southern Sindh (Pakistan). Environmental Monitoring and Assessment, 177(1-4), 39-50.

Meride, Y., & Ayenew, B. (2016). Drinking water quality assessment and its effects on residents health in Wondo genet campus, Ethiopia. Environmental Systems Research, 5(1), 1.

Mohsin, M., Safdar, S., Asghar, F., & Jamal, F. (2013). Assessment of drinking water quality and its impact on residents health in Bahawalpur city. International Journal of Humanities and Social Science, 3(15), 114-28.

Montaser, M., Mahfouz, M. E., El-Shazly, S. A., Abdel-Rahman, G. H., & Bakry, S. (2010). Toxicity of heavy metals on fish at Jeddah coast KSA: Metallothionein expression as a biomarker and histopathological study on liver and gills. World J. Fish Mar. Sci, 2(3), 174-185.

Nabeela, F., Azizullah, A., Bibi, R., Uzma, S., Murad, W., Shakir, S. K., ...& Häder, D. P. (2014). Microbial contamination of drinking water in Pakistan—a review. Environmental Science and Pollution Research, 21(24), 13929-13942.

Ouda, O. K. (2013). Towards assessment of Saudi Arabia public awareness of water shortage problem. Resources and Environment, 3(1), 10-13.

Pal, A., Gin, K. Y. H., Lin, A. Y. C., & Reinhard, M. (2010). Impacts of emerging organic contaminants on freshwater resources: review of recent occurrences, sources, fate and effects. Science of the total environment, 408(24), 6062-6069.

Raza, M., Hussain, F., Lee, J. Y., Shakoor, M. B., & Kwon, K. D. (2017). Groundwater status in Pakistan: A review of contamination, health risks, and potential needs. Critical Reviews in Environmental Science and Technology, 47(18), 1713-1762.

Redwan, N. A., & Bagatadah, R. A. (2012). Health risk assessment associated with norovirus incidence in raw wastewater in Jeddah, Saudi Arabia. Austr J Basic ApplSci, 6(3), 43-48.

Rehman, F., & Cheema, T. (2016). Effects of sewage waste disposal on the groundwater quality and agricultural potential of a floodplain near Jeddah, Saudi Arabia. Arabian Journal of Geosciences, 9(4), 307.

Rehman, F., & Cheema, T. (2017). Boron contamination in groundwater at a sewage waste disposal facility near Jeddah, Saudi Arabia. Environmental Earth Sciences, 76(5), 218.

Rehman, F., & Rehman, F. (2014). Water importance and its contamination through domestic sewage: Short review. Greener J. Phys. Sci, 4(3), 045-048.

Renaud, F. G., Birkmann, J., Damm, M., & Gallopín, G. C. (2010). Understanding multiple thresholds of coupled social–ecological systems exposed to natural hazards as external shocks. Natural Hazards, 55(3), 749-763.

Sankpal, U. T., Pius, H., Khan, M., Shukoor, M. I., Maliakal, P., Lee, C. M., ...& Basha, R. (2012). Environmental factors in causing human cancers: emphasis on tumorigenesis. Tumor Biology, 33(5), 1265-1274.

Shahid, M., Nergis, Y., Siddiqui, S. A., & Choudhry, A. F. (2014). Environmental impact of municipal solid waste in Karachi city. World Applied Sciences Journal, 29(12), 1516-1526.

Sharaf, M. A. M. (2011). Hydrogeology and hydrochemistry of the aquifer system of Wadi An Numan, Makkah Al Mukarramah, Saudi Arabia. AQUA mundi, 035-052.

Sharma, A. K., Tjell, J. C., Sloth, J. J., & Holm, P. E. (2014). Review of arsenic contamination, exposure through water and food and low cost mitigation options for rural areas. Applied Geochemistry, 41, 11-33.

Shon, H. K., Vigneswaran, S., & Snyder, S. A. (2006). Effluent organic matter (EfOM) in wastewater: constituents, effects, and treatment. Critical reviews in environmental science and technology, 36(4), 327-374.

Tarasenko, S. (2009). Wastewater Treatment in Antarctica. http://hdl.handle.net/10092/14196

Tjandraatmadja, G., & Diaper, C. (2006). Sources of Critical Contaminants in domestic wastewater: a literature review.

Ul-Haq, N., Arain, M. A., Badar, N., Rasheed, M., & Haque, Z. (2011). Drinking water: a major source of lead exposure in Karachi, Pakistan. Eastern Mediterranean Health Journal, 17(11), 882.

Wang, J., & Chen, C. (2015). The current status of heavy metal pollution and treatment technology development in China. Environmental Technology Reviews, 4(1), 39-53.

Wu, J., & Sun, Z. (2016). Evaluation of shallow groundwater contamination and associated human health risk in an alluvial plain impacted by agricultural and industrial activities, mid-west China. Exposure and Health, 8(3), 311-329.

WWDR, U. (2006). Water in a changing world.

WWDR, U. (2009). The United Nations world water development report 3. Earthscan, London Google Scholar.

Yi, Q. (Ed.). (2009). Point Sources of Pollution. Local Effects and Their Control: Vehicular Emissions. Eolss Publishers Company Limited.