International Journal of Chemical and Biochemical Sciences
(ISSN 2226-9614)

Journal Home page: www.iscientific.org/Journal.html

Untreated Wastewater Reasons and Causes: A Review of Most Affected Areas and Cities

Ayesha Tariq and Ayesha Mushtaq*

Department of Chemistry, University of Agricultural Faisalabad, Pakistan.

Abstract

Wastewater is one of the serious environmental concerns because water quality criterion of surface water and groundwater set by WHO are frequently violated. Approximately, 380 billion m^3 of municipal wastewater is generated globally and is estimated to increase 24% by 2030 and 51% by 2050. On the average, most of the cities of the developing countries discharge 30-70 mm^3 of wastewater per capita per day. The availability of fresh water is declining day by day. This situation is getting worse with time and the major contributing factors are rapid urbanization, industrialization, population growth, increase in use of insecticides and pesticides in agricultural activities, lack of proper wastes treatment systems and lack of implementation of water management policies. Many contaminants like organic matter, inorganic pollutants, nitrates and phosphate, fluoride, oil spillage, heavy metals and water-soluble radioactive substances are polluting the world's water when they are disposed of in water bodies without any treatment. The sad reality around the globe is that, minor portion of wastes generated are treated, the rest are disposed of without adequate treatment. But in some developing countries this situation is worse than others. The disposal of untreated wastes and uncontrolled water pollution poses economic and ecological effects. The main goal of this review is to discuss main causes, significant sources and impacts of untreated wastewater by giving an overview of most affected areas of world.

Keywords: Wastewater, Major pollutants, groundwater, surface water, South Asia, East Asia, Sub-Saharan Africa, Latin America

Full length review article **Corresponding Author*, e-mail: *tariqayesha559@gmail.com*

1. Introduction

Man's existence on Earth is supported by three basic resources – air, water and soil, the precious blessings of nature. Among these, water is the basic medium for the origin of life [1].The World Health Organization (WHO) has designated water as a "major tool for improving public health" because its availability prevents many diseases and greatly improves sanitation [2]. Human societies depend on water for survival and development, and global demand is increasing over time due to population growth, expansion of irrigated arable land, economic development, and changing diets [3-5].

The oceans contain 97% of the world's water, but its high salinity makes it unsuitable for consumption. About 2% of total water is available as polar ice caps and glaciers. Freshwater in all forms i.e., surface water; rivers, streams, lakes and groundwater constitutes only 1% of the entire world's water and this freshwater is being used by agriculture (69%), industry (23%), and domestic purposes (8%). Global fresh water usage for domestic, agricultural, and industrial purposes in past years (1950-2014) is shown in Fig. 1. Unfortunately, this small amount of freshwater is facing stress due to immense increase in population, increase in urban areas and unchecked use of water in industrial and agriculture activities i.e., the biggest polluters [6-7].

The United Nations reports that with the increase in population, the availability of safe water is decreasing. Unfortunately, water pollution pollutes the remaining small fraction of freshwater [8-9]. Many countries of world will be severely threatened by freshwater scarcity in the next two decades [10]. The problem is exacerbated in low- and middle-income countries by severe contamination of water sources with pollutants, which is expected to be caused due to poor management, shortage of skilled workers and financial issues [11-12]. Water pollution is a problem that plagues people all over the world [13-14]. Major sources of this contamination are planned and accidental dumping of poisonous chemicals, pollutants, and dangerous compounds into diverse bodies of water [15-16]. According to European Investment Bank (May 2022), each year about 380 billion m^3 of municipal wastewater is generated globally and it is estimated to increase 24% by 2030 and 51% by 2050. Fig. 2 shows the global wastewater production estimation by 2050. This is the worldwide reality that, only minor fraction of total wastewater produced is collected to be treat properly. These estimates suggest that approximately 48% (half) of all the wastewater generated worldwide is liquidated into the environment lacking proper treatment, although, the magnitude of wastewater generation varies from region to region. Of course, due to overpopulation, rampant industrial

activity and questionable sanitary infrastructure, some countries are more responsible than others for the pollution of their water supply and are therefore considered the main violators of their water bodies. On average, in high-income countries 70 percent of generated water is treated. Approximately, 38% of wastewater generated in the upper middle-income countries and 28% in the lower middle-income countries is treated. Low-income countries treat only 8% of the wastewater they generate [17].

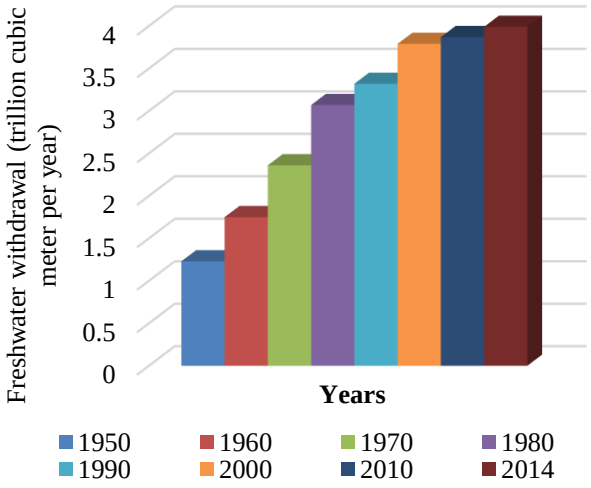

Fig. 1. Global fresh water usage for domestic, agricultural, and industrial purposes in past years (1950-2014) [18].

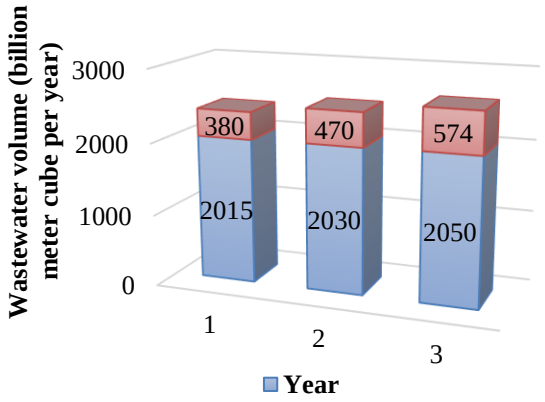

Fig. 2. Global wastewater production estimation by 2050 [19].

According to UN-Water, increased use of fertilizers and pesticides, and use of wastewater for irrigation pollute water reservoirs. Industrial areas are continuously discharging wastes into waterways. In poor urban areas, sewage systems are the dumping places of much of water pollutants. Domestic sewage, humans waste, noxious chemicals, and medicinal waste are airborne and polluting the environment and water in residential areas with dense population. Globally, 44% of domestic wastewater is not safely handled, and water quality data is not collected in most of the countries on regular basis. This means that more than 3 billion people are at risk because the health of freshwater ecosystems is unknown [20].

Water is a major contributing source of infection because of its solvent properties [21]. Approximately, 80% of transmission of diseases occur through water contamination. Drinking water in various countries does not meet WHO standards [22]. About 3.1% of deaths are caused by unsanitary conditions and poor water quality. This untreated wastewater directly contributes to an increase in infectious diseases such as cholera, typhoid fever, and other diseases such as gastrointestinal disease, diarrhea, vomiting, skin and kidney problems [23]. These diseases kill 2,97,000 children below the age of five each year, or 800 children per day. Child mortality from diarrhea is highest in the poorest regions of countries such as Afghanistan, India and the Democratic Republic of the Congo [24]. In severe cases, excessive nutrients are present in receiving water causing rapid growth of algal blooms and thus deplete the water dissolved oxygen. Aquatic bodies stink and die from lack of oxygen [25-26].

2. Composition of wastewater

Wastewater is generally defined as “used” water that has been contaminated by human activity [27-28]. Wastewater is a complex matrix, and the composition of wastewater differs greatly dependent on the major contributing foundation of wastewater, and level of treatment [29]. Wastewater is reported to contain over 90% water on a dry weight basis, but less than 10% are solids i.e., 40 to 50% organics substances, 30 to 40% inert materials, 10 to 15% non-degradable substances and 5 to 8% other materials [30]. Among other substances, wastewater also contains various concentrations of micronutrients such as Mn (1.6-15) ppm, Cu (0.6-1.9) ppm, Zn (2.8-11) ppm, Pb (1.5-40) ppm, Cd (0.15-5.80 ppm) and Ni (1-6.4) ppm and Fe (5.6-205) ppm. Industrial wastes also contain toxic levels of heavy metals like Ni, Hg, Pb, Cd and Cr etc. [31]. On the other hand, sewage effluents are characterized by toxic concentrations of EC, COD, BOD, TDS, SAR, and RSC [32].

3. Major sources contribute in wastewater generation

Wastewater generally consists of municipal wastewater, agricultural wastewater, institutional and industrial wastewater, storm water and groundwater seepage, depending upon the source of the wastewater generation [5]. The main sources of sewage are household sewage, rapid industrialization, population increase, pesticides and fertilizers, plastics, rapid increase in urban areas, and poor management systems [31].

Domestic wastewater is a primary source that accounts for 75-80% of water pollution [33]. A large amount of municipal wastewater is discharged into rivers, most of which remains untreated. Domestic wastewater is used water that contains toxins, solid waste, plastic debris, and bacterial contaminants. 25% of surface and groundwater pollution is caused by industrial sectors as industrial wastewater is discharged untreated into water bodies with more harmful effects. Population growth also plays a major role in wastewater

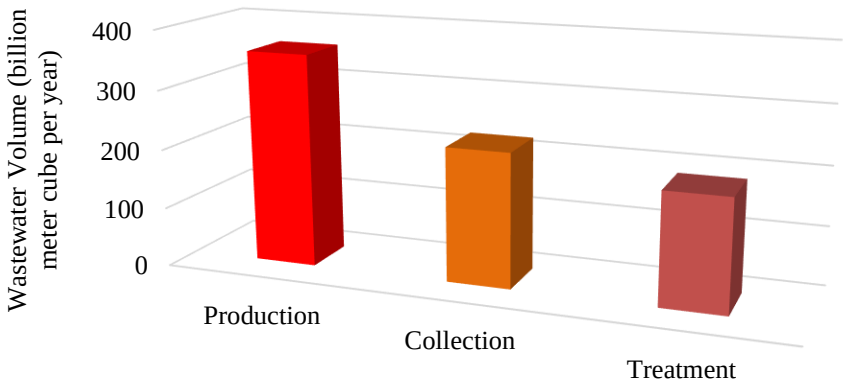

Fig. 3. Global wastewater production and its treatment ($10^9 m^3 y^{-1}$) [34].

Production [9]. A growing population means an increased need for fresh water, which means a large amount of wastewater is generated, especially in densely populated areas [23]. According to the United Nations, the population is growing at a rate of 83 million people or 1% per year, and this population growth is having a negative impact [35]. Secondary sources of wastewater generation are the disposal of toxic chemicals from industrial wastewater and the leaching of pesticides and fertilizers from agricultural activities into water bodies, which act as non-point water sources [21]. In addition to all these causes, air pollution, global warming and other climate changes also affect water quality. Air pollution indirectly affects water bodies. Sulfur dioxide, nitrogen oxides, and carbon monoxide gases react with oxygen and water vapor in the air to produce acid rain. Acid rainwater can leach aluminum out of clay particles in the soil and run into streams and lakes, contaminating water sources. Poorly managed wastewater treatment also releases large amounts of wastewater. This poor management is due to lack of reliable energy supply, inadequate budgetary allocation, lack of funding, inadequate wastewater treatment plant infrastructure, lack of technology, and mismatch of urbanization and wastewater treatment resources [23].

4. Global statistics of wastewater production and its treatment

The primary causes of wastewater production throughout the world include rapid expansion in the population and accelerated industrial extension etc [36-37]. These factors are suppressing the freshwater quality [38-39]. According to a recent study, 4200 km^3 of total available freshwater is withdrawn globally as a result of human activities, and about 60% of this amount is released as wastewater [40]. Another study reported that, worldwide the production of wastewater is about 360-billion-meter cube per year. Out of this approximately, 226-billion-meter cube per year is collected which accounts for 63% and only there is a treatment of 52% (188.1-billion-meter cube per year). Global wastewater production, collection and treatment is shown in Fig. 3. Approximately, 171.3-billion-meter cube (48%) per year of wastewater produced globally is discharged into environment in untreated form and therefore affecting the ecosystem [34]. Worldwide wastewater production is expected to increase to 470-billion-meter cube per year by the year 2030 and will reach 574-billion-meter cube per year by the end of 2050 [19]. A recent study gives detailed report on wastewater production and treatment in different geographical regions as wastewater production and treatment varies across different regions [41-42]. Wastewater production, collection and treatment ($10^9 m^3 y^{-1}$) in different regions is shown in Fig. 4. The rate of collection of wastewaters produced and its treatment is highest in Western Europe and lowest in Southern Asia and sub-Saharan Africa. Approximately 86 % of total wastewater produced annually is treated in Western Europe, 48% in East Asia, 16% in Southern Asia and sub-Saharan Africa and 36% in Latin America and Caribbean. Considering the numbers, it is estimated that the wastewater treatment is notably low in Asia particularly southern part of Asia, Africa particularly sub-Saharan areas and Latin America, potential indicators of high untreated wastewater producers [15]. Due to a lack of institutional arrangements, financing, technical expertise, and infrastructure, the dumping of untreated wastewater has continued to be a regular phenomenon in developing countries [40-43]. Due to overpopulation, rampant industrial activity and questionable sanitary infrastructure, some developing countries are more responsible than others for the pollution of their water supply and are therefore considered the main violators of their water bodies. On average, in high-income countries, approximately 70 percent of generated water is treated, according to UN Water. About 38% of wastewater generated in upper middle-income countries and 28% in lower middle-income countries is treated. Low-income countries treat only 8% of the wastewater they generated [17]. Wastewater production, collection and its treatment ($10^9 m^3$ per year) in accordance with economic development of countries is shown in Fig. 5.

5. Potential causes of wastewater generation in most affected areas of world

Although, the untreated wastewater production (Fig. 4) and its negative impacts is the global concern. But, in this study we will take into account the potential causes of untreated wastewater production and their adverse effects in most affected parts of world such as Southern Asia, East Asia,

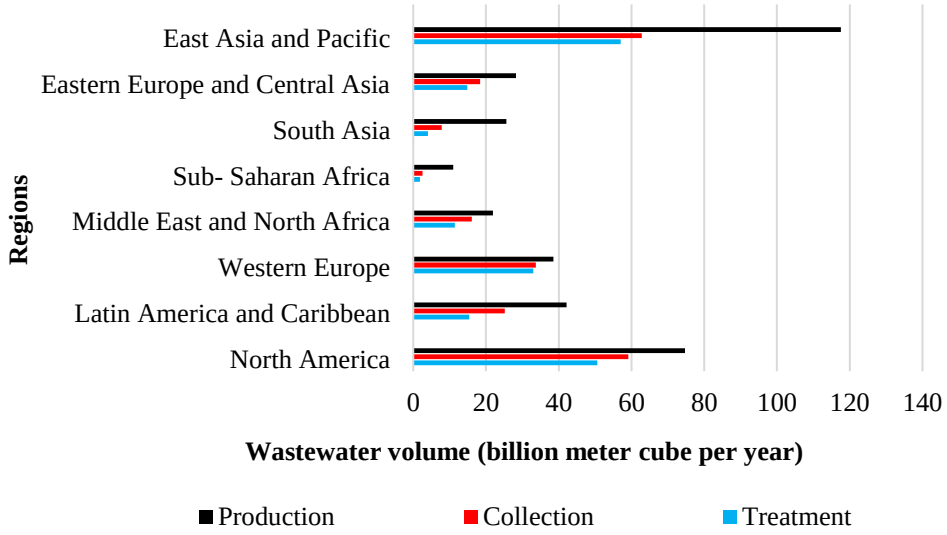

Fig. 4. Wastewater production, collection and treatment ($10^9 m^3 y^{-1}$) in different regions [34].

sub-Saharan Africa and Latin America and Caribbean according to different studies [15-44]. Based on most polluted rivers, water pollution disasters, reasons and causes of annual wastewater production and its treatment, and discharge of untreated wastewater in most affected areas of these regions are described below.

5.1. Most affected areas of South and East Asia

Asia is indeed the world's largest continent, in terms of both geographical area and people. It is divided into five regions: South Asia, Central Asia, East Asia, South-east Asia and West Asia. It encompasses an area of much more than 44 million km^2, accounting for approximately 30 percent of the overall land area and 8 percent of the entire surface area of the planet with a network of rivers and streams. But water supplies of these networks of rivers and streams are under significant strain across Asia as a result of population development and the requirement for higher agricultural productivity. Yearly water withdrawals and back flows are greater in this region compared to all other regions. The yearly amount of waste water created, omitting agricultural discharge, is around 142 km^3. Insufficient sanitation, and treatment systems for sewage and wastewater result in considerable amounts of wastewater entering aquatic bodies that can be adapted for human consumption. Non-point sources of pollution, mostly agricultural, continues to be a cause of concern, particularly considering the increase in pesticide consumption. As Asia's economies expand and adapt, industrial waste also plays a role. Nature and humans are feeling the effects: about 42% of fatalities are connected with unhealthy or insufficient water, sanitation, and hygiene supply in Asia. Asian nations are working together to solve these issues, but the speed and scope of policy action is slow and must accelerate urgently. In many areas, quality is continuously declining, and limited efforts are being attempted to evaluate and correct the issue [45]. Wastewater production and its treatment is a challenge all across the Asia but study estimated that treatment is particularly low in southern part of Asia [15]. A review of most affected areas in South Asia and East Asia with untreated wastewater contamination and main reasons and causes behind this contamination in these areas are mentioned here.

5.1.1. India

With a population of roughly 1.38 billion, India is the 2nd utmost populous nation in world and is member of South Asia. India suffers greatly from water pollution, with an estimation of about 70% of its surface water is not suitable for use [46]. In actual fact, nearly 80% of India's water bodies are said to be highly polluted [47]. The major sources of water pollution are industrial, agricultural and domestic wastes. In India, nearly 91 million habitants lack access to sufficient clean water and about 229 million lack better sanitation [46]. About 50 billion liters of industrial and domestic wastewater is discharged from India's cities each year, and approximately 80% of this municipal waste ends up in the country's rivers [48]. Cities having populations greater than 1 lakh inhabitants are anticipated to generate approximately 16.662 billion liters of wastewater every day [47]. With 21 large cities nearing water scarcity and several cities suffering from cutbacks in water supply, India shared the list of water-stressed nations [49].

As India grows and becomes more urban, its waters are becoming more and more toxic. Only about 10% of the wastewater produced is treated. The rest is discharged directly into the water. About 70% of the wastewater generated in India remains untreated. The Sri Lanka-based International Water Management Institute also notes that India is a water stressed country, with nearly 33% of rivers which are being polluted moderately or heavily. India's

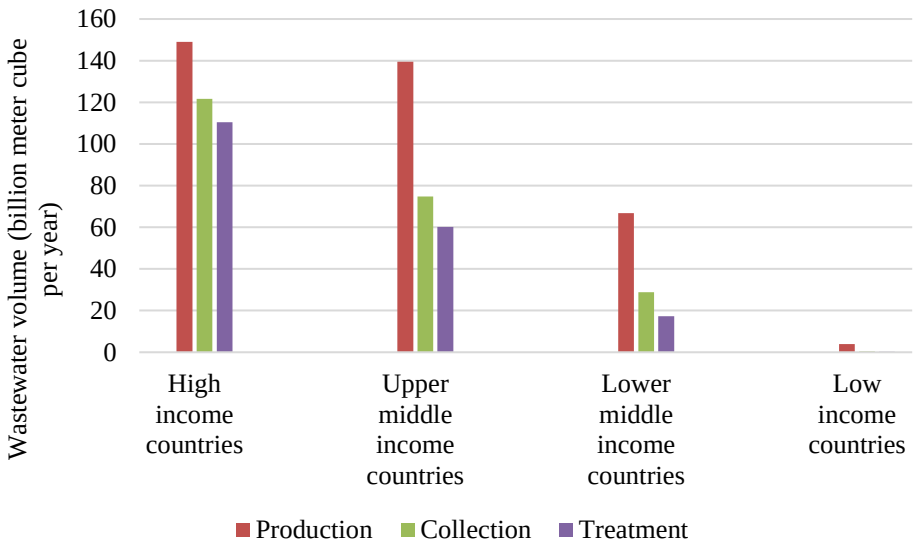

Fig. 5. Wastewater production, collection and its treatment($10^9 m^3 y^{-1}$) in accordance with economic development of countries [17-34].

groundwater resources are heavily polluted by leaching of fluoride, arsenic, nitrates, iron, heavy metals, and pesticide and fertilizer remains [50].

The fluoride contamination has been observed in aquifers of northwestern India, particularly in Rajasthan and Gujarat, where alluvium aquifers predominate. Fluoride contamination is also reported in major districts of Indian state of Assam in eastern India such as Kamrup, Golaghat, Karimganj etc., in major cities in Indian state of Bihar in northern India such as Gaya, Kaimur, Jamui etc., in western India such as Ajmer, Bundi, Mehasana etc., and in southern India such as Salem, and Nalgonda etc. Fluorosis, caused by fluoride contamination, is a chief hassle in India, and over 62 million people in 20 states are affected by fluoride contamination [51]. Another research suggested that many places in West Bengal are contaminated with arsenic, although Bihar is a growing state with high arsenic contamination [52]. The study of different reviews showed that freshwater systems of Delhi, Bhopal etc. and some rural areas are also affected with significant levels of pesticides [53].

Toxins from untreated industrial waste and disposal areas, and bacterial contaminants from surface soils and water sources can also contaminate groundwater reserves. Open stools are also a major cause of water pollution. According to the WASH Report of 2021, about 15% of India's total population defecate in the open because they do not have water connections or toilets in their homes [50]. It is also reported that more than 4,000 septic tank trucks full of sewage sludge are dumped into India's longest river, the Ganges, and its tributaries every day, with each truck containing an average of 5,000 liters of human waste. A 2021 study conducted by ASAR Social Impact Advisors, a consultancy based in Bangalore, and its two local research centers in Nagpur's Center for Sustainable Development and Manthan Adhyayan Kendra in Pune, found that toxic metals such as mercury and arsenic, as well as fluoride, were found in groundwater. In fast-growing Nagpur, roughly 93% of residents depend on these water sources for their water consumption. It appears to be due to the burning of coal that produces around 70% of the country's electricity [50].

One of important river in India, the Ganges is primarily a dumping place for toxic waste from highly polluted industries and communal enterprises throughout the Ganges Basin [54] and is considered among the most polluted rivers of India. Cities and towns along the Ganga generate approximately 33% of country's wastewater [47]. The most pollution causing cities on Ganges are Kanpur, Bhagalpur, Patna and Kolkata. In these cities, domestic as well as, industrial wastewater is untreated and discharged into rivers. The industrial city Kanpur is home to 45 tanneries and other polluting factories, responsible for approximately 18% of the total water pollution of the Ganges [54]. It is also noticed that nearly 6.614 billion liters /day of untreated wastewater is released into the Ganga River, with organic pollutants stuff is about 426 tons/day [49].

In Delhi, the Yamuna River, a tributary of the Ganges, runs along most polluted rivers in India. It is clogged with water hyacinths weeds as a result of eutrophication. When the monsoon sets in, dead fish in the river are found. This is because the concentrations of pesticides and other pollutants have risen sharply. About 19 drainage channels in Delhi drain into the Yamuna River due to a poor sewage treatment system. Wet sewage is discharged into these channels, from where it flows into rivers. Industrial waste also enters the river from industrial sectors (approximately 22 in Haryana, 42 in Delhi and 17 in Uttar Pradesh) and many smaller ones. Delhi's factories alone are responsible for approximately 80% of the river's pollution [55-56].

The Bharalu River, a branch of the Brahmaputra River in Assam, India, is one of the most polluted tributaries of the Brahmaputra River. Most of municipal solid waste and other wastes from the city affect the overall water health of the Brahmaputra River. BOD, fluoride, pH and dissolved oxygen are estimated to be the major causes of pollution in the Bharalu River. The main sources of these pollutants are dead plants and animals, animal manure, pulp and paper mill

effluents, sewage treatment plant effluents, sewage treatment plant malfunctions, stormwater runoff, steel and fiberglass industries. Fluctuations in river water pH are caused by emissions from agricultural runoff, acidic mine runoff, and fossil fuels such as carbon dioxide. Carbon dioxide becomes weakly acidic when dissolved in river water [57].

The disposal of residential as well as commercial wastewater into watercourses poses health, ecological and economic losses. In around 118 Indian cities, there is an indirect while in about 41 cities, there is direct discharge of wastewater in water bodies. Due to a shortage of waste treatment capacity, approximately 38791 million liters/ day of untreated sewage which accounts for roughly 62% of overall sewage produced is now dumped into aquatic bodies [49]. The Indian administration has set sewage discharge limitations, which are being amended in conjunction with the implementation of new laws and regulations to manage rising water pollution. The Central Pollution Control Board rules define emission parameters for different pollutants such as pH, color, BOD, TOC etc. from different sources. Despite these developments towards tackling water pollution, river and stream pollution is continuously increasing [49].

This polluted water in India causes infectious diseases like cholera, typhoid fever and other illnesses like stomach flu, diarrhea, vomiting, skin and kidney problem. Water pollutants are killing sea weeds, mollusks, marine birds, fishes, crustaceans and other sea organisms that serve as food for human. Every year approximately 38 million Indians suffer from water-borne diseases and the mortality rate from these water-borne diseases is high [58].

5.1.2. China

China is the East Asian country and is the world's most populus country having population size is about 1.4 billion. For the last decades, tremendous economic development, urbanization and industrialization in China brought about severe environmental contamination, out of which water pollution mainly is of deep concern [59-60]. In China, it is projected that there are 40 billion tons of water shortages every year on average. China's freshwater resources account for about 2.8 trillion cubic meters of water, accounts for approximately 6% of total world's water resources. Over 80% of China's lakes are considered to be eutrophic, more than 40 percent of rivers are extremely polluted, and groundwater is ubiquitously contaminated in both shallow and deep aquifers [61].

According to various reports, surface and groundwater of China has been deteriorating day by day. Water pollution is resulting from disposal of large volume of untreated wastewater which has adverse effects such as ecological degradation, declining the water sources efficiencies and decreasing water amount for consumption purposes. The waste water percentile in urban areas is above than 90% with no qualified water source in cities. There were two main causes of water contamination in China i.e., Industrial effluents & domestic waste. The Ministry of Water Resources reported that wastewater discharge across the country was supposed to be about 73.1 billion tons in 2006 year. The 2/3rd part of this discharge was from industrial sectors and 1/3rd was from domestic sewage [59].

According to China's Water Resource Bulletin 2018 (Ministry of Water Resources 2018), just 81.6% of the total of rivers, about 25 % of total lakes, approximately 87.3% of reservoirs and 23.9% of shallow groundwater satisfied the standards for sources of drinkable water [62]. Studies showed that nowadays, eutrophication remains the China's most important lake problem, with Taihu, Dianchihu and Chaohu lakes being the most severe instances. Heavily loaded point and non-point pollution from sewage streams, industrial effluents, and agricultural runoff are prevalent stressors of these lakes. As a result, the water quality of Taihu Lake has fallen 1 grade every ten years during the last 30 years. The water quality of the Huaihe river (between the Yellow River and Yangtze), the Liaohe river (principal *river* in southern Northeast China), and the Haihe river in northern China is relatively poor, with the Haihe River seems to be the most polluted. Municipal sewage and industrial effluents discharge was the primary cause of pollution in these rivers [61].

In 2008, quality of the water in 20.8 percent of 409 surveyed parts of China's 200 main rivers fell below class V, the worst class of China's National Water Quality Standard. Water of this quality has virtually no functional use, even for irrigation purposes [63]. The Ministry of Water Resources of the People's Republic of China in 2005 investigated the main water resources of China for major pollutants and reported that the major pollutants of Songhua River Basin and Liaohe River Basin are COD, BOD, ammonia nitrogen and permanganate index [59].

Chlorophenol pollutants (CPs) have also been found in rather high amounts in several Chinese waterways. An analysis discovered that 2,4-dichlorophenol and 2,4,6-trichlorophenol were more commonly observed in greater amounts in north Chinese waterways than in south Chinese rivers. The Yellow, Huaihe, and Haihe rivers had the highest concentrations of 2,4-dichlorophenol and 2,4,6-trichlorophenol, whereas the Yangtze River had the highest concentrations of pentachlorophenol. Many pollution incidents have occurred in China's rivers, including cadmium pollution in Beijiang River (Guangdong Province), phenolic pollution of Liaoning Province's Hunhe River, occurrence of cadmium pollution in Xiangjiang River (largest river of Hunan Province), and leakage of diesel oil in Gongyi river in the middle of Henan Province. This surface water will inevitably become polluted unless contaminants are efficiently removed [61-64].

Studies also showed that the Tonghui River and Guanting Reservoir of Beijing, Minjiang River Estuary and Wuchuan River in China had relatively higher concentrations of dichlorodiphenyltrichloroethanes (DDTs) and hexachlorocyclohexanes (HCHs) in water [65]. In last decades, river pollution in China was mainly due to disposal of effluents as result of industrial activities. However, according to the China Pollution Source Census (2010), agricultural sector is now a major contributing source of water pollution in China than industrial wastes. Considering pesticide pollution, large number of studies documented that

organochlorine and organophosphorus pesticides are detected in water bodies of China [66-67].

In Northwest of China and North China Plain, nitrate contamination occurs due to excess fertilizer use as they are most cultivated areas of China. Therefore, fertilizer's use is considering as most dominant source of water contamination in these areas. Return flow of irrigation water having high concentrations of nitrates, salts and agrochemicals resulting in diffuse pollution of ground water [68]. Diffuse pollution of ground water is global concern but it is particularly high in China [69]. It also appears that septic wastes and animal dung are important sources of nitrate in the groundwater in many regions. Overall, the most serious water contamination occurs in northern China. Based on 2019 Blue City Water Quality Index, released by the Institute of Public and Environmental Affairs, many areas of Northern China (for example, Hebei and Shanxi provinces) have relatively low water quality [70]. The North China Plain, with accelerated agricultural and industrial activities, is the area of China's major water and other environmental threats. The North China Plain is also famous for 'cancer villages' in China. Cancer villages are areas where cancer mortality rate is high [71-72].

China's National Health Commission shows that approximately 7.8 million cases of infectious diseases were reported in 2018, including waterborne diseases (18.9%) [62]. About 190 million people get sick and 60,000 die each year from various diseases and injuries related to water pollution [73]. Fluorosis and arsenic poisoning are still threatening the health of Chinese people. Villages with high cancer rates in the Huai River Basin face serious medical problems. For an instance, over the last 30 years, cancer mortality has increased significantly in Yingdong District of Fuyang city located in Anhui Province, in Shenqiu state in the east of Henan Province, and in cities of central China in Hubei Province [62].

5.1.3. Pakistan

Pakistan is a South Asian country with the population size of about 243 million people. It is ranking 5th in most populated countries of world. Alike other world's developing countries, Pakistan is also suffering from water contamination. It is also among the water stressed area as it is depleting fresh water resources caused by increased pressure for different water usages [74-75]. The main sources of contamination of water bodies are household sewage, rapid industrialization, rapid urbanization, poor management systems and population increase [31]. Pakistan's population and urbanization has been increasing tremendously, resulting in an increase in domestic water demand. It is estimated that population of Pakistan will reach to almost 275 million in 2050 and urbanization from approximately 24% in 1980 to 50% in 2025 of total population. Population Growth of Pakistan in millions from 1980 to 2050 is shown in Fig. 6 [74]. Domestic water demand increase with population growth of Pakistan is shown in Fig. 7.

In Pakistan, microbes, inorganic substances (toxic metals, salts and acids), cations and anions (nitrates, sulphates, phosphates, fluoride, magnesium and calcium ions), water-soluble radioactive substances, oil, insecticides and pesticides are considered as effective water contaminants. These water contaminants are mainly due to human activities i.e., disposal of industrial and municipal and agricultural effluents in water bodies [11]. Piped water is also polluted since it is installed so near to sewage pipelines or drainage channels, resulting in a slew of deadly water-borne infections. In Pakistan, diarrhea was shown to be responsible for around 45% of newborn fatalities and contribute about 60 % among all severe water-borne infections. As stated by WHO, gastro-intestinal ailments account for 25 percent to 30 percent on average of all diseases [74].

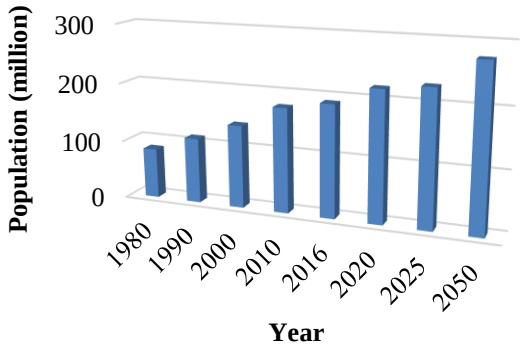

Fig. 6. Population Growth of Pakistan (1980-2050) [74].

According to estimation of The Government of Pakistan, the urban areas are generators of approximately 87,000 tons of solid waste per day [76-77]. Karachi, the biggest city of Pakistan, generates over 13,500 tons of domestic waste per day [78]. Lahore, the 2nd biggest city of Pakistan also has severe water contaminated problems. The Ravi River is the biggest water supply source in Lahore. Approximately, 11 million people depends on this river. But the river acts as spillway for industries [79]. It is estimated that in every second approximately 3304 cubic feet of wastewater is discharged without treatment in the Ravi River from different drains in Lahore [80].

Due to improper disposal of untreated pollutants, thickly populated cities of Pakistan like Karachi, Lahore, Faisalabad, Islamabad, Rawalpindi, Peshawar, Gujrat and Sialkot have no safe water for consumption [81]. In Pakistan around 1228, out of 6634 registered industries are considered to be high polluters [82]. High concentrations of organic and toxic substances in the waste effluents of industries, making them one of the major water polluters in Pakistan [83]. Textile, pharma, ceramics, petrochemicals, food, oil mills, steel, fertilizer factories, leather tanning and sugar factories are the main sectors which are causing water pollution. River Kabul in Khyber Pakhtunkhwa, collects nearly about 80,000 m^3 (8×10^7 L) of industrial wastewater daily. The capital of Pakistan, Islamabad's two industrial estates are draining there effluents in the Sawan River as these estates lack wastewater disposal systems [11]. These industries produce large volumes of wastewater containing high concentrations of pollutants like toxic metals, nitrates, cations and anions [82-84].

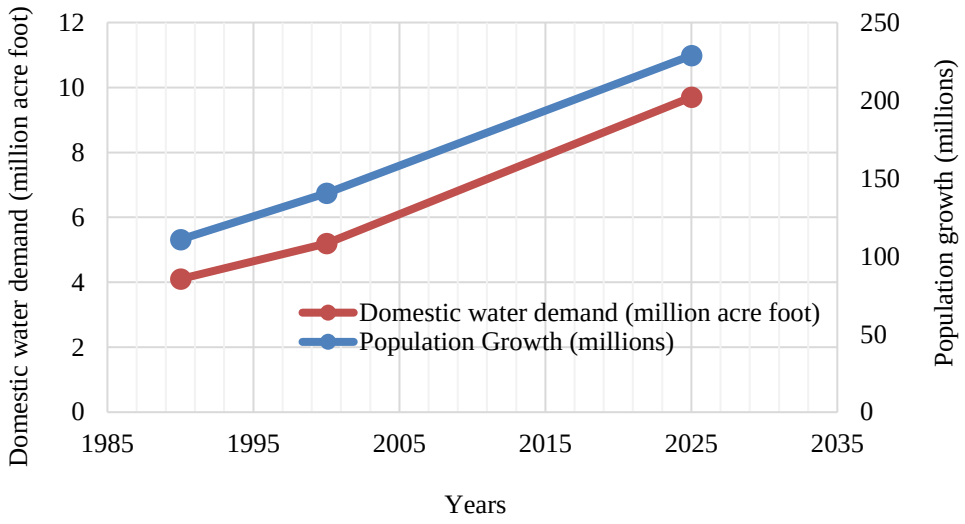

Fig. 7. Domestic water demand with population growth of Pakistan (1990-2025) [74].

Different cities in our country release an estimated 40 G L of wastes into water bodies every day. Industrial wastewater is mostly produced by the nation's largest cities, including Karachi, Lahore, Faisalabad, Sialkot, Peshawar, Quetta and Hyderabad. Domestic and municipal trash, in addition to industrial wastes, seriously contaminate water supplies. The massive use of agrochemicals in agriculture is another significant source of water contamination. When applied to cropland, agricultural chemicals such as fertilizers and pesticides with higher amounts of chemicals such as nitrates, ammonia, phosphates and sulphates mix with irrigation water and eventually leak into the soil to reach natural water supplies. In addition, some fertilizers contain heavy metals as by-product, and the extensive use of such fertilizers results in the accumulation of these toxic metals in soil and water [11].

The primary causes of Pakistan's numerous public health issues related to water pollution are microbial and chemical pollutants. Studies conducted in major cities like Karachi, Islamabad, Lahore, Rawalpindi etc. reported that major contamination in these areas is bacteriological contamination. A recent study reported that water samples from Islamabad's Rawal Lake (which supplies drinking water to more than 1.5 million people in Rawalpindi) and its tributaries may be contaminated with bacteria [85]. Bacteriological contamination is mainly due to leaching of municipal wastewater. The surface run-off, increased concentration of nutrients and municipal waste are the major contributing sources of bacteriological contamination. Microbial contamination of drinking water is a major cause of waterborne diseases such as diarrhea, nausea and typhoid fever, especially in children and people with weakened immune systems [11].

These major cities are also attributed with toxic heavy metals contamination. These metals are released into surface and groundwater through a variety of man-made activities, including the extensive use of pesticides in agriculture and dispose-off of industrial and metropolitan waste inappropriately. Most of the metals are considered to be indispensable to our health, but they cause water pollution when overloaded [86] . Studies shows that ground and surface water of Karachi mainly consist of high concentrations of Zn, Cd, Hg and Ni. According to the statistics of numerous studies, Sindh and Khyber Pakhtunkhwa have relatively high Cd contamination in their ground water than Punjab does [87]. The highest Mn (2.56 mg/L) contamination was reported in Khyber Pakhtunkhwa [86] followed by Faisalabad [88]. Higher Zn contamination was reported in Karachi [11].

Higher chromium contamination was found in sources of drinking water of Lahore, Gujrat and Sialkot due to presence of leather industries and tanneries there [84]. Reports showed that, the groundwater samples from Khyber Pakhtunkhwa and Karachi have the highest concentration of nickel [86]. About 75 percent of surface water samples from Karachi, the largest metropolis in the nation, are above the USEPA's standards for nickel in drinking water. Heavy metals contamination causes serious health problems like neurological disorders, cancer, liver and heart diseases etc. Agricultural practices require high pesticidal use in the entire world. Worldwide estimation of annual pesticidal use is about 2.5 million tons with continuous increases of which Pakistan alone is responsible for use of approximately 70 thousand tons of pesticides annually with increasing annual rate of about 6%. It is estimated that only about 0.1% of applied pesticides reach the targeted organisms and the remaining portion is lost thus causing environmental pollution. In Pakistan, this problem is further increased due to improper storage, usage of outdated pesticides and lack of awareness of its harmful effects [11].

5.1.4. Bangladesh

Bangladesh, formally the People's Republic of Bangladesh, and is ranking 8th in the world's most populated nations. Bangladesh, a riverain state, blessed with about 230 large and minor rivers [89], located to the east of India on the Gulf of Bengal, is a South Asian nation with an estimated population of over 180 million inhabitants spread across 144,000 km^2, and acknowledged with lush flora and numerous rivers [90-91]. It has witnessed fast industrialization, vast urbanization, and substantial digitization in recent decades in Bangladesh, all of which have had major environmental repercussions. Because of the fast development in terms of industrialization and urbanization in Bangladesh, fresh water sources are being poisoned, particularly arsenic poisoning is threatening the potability of these natural resources [90], as arsenic is a fatal and WHO-classified carcinogenic element [92].

Regarding both quality and quantity of available water in Bangladesh, the supply of water has surfaced as a key worry for the future. About 97% of rural dwellers of Bangladesh have access to tube-well water for drinking purposes but regrettably arsenic pollution of groundwater has turned tube-well water unsuitable for drinking across several regions of the country particularly urban areas [93]. Throughout the first ten years period of kilo-annum, round about 35 to 77 million individuals were chronically exposed to arsenic (Flanagan et al., 2012). The acceptable limit of arsenic contamination of drinking water in Bangladesh is 0.05 milligrams per liter, however in certain areas, its concentration is found 70 times higher than acceptable limit. Therefore, nearly 80 million people are suffering from arsenic exposure in Bangladesh [94]. Fazal et al. (2001) reported that arsenopyrite (FeAsS) mineral is a primary cause of arsenic contamination of water bodies of Bangladesh. The two ideas established to explain arsenic mobilization are oxidation of pyrite and oxy-hydroxides reduction [95-96].

The studies on water sources in Barapukuria near coal mine area, in Dinajpur (district in the Rangpur Division of northern Bangladesh) [97], in Dhaka Narayanganj Demra Embankment [98] and in Singair (upazila of Manikganj District) [99] etc. also revealed the prominent levels of other trace elements like chromium, manganese, lead, and cadmium etc. Moreover, microbial pollution particularly bacteriological is also reported to be a serious contaminant in Bangladesh, especially in rural areas such as Gakulnagar village in Dhaka district, where 60 percent of tube-well water is polluted by total coliform bacteria [100]. Furthermore, another research found three tube-wells in Sardarkandi village in Dhaka district, are substantially polluted with total coliforms [101]. Likewise, approximately 207 water samples collected from areas of Cumilla District of Chittagong Division, from Brahmanbaria District and from Sirajganj District in the Rajshahi Division, were analyzed and about 41 percent of them were affected by total coliform, additionally 29 percent samples with thermos-tolerant coliform and about 13 percent with E. coli [102].

In Bangladesh, the major reason behind this chronic contamination is sanitation problems. Around 60% of rural dwellers lack access to sanitation infrastructure. The Dhaka Water and Sewerage Authority (DWASA) can provide service to only 15 to 20% of the total city's population. Approximately, 30% of Dhaka's residents, 50% of Chittagong's inhabitants and 35% of other district's population do not have access to hygienic latrines or defecate open into environment. Solid waste handling systems have continually been unable to keep up with the massive volume of solid garbage generated in cities. The Dhaka City Corporation collects only approximately 40% to 50% of all produced garbage in Dhaka, while waste collection units' coverage in other major cities ranges from 60% to 70%. Due to lack of solid waste management services, particularly among the urban areas, there is a frequent disposal of garbage into water bodies. Except for a few established residential neighborhoods (such as Dhanmondi, Gulshan, Banani, Baridhara, and others), urban centers in Bangladesh, including Dhaka and other major cities, are expanding without adequate sewage and drainage facilities.

Surface water contamination in Bangladesh's urban areas is mostly caused by industrial pollutants. Bangladesh's main mechanical production areas are Dhaka, Chittagong, Khulna and Bogra [94]. Just approximately 40% of sectors have effluent treatment plants, according to 2009 industrial research, performed by the Bangladesh Center for Advanced Studies (BCAS). ETPs were under development in 10% of industrial sectors at that time, while around 50% of industries had no effluents treatment setup at all (Amin, 2015). The Department of Environment (DoE) has recognized 1,176 polluting industrial sites around the country [94]. In terms of total discharge in water (as measured by biological oxygen demand and total suspended solids), the pulp and paper industrial sector is the largest contributor which accounts for 47%, accompanied by pharmaceutical industries (16%), metal processing (14%), food manufacturers (12%), fertilizer's and pesticidal use (7%), industrial chemicals use (1%), and certain other industries (3%) [103]. Dhaka as well as adjacent districts, such as Gazipur and Narayanganj, have been the biggest victims of unregulated industrialization, resulting in serious water quality problems. Although, Dhaka is amid by rivers, but water of these river systems is too filthy to be drinkable. Throughout the city, 19 principal and as well as 41 subsidiary river discharge locations are present. Illegal discharge of unprocessed effluents from several industrial sectors around those rivers contaminates the water [95-104-105].

According to a World Bank research, Dhaka's periphery rivers receive 1.5 million m^3 of effluents/day from approximately 7,000 manufacturing units in the surrounding districts with an additional 0.5 million m^3 coming from some other sources [106]. Tanneries at Dhaka's Hazaribagh and Rayer Bazar discharged 15,000 m^3 of liquid waste, 19,000 kilos of solid garbage, and 17,600 kilos of BOD in the Buriganga river [107]. Kaliakoir, subdistrict of the Gazipur district, part of Dhaka division, where an uncontrolled industrial complex has emerged during the last 20 years. This industrial complex has been using Mokosh Beel (Gazipur's perennial beel), Turang River, a tributary of Buriganga River and Ratanpur Khal water bodies as disposal sites for the disposal of 30 billion liters of effluent's containing water per year [108].

Many textile manufacturing and dyeing sectors, as well as other enterprises located around the Dhaka-Narayangonj-Demra embankment, dump huge amounts of industrial effluents into several waterways, which finally reach the Shitalakshya River, a distributary of the Brahmaputra. Nearly 80% of overall industries lack treatment plants and hence dump untreated harmful effluents into water ways [95-98]. Discharge of significant amount of industrial effluents in Karnaphuli River, major watercourse of Chittagong region in Bangladesh, is also reported from spinning and steel plants, oil refineries and fabric industries [109].The shipbreaking business is among the Bangladesh's fastest expanding businesses, and it contributes significantly to trace metals contamination of groundwater in Bangladesh's coastal regions [110].

Human waste pollution of confined water bodies is also a big issue in Bangladesh [111]. According to prior estimates, Bangladesh generates around 16,380 tons of garbage daily [95-112]. The worst victims of this type of water contamination are urban areas. Wastewater output alone from Dhaka capital is around 1.22 million m^3 per day, however treatment ability of Dhaka's only sludge treatment facility, "Pagla Sewage Treatment Plant," is only 0.12 millionm^3 of effluents per day [95-113]. Agricultural sector, Bangladesh's economic backbone, accounting for 15.33% of country's GDP and half of total economic output [114] is also a major cause of pollution. Local farmers utilize a variety of organophosphorus and carbamate insecticides, however owing to a lack of sufficient education, they abuse these chemicals [115-116]. Pesticides and insecticides misuse is continuously polluting fresh water, primarily caused by rain or agricultural runoff [95-117].

Some smaller causes can also result in water body pollution. According to Bhuiyan et al. (2010), the Barapukuria coal mining is blaming for heavy metal discharge and thermal contamination of local water sources [97]. An unintentional oil spill can potentially have serious consequences for the water quality and marine life species in vast waterways. A recent 'oil spillage event led to approximately 350 thousand liters of oil spilling across 60-kilometer-long region of Shela and Passur rivers within Sundarbans, country's the biggest mangrove forest [95]. The discharge of all these types of contaminants is seriously affecting the human life in Bangladesh. Due to water contamination, the most common diseases found in the people of Bangladesh are melanosis, hyperkeratosis, gangrene, skin cancer, diarrhea, hepatitis A and hepatitis B, vomiting, blurred vision, nausea, typhoid, difficulty in breathing, and deficit hyperactivity disorder. In Bangladesh, annually over 1 lac children below five years die as a result of diarrheal epidemics. According to the 2004 Bangladesh Demographic and Health Survey (BDHS), diarrhea alone was responsible for 5.1 percent of all infant fatalities. An estimation shows that, annually approximately 43,000 people of Bangladesh die as a result of arsenic poisoning [95].

5.2. Review of most affected areas of sub-Saharan Africa

Africa is the second largest continent on earth. After Asia, it is most populated continent of world. The continent consists of five regions i.e., South Africa, Central Africa, North Africa, East Africa and West Africa and is endowed with natural and mineral resources i.e., coal, metal ores, gold and oil etc. [118]. But the development in the mining of these resources has resulted in severe environmental contamination particularly water pollution. Development related urbanization and population increase of the African continent is not without its negative consequences on the environment and ecology. This development has also made a significant contribution to the existing pollution of water resources and created a large strain on water resources. African cities are facing tremendous population growth, with 54% of the continent's population predicted to live in urban areas by 2030 [119].

Water contamination in Africa is mostly caused by untreated domestic wastes, agricultural effluents, industrial discharges and storm water runoff [120]. A major cause of surface water pollution is untreated sewage discharged into the water from urban areas and factories. A few African nations have regulations regarding the discharge of wastewater into surface waterways, however it is uncertain if these regulations are actually being followed or not [121].Biological and chemical water quality of major sources of water supply is often poor because to the continent's near proximity to poor sanitary facilities [122-123]. According to predictions, the state of Africa's different water resources will continue to worsen, adding to the burden of disease and the risks to the environment and public health. Wastewater (WW) discharge into the environment is still a common practice in developing nations despite advancements in WW collection and treatment [124].

But untreated wastewater problems are particularly high in sub-Saharan Africa which is the area in the south of Sahara Desert in African continent. Ongoing population and industrial expansion have been negatively impacted the water quality of sub-Saharan Africa as vast amount of untreated waste water is produced by these activities. Only around 10% of produced WW is treated before being released into the environment, thus reduces the water's quality of this region. It is estimated that only 25% residents have access to quality drinking water and approximately less than 30% have access to essential sanitation facilities. The population of nations of sub-Saharan Africa is predicted to exceed 1 billion, and it is growing faster than most other parts of earth. SSA is undergoing a historically rapid urban drift. Between 2010 and 2035, the number of urban residents is projected to more than quadruple, to be between 300 and 700 million [125].

Due to insufficient water supplies allocation, inefficient wastewater remediation, weak government policies, and deficient political determination to deal with the wastewater generation issue, Sub-Saharan Africa is far from achieving the sustainable development goals (SDGs) [126-127]. The water crisis has been particularly severe in countries like Uganda, South Africa, Nigeria, Ethiopia, Democratic Republic of Congo, Ghana and Somalia etc. [126-128].

5.2.1. Nigeria

Nigeria, Africa's most populus nation, with population of more than 199 million residents [129], is blessed with large number of water bodies. These water supplies fulfill the household, agricultural, recreation, transportation, and industrial requirements. But there is an uncontrolled dumping of untreated effluents into these water bodies of Nigeria as different rules and regulations for the protection of water bodies are not effective. In Nigeria, over 66.3 million people lack access to clean water for drinking purposes [130].

The untreated effluents discharge contains a variety of contaminants, including heavy metals, phosphates, oil and grease, nitrates, and chlorides etc. [131]. This poor water quality has affected several areas around the nation, seriously jeopardizing the general public's health [132]. In Nigeria, the majority of wastewater is sent to water management facilities, but only a small portion of the populace has access to adequate sewage system that is connected to the facilities for treatment [133]. In general, metropolitan cities' water quality has improved, while rural communities water quality is still subpar [130-134].

Oil drilling activities [135-136], domestic activities, agricultural activities [137], mining activities [138], commercial slaughterhouses/abattoirs [139-140], and some other industrial activities have all contributed to water pollution in Nigeria [141].The primary causes of natural water contamination are effluents from home and industrial operations. This imposes a heavy financial and wastewater management can therefore result in a point-source pollution issue, which not only significantly raises treatment costs but also exposes water sources to a variety of chemical pollutants and microbiological contaminants. Larger Nigerian cities like Lagos, Port Harcourt, Ibadan, Kano and others are suffering from effects of pollution from industrial effluents that are dumped carelessly into the lagoon, rivers, streams and fields [39].

Surface water pollution in Nigeria is mainly caused by direct and indirect discharge of industrial effluents (approximately 18%) from tanneries, textile industries, breweries etc. and effluents from oil refineries and gas industries (which alone accounts for 9% of surface water contamination) [133]. According to research by Veil et al. (2004), the petrochemical and crude oil processing industries release over 14 billion barrels of water worth of effluents into the environment every year [142]. Studies reported that The Nun River in Bayelsa state was found to contain significant levels of lead(II) and cadmium (II) owing to petroleum development activities between Gbarantoru and Tombia towns [143]. Toxic heavy metals discharge from oil exploration activities have been found in Ilaje gulfs [144]. Because of petroleum exploration, total hydrocarbon concentration of the Qua-Iboe River in Akwa-Ibom state was found to be greater than guiding norms [145].

Spillage has been recorded in downstream industry, which supplies petroleum and petrochemicals. Fluvial system of Oghara town in Delta state was found acidic and nickel-contaminated, rendering it polluted and unfit for drinking [146]. Petrochemical effluents leakage results in toxic level of heavy metals and their severe effect in Ubeji creek, Warri, Delta state [147]. As Nigeria is rich in minerals deposits like coal, gypsum, iron ore, rock salt, tac clay, gemstones, limestone, tin ore, gold etc. The exploitation of these minerals has polluted Nigeria's waterways [141]. Gold mining activities in Igun-Ijesha has resulted in excessive heavy metals concentrations in Osun state's Oika, Eriper, and Justice Ibidapo rivers [148]. Effluents discharge from some other industries has also been noticed in water bodies of Nnewi (industrial city in Anambra state) [149], Ota, town in Ogun state [150], Kano, capital of Kano state [151] and other urban areas in the country [152].

Slaughter house or Abattoir effluents are also affecting the Nigeria's water quality as Nigeria's most localities have an abattoir. Due to presence of large number of microorganisms, these effluents are the sources of bacteriological contamination of Nigeria's most of the rivers [153]. Different studies have reported the release of effluents having microbial load from slaughter houses in Ogun River (water way in Ogun state), Usuma River in Gwagwalada [154], and Ikoli Creek in Bayelsa state [155] etc. Water of boreholes in Akure, Ondo state, showed significant amounts of Cr owing to slaughterhouse waste [156-157].

Domestic sewage and effluents are another major contributing cause of water quality deterioration. Municipal trash with high microbial load is occasionally dumped into water bodies in metropolitan areas (PN, 2013). Additionally, due to inadequate drainage systems, municipal run-off from contaminated metropolitan areas discharges into aquatic bodies after a significant rainstorm [158]. Different studies have reported pollution of water bodies by domestic effluents in different states of Nigeria such as Epie creek (a tributary in Bayelsa state in Nigeria) [159], Nun river in Bayelsa state [160], Ado-Ekiti (capital city of Ekiti state of Nigeria) [161] and Siluko river, Benin city etc. [162].

Open defecation of municipal garbage is still common in Nigeria, particularly in metropolitan areas [163]. Due to relative vicinity between the dumpsites and water sources, the leachate from these landfills becomes a source of worry for Nigeria's water quality [164]. Comprehensive waste management approaches have been reported in places such as Ibadan (populus city of Oyo state), Akure (capital city of Ondo state), Lagos, and Abuja etc. [141]. The extensive use of this contaminated-water full of hazardous pollutants, due to shortage of suitable treatment funds, is expected to rise the frequency of water-borne illnesses and ecosystem degradation rate in Nigeria [165].

5.2.2. Uganda

Uganda, formally the Republic of Uganda, is an East African landlocked country. Uganda has an abundance of water resources, including vast wetlands, the White Nile River, and huge lakes like Lake Victoria. Around 35% of its water supplies originate in neighboring nations, posing water supply or water quality concerns due to severe contamination or even over in upstream regions [166]. Uganda now has a population of about 34.76 million inhabitants [167], with approximately 20 percent living in metropolitan regions [168] and the remaining 80 percent living in rural and suburban

regions. Uganda uses surface water and groundwater as fresh water sources. Surface water accounts for 15.4 percent of country's land area and is utilized by both urban and rural inhabitants [169].

Lake Victoria accounts for approximately 85 percent of all fresh surface water. Uganda's total groundwater sources are estimated to be around 29-million-m^3 per year, feeding more than 80% of rural and slum settlements. Despite country's vast surface and groundwater sources, poor communities in rural and urban areas face intermittent shortages in drinking water supplies. This water pollution is mainly caused by human sources such as sewage and industrial wastes discharge, agricultural wastes, and runoff during heavy rains [170-171].

Fresh water delivery is frequently insufficient due to low funds, insufficient capacity, flaws in rules and regulations, and a lack of viable options for service delivery all government agencies [172]. Even Lake Victoria, which is primarily located in Tanzania and Uganda and borders Kenya, is the world's second largest and the largest fresh water lake of Africa. It accounts for around 85% of Uganda's total fresh surface water and supply water for domestic and industrial purposes in the East African region and supporting the livelihood of millions of people [169-173].

Due to excessive nutrient's input (particularly phosphorous and nitrogen), this lake has become eutrophic, promoting the growth of the common water hyacinth and algae [169-174], intensive color, turbidity levels of up to 84.0 nephelometric turbidity units (NTUs), and pathogenic microorganisms occurring in the Lake [174]. Algal growth has increased manifold since the 1960 [175-176], making water green due to poor microbial quality [177]. The main causes of lake's contamination are partially treated domestic and industrial discharge, and agricultural runoff. There are large number of small and large scale industries in the catchment area of Lake and results in high organic and nutrient-rich effluents loaded with metal discharge in lake without pre-treatment [170]. Native fish and slum communities also dump their excreta directly in Lake. In Kampala City, the capital of Uganda, located within Lake basin, most of the wetlands around the lake have been cleared for farming and human settlement, which results in effluents discharge in L. Victoria's Inner Murchison Bay [178].

In rural and slum communities, the major contamination is bacteriological contamination. This contamination is attributed to unsanitary activities such as wide-spread usage of poorly constructed pit latrines and dilapidated drainage systems, as well as utter absence of basic sanitation where open defecation is practiced [170]. Study estimated that approximately 90 percent of households in Kampala, Uganda's capital city, utilize on-site sanitation facilities, predominantly pit latrines [179-180]. Such self-employed sanitation facilities are difficult to maintain, particularly in heavily populated places [166]. The majority of Ugandan's live in poverty with approximate earning less than $1 per day, which greatly impedes the implementation of efforts for enhancing potable water owing to sustainability concerns [170].

This contamination results in transmission of waterborne diseases such as cholera, typhoid, dysentery, guinea worm among others. Each year, cholera kills number of people throughout Africa [181] and is also a major cause of morbidity and mortality in Uganda [182]. Majority (58%) of the reported cholera cases during the period 2011–2015, are reported in the fishing communities in the catchment area of major lakes and rivers which constitutes 5% of the Uganda's population [183] and these cholera outbreaks mainly occur due to usage contaminated surface water and the springs [184-185].

5.2.3. Ghana

Ghana is West African nation and is famous for gold mining activities. It covers an area of approximately 240,000 km^2 and is home to an estimated population of approximately 22.5 million people, with 42% urban and remaining 58% rural. The country is blessed with abundant water resources. It has three major river systems: the Volta River, the Coastal River system, and the Southwestern river system [186-188]. Approximately 60 percent of Ghana's water sources are polluted, with the majority of them being in critical situation (such as those located in the southwest or coastal areas), owing to surging levels of contamination from industrial effluents, illegal mining activities, agricultural production, domestic disposals, fertilizers and pesticides leaching, as well as the most current and worrisome canker being illegal artisanal mining named as Galamsey [189-191].

Illegal mining remains a persistent threat, as practically all fresh water sources near mining locations, notably Ghana's southwestern river systems, are severely contaminated [191]. According to different studies, arsenic, lead and iron were the most prevalent mining-related metallic contaminants discovered in surface water bodies of Ghana [192]. It is estimated that fresh water bodies of Ghana such as River Pra and River Ankobra in southern Ghana, River Birim (a tributary of Pra River) in the Eastern Region of Ghana and the Enu River in Ashanti Region have been polluted as a result of illicit mining activities. Several water bodies in the central region, notably around Cape Coast have also been contaminated due to illicit mining activities [55-189].

Moreover, the use of chemicals such as dichlorodiphenyltrichloroethane DDT in fisheries combined with accelerated population increase has rendered water supplies completely unmanageable [193-194]. This issue goes to the new Juaben communities and Koforidua town where fishing activities have been polluting fresh water sources around these communities [191]. Insufficient domestic and industrial wastewater treatment has been polluting water resources in and around metropolitan centers of country. Waterways near industrial regions (for example Korle Lagoon in Accra) are slowly dying as a result of untreated domestic and industrial wastewater discharge, causing foul odors and nutrient build-up leading to algal blooms [191].

Wastewater generated through domestic and industrial uses including storm water in urban Ghana is estimated at about 760 million m^3/y [186]. It is also alleged that The Densu

River in the Greater Accra, which depends upon Western Accra around Weija dam for water supply and the Black Volta in the upper west region, have been contaminated due to industrial effluents and farming operations. Sand wining is the primary activity responsible for water pollution in the Northern areas. For example, The Nawuni River in the northern area has seen significant sand mining operations and therefore altering the river color. All these sources combined with significant population expansion, prompted Ghana Water Company to build new water treatment facilities to supplement the provision of clean drinking water [55-191].

5.3. Areas affected in Latin America and Caribbean

Latin America and the Caribbean (LAC) is made up of 33 independent nations that are members of the Community of Latin American and Caribbean States, as well as a series of tiny dependent states on islands. The independent states span an area of about 20.5 million km^2, and the region's total available freshwater resources are around 18.5 billion m3 per year, accounting for 34 percent of the global supply of water. Therefore, LAC has comparatively abundant water resources [195]. This region's population was 609 million in 2012 which accounted 8.6 percent of world's population, quickly rising at a pace of 1.25% per year, and is expected to cross 700 million by 2025 [196].

Rapid increase in population and urbanization are putting significant strain on fresh water resources [195]. In 1995, around 78% of South America's population lived in urban areas, but by 2025, it is expected that 88 % of the population would be clustered in urban regions. The proportion of the Central American population living in cities is predicted to rise to 60 to 80 %, based on the area. Just 41% of the urban residents have accessibility to sewerage systems, and as a result 90% of the untreated urban wastewater is dumped into the environment. Water contamination from inadequately treated or untreated home and industrial effluents, agrochemical's runoff, and wastes from mining activities is becoming growing concern in LAC. Detergents, fertilizers, petroleum and its derivatives, toxic metals, and oxygen-depleting substances from different processing plants such as canneries, slaughterhouses, meat processing plants and paper and pulp industries are among the most common contaminants found in water [196].

Agriculture is the primary consumer of freshwater in the LAC. Agricultural sector contributed to 68 percent of total freshwater extraction in LAC in 2011, while the industrial and household sectors contributed to 11 percent and 21 percent, respectively [195]. Different challenges such as significant climatic differences, varying levels of economic growth rates of different countries, huge social injustices, lack of adequate financial accounting and clarity, and administrative and institutional deficiencies are complicating the implementation of water management policies. Nutrient pollution has been highlighted among the major stressors on biodiversity of Latin America, with a typically growing tendency. The pollution absorption capacity of rivers has been totally utilized in areas of Mexico, parts of Central America, and many coastal regions of South America [197]. Particularly high levels of water pollution are found in Mexico and the southern region of Latin America [198]. Water contamination is partially triggered due to shortage of water treatment facilities and water sector governance. Despite having treatment facilities to treat approximately 35 percent of the wastewater, only 20 percent of the wastewater in LAC is efficiently treated [197]. Over 70 percent of sewage is dumped untreated into nearby aquatic bodies, and therefore generating significant water contamination concerns [199].

Untreated wastewater from the residential and commercial sectors makes up the majority of total nitrogen-related wastewater in most of the rivers because aquatic habitats are utilized as sinks for effluents from different sources across the region. For instance, in Jamaica, an island in Caribbean Sea, effluents from the rum and bauxite industries, have damaged both ground as well as surface water resources. The biggest polluter in the region is Brazil – the country with the largest water resources [200]. [201] discuss the "huge usage of pesticides" in Brazil's agriculture sector. Substantial investments planned for waste management of larger LAC cities including Buenos Aires (capital of Argentina), Mexico City (capital of Mexico), Bogota (capital of Colombia), and Lima (capital of Peru) etc., have been postponed due to a lack of robust institutions and legislative frameworks that impede efficient implementation [195].

Tourism, the second-largest currency earner in much of the Caribbean, puts further strain on water resources. Tourism uses a lot of freshwater (especially for hotel premises and swimming pools etc.) and creates a lot of effluent, especially in coastal locations like Montevideo, Lima, Rio de Janeiro, and other coastal areas [196]. Due to significant number of industries and population, the metropolitan areas encounter the greatest challenges in terms of water quality. Almost all the rivers that drain urban effluents from larger cities including Argentina's Riachuelo river, the Tietê river in Sao Paulo state (Brazil), the Mapocho River in Chile, and the Bogotá River in Colombia etc., are heavily polluted. Storm-water runoff is another cause of pollution in the region's main metropolitan centers [196].

In Argentina, salty water invasion threatens coastal regions around Mar del Plata and is reported to have caused salinity of certain aquifers in the Buenos Aires area. According to case studies in Argentina, approximately four million residents of center-northern provinces are exposed to arsenic contamination of water bodies [202] and are thus continuously exposed to arsenic-related diseases such as skin lesions and cancer [203]. In Ecuador, about 3,300 tons of solid waste is dumped annually, which is said to have affected the water quality of the Tomebamba and Machanagara rivers. Direct solid wastes dumping in water bodies has also been reported from Haiti and the Netherlands Antilles. In Brazil's Guanabara Bay, most solid waste is dumped at the bay's edge, and in the city of Rio de Janeiro alone he dumps more than 3,000 tons a day. In Caracas, the capital of Venezuela, household solid waste is also reported to be contributing to water pollution problems. Medellín, Colombia and Santiago, Chile are characterized by bacteriological contamination of adjacent water bodies due to lack of wastewater treatment. Mexico reports salmonella poisoning as well as other stomach problems higher than the national average among

1,500,000 individuals who live near extremely polluted Coatzacoalcos River that feeds mainly the south part of the state of the Veracruz. Low-income populations are typically the most affected, as they lack safe water and proper sanitation services. In Mendoza, Argentina water pollution from agricultural effluents drainage into irrigation canals is severe [196].

The situation has the potential to be disastrous. In addition to the detrimental consequences of these anthropogenic activities on the ecosystem, this scenario poses a significant risk to the health of the region's inhabitants and may increase mortality rates. In the early 1990s, an outbreak of cholera disease in Peru expanded across a large portion of the continent, leading to more than 1.3 million illnesses and far more than 11,000 fatalities. Polluted water is also widely used for irrigation purposes, facilitating the spread of waterborne diseases such as diarrhea, hepatitis, intestinal infections, Cholera and others. For example, around 90,000 hectares of agricultural area in Mexico's Tula Valley is irrigated with wastewater from Mexico City, and about 62,000 hectares of vegetables are irrigated with wastewater from sewage flow of Santiago, a capital city. [196].

6. Consequences of untreated wastewater discharge

The discharge of wastewater effluents is responsible for the deterioration of water bodies that receive it, such as rivers, lakes and streams which negatively influences health of the public, biodiversity, and the ecological environment [204-205]. Polluted wastewater discharged can have a variety of negative consequences on the health of receiving water bodies, depending on discharge volume and chemical as well as microbiological composition of effluents. It also relies on the kind of discharge, such as the concentration of suspended particles or organic matter or dangerous pollutants such as heavy metals and as well as the characteristics of water bodies that receive these effluents [206].

6.1. Health Impacts

Water is a major contributing source of infection because of its solvent properties. 80% of transmission of diseases occur through water. Drinking water in various countries does not meet WHO standards [22]. About 3.1% of deaths are caused by unsanitary conditions and poor water quality [23]. Due to the scarcity of water treatment facilities across many nations, wastewater is frequently released from domestic, agricultural, and industrial sources into waterways without adequate treatment [207].The wide use of this untreated wastewater for agricultural purposes directly contributes to an increase in infectious diseases [208]. Excreta-related infections, skin irritations, and toxic compounds released from these sources affect the health of farmers and agricultural employees, populations living near wastewater irrigated areas, and consumers of crops irrigated with wastewater [209]. About 3.4 million people/ year die globally from water-related diseases [95]. Salmonellosis, typhoid, cholera, hepatitis A, polio, gastroenteritis, as well as other diarrheal disorders have been associated to wastewater exposure [210].

Helminth infections, particularly ascariasis, are frequently connected to wastewater exposure and have been related to anemia and poor mental and physical development [211]. Agricultural laborer's develop skin disorders such as dermatitis and rashes as a result of their regular exposure with untreated wastewater. Heavy metals exposure via contaminated foods, occupational intake or inhalation of irrigated soil has been related to a variety of chronic health problems. For example, cadmium buildup, especially in kidneys, causes renal damage and osteoporosis [212]. Because of these broad health dangers, organizations such as the WHO have set recommendations to guarantee that pollutant's level in wastewater are kept below the hazardous level for human health [210].

6.2. Ecological Impacts

The widespread usage of wastewater is expected to accelerate environmental degradation. The consequences of such deterioration may include release of harmful substances, decreased dissolved oxygen levels, physiological changes of receiving waterways, bioaccumulation or biomagnification in marine life, and increased nutrient loads [165]. The loss of dissolved oxygen is exacerbated by eutrophication caused by an overabundance of nutrients. Low dissolved oxygen levels have an influence on fish survival by raising their vulnerability to diseases, retarding development, hindered swimming ability, altering diet and locomotion, and, in severe cases, leading to quick death [213].

Poorly handled wastewater discharges can also cause physiological changes of waterbodies. All aquatic organisms can tolerate a specific temperature range. If the average temperature of water rises it can affect ecosystem. Urban water effluents are warmer than receiving water and therefore contribute in thermal augmentation. Furthermore, suspended solids discharge can also result in reduced photosynthesis due to low penetration of sunlight [165]. Another ecological consequence of untreated wastewater, sometimes potentially health-related, is the process of biological accumulation and biomagnification of pollutants. These pollutants can be immeasurable or present at low concentrations in water, and sometimes be detected in high quantities in animals and plants tissues. Moreover, harmful chemicals released from wastewater into waterways have direct deleterious effects on land plants and animals [213].

7. Health, ecological and economic benefits of effective wastewater treatment

Large capital investments for infrastructure of wastewater and sanitation would provide enormous advantages to public health, protect the natural world from pollution and deterioration, and considerably improve people's quality of life. Effective wastewater management will dramatically reduce infectious diseases in surroundings and protect public health from terminal illness. Besides the environmental and health advantages of effective sewage treatment plants, there are economic benefits such as cost savings that result from reusing wastewater for various purposes such as irrigation [125]. Successful WWM would also result in the supply of safe and excellent drinking water, motivation to pay for high-quality water for drinking, water

conservation, and sewage reduction. Additional economic advantages of successful wastewater management are the use of sewage sludge to generate renewable energy or indeed the improvement of water bodies [214].

8. Solutions and Recommendations

There are a number of factors that contribute to the contamination of freshwater bodies. Therefore, in order to reduce the global freshwater quality crises, particularly in developing countries, it is recommended to develop water quality standards and enhance water quality monitoring. It is the basic requirement to develop effective water quality laws and policies or to reform existing ones. Strict legislative infrastructures supported by effective governance should be required for continuous monitoring of the implementation of these policies. Public awareness institutes should be established to educate people about the importance of safe water.

9. Conclusions

Environmental pollution especially water pollution due to uncontrolled release of untreated wastewater has become a major issue as it is impacting aquatic life, human health and development of many nations. This is the global reality, that petite portion of wastes generated are treated, the rest are disposed of without adequate treatment. Both surface and ground water sources of developed and developing nations are extremely polluted and are becoming extremely harmful for human consumption, since the great majority of toxins (organic matter, inorganic pollutants, nitrates and phosphate, fluoride, oil spillage, heavy metals and water-soluble radioactive substances) exceed the quality criteria for water. Although, this is a worldwide problem, but in some developing countries this situation is worse than others especially in Southern Asia, Africa and Latin America. Pathogen and chemical pollution levels have increased in more than half of river lengths across all three continents, while salt pollution has increased in about a third. Significant pathogen contamination is projected to afflict one-quarter of Latin American, 10% to 25% of African, and one-third to half of Asian river spans. This situation is getting worse with time and the major contributing factors are rapid urbanization, industrialization, population growth, increase in use of insecticides and pesticides in agricultural activities, lack of proper wastes treatment systems and poor sanitation system. This poor management is due to lack of reliable energy supply, inadequate budgetary allocation, lack of funding, inadequate wastewater treatment plants infrastructure, lack of technology, and mismatch of urbanization and wastewater treatment resources. There is also a lack of effective water quality monitoring, particularly in rural areas. Water sanitization education is also not available, though some organizations provide instructions, the majority of the population is uninterested. This review of most affected areas and cities shows that in urban areas the major contributing factor for contamination of water resources is disproportionation of unlimited industrialization and urbanization with wastewater treatment means but in rural areas, poor water quality is mainly linked to bacteriological contamination due to poor sanitary conditions. It is assed that about 8 to 25 million individuals in Latin America, 32 to 164 million in Africa, and 31 to 134 million in Asia are at danger. This untreated wastewater dumping significantly contributes to death of marine life, a rise in diarrheal illnesses such as epidemic cholera, typhoid fever, and rotavirus etc. and additional infections like skin irritation and kidney problems etc. The poorest populations in countries have the greatest incidence of diarrhea-related child fatalities. Water-borne diseases have been linked to bacterial and chemical pollution of public drinking water in various sections of the countries.

References

[1] A.K. Dwivedi. (2017). Researches in water pollution: A review. International Research Journal of Natural and Applied Sciences. 4(1): 118-142.

[2] K. Qamar, G. Nchasi, H.T. Mirha, J.A. Siddiqui, K. Jahangir, S.K. Shaeen, Z. Islam, M.Y. Essar. (2022). Water sanitation problem in Pakistan: A review on disease prevalence, strategies for treatment and prevention. Annals of Medicine and Surgery. 104709.

[3] T. Ma, S. Sun, G. Fu, J.W. Hall, Y. Ni, L. He, J. Yi, N. Zhao, Y. Du, T. Pei. (2020). Pollution exacerbates China's water scarcity and its regional inequality. Nature communications. 11(1): 650.

[4] M.A. Dutt, M.A. Hanif, F. Nadeem, H.N. Bhatti. (2020). A review of advances in engineered composite materials popular for wastewater treatment. Journal of Environmental Chemical Engineering. 8(5): 104073.

[5] A. Hanif, S. Ali, M.A. Hanif, U. Rashid, H.N. Bhatti, M. Asghar, A. Alsalme, D.A. Giannakoudakis. (2021). A novel combined treatment process of hybrid biosorbent–nanofiltration for effective Pb (II) removal from wastewater. Water. 13(23): 3316.

[6] N. Singh, G. Nagpal, S. Agrawal. (2018). Water purification by using adsorbents: a review. Environmental technology & innovation. 11: 187-240.

[7] A. Magnuszewskiego. (2014). Study of physico-chemical properties of the surface and ground water. American Journal of Environmental Sciences. 219-235.

[8] M.A. Hanif, R. Nadeem, M.N. Zafar, K. Akhtar, H.N. Bhatti. (2007). Kinetic studies for Ni (II) biosorption from industrial wastewater by Cassia fistula (Golden Shower) biomass. Journal of hazardous materials. 145(3): 501-505.

[9] M.A. Hanif, R. Nadeem, M.N. Zafar, H. Bhatti, R. Nawaz. (2008). Physico-chemical treatment of textile wastewater using natural coagulant cassia. J. Chem. Soc. Pak. 30(3): 385.

[10] F. Shafqat, H.N. Bhatt, M.A. Hanif, A. Zubair. (2008). Kinetic and equilibrium studies of Cr (III) and Cr (VI) sorption from aqueous solution using Rosa Gruss an Teplitz (red rose) waste biomass. Journal of the Chilean Chemical Society. 53(4): 1667-1672.

[11] A. Azizullah, M.N.K. Khattak, P. Richter, D.-P. Häder. (2011). Water pollution in Pakistan and its

impact on public health—a review. Environment international. 37(2): 479-497.
[12] I. Akbar, M.A. Hanif, U. Rashid, I.A. Bhatti, R.A. Khan, E.A. Kazerooni. (2022). Green Nanocomposite for the Adsorption of Toxic Dyes Removal from Colored Waters. Coatings. 12(12): 1955.
[13] M. Ashfaq, S. Ahmad, M. Sagheer, M. Hanif, S. Abbas, M. Yasir. (2012). Bioaccumulation of chromium (III) in silkworm (Bombyx mori L.) in relation to mulberry, soil and wastewater metal concentrations. J. Anim. Plant Sci. 22(3): 627-634.
[14] M.A. Hanif, H.N. Bhatti, M. Asgher, M.I. Jilani, I.A. Bhatti. (2015). Remediation of Pb (II) using Pleurotus sajor-caju isolated from metal-contaminated site. Desalination and Water Treatment. 56(9): 2532-2542.
[15] E.R. Jones, M.T. Van Vliet, M. Qadir, M.F. Bierkens. (2021). Country-level and gridded estimates of wastewater production, collection, treatment and reuse. Earth System Science Data. 13(2): 237-254.
[16] R. Nadeem, M.A. Hanif, A. Mahmood, M.S. Jamil, M. Ashraf. (2009). Biosorption of Cu (II) ions from aqueous effluents by blackgram bran (BGB). Journal of hazardous materials. 168(2-3): 1622-1625.
[17] © European Investment Bank. (2022). Wastewater as a resource, May 2022. 40.
[18] H. Ritchie, M. Roser. (2017). Water use and stress. Our World in Data.
[19] M. Qadir, P. Drechsel, B. Jiménez Cisneros, Y. Kim, A. Pramanik, P. Mehta, O. Olaniyan In *Global and regional potential of wastewater as a water, nutrient and energy source*, Natural resources forum, 2020; Wiley Online Library: 2020; pp 40-51.
[20] UN-Water. (2021). Water Quality and Wastewater.
[21] A. Akhtar, M.A. Hanif, U. Rashid, I.A. Bhatti, F.A. Alharthi, E.A. Kazerooni. (2022). Advanced Treatment of Direct Dye Wastewater Using Novel Composites Produced from Hoshanar and Sunny Grey Waste. Separations. 9(12): 425.
[22] N. Khan, S.T. Hussain, A. Saboor, N. Jamila, K.S. Kim. (2013). Physicochemical investigation of the drinking water sources from Mardan, Khyber Pakhtunkhwa, Pakistan. International journal of physical sciences. 8(33): 1661-1671.
[23] M. Haseena, M.F. Malik, A. Javed, S. Arshad, N. Asif, S. Zulfiqar, J. Hanif. (2017). Water pollution and human health. Environmental Risk Assessment and Remediation. 1(3).
[24] J. Thomas. (2021). Untreated wastewater in developing countries: 14 Billion a day and we don't know where it ends up. Environment. 2.
[25] B.M. Teklu, A. Haileslassie, W. Mekuria. (2022). Pesticides as water pollutants and level of risks to environment and people: an example from Central Rift Valley of Ethiopia. Environment, Development and Sustainability. 24(4): 5275-5294.
[26] H.N. Bhatti, M.A. Hanif, M. Qasim. (2008). Biodiesel production from waste tallow. Fuel. 87(13-14): 2961-2966.
[27] J. Mateo-Sagasta, L. Raschid-Sally, A. Thebo. (2015). Global wastewater and sludge production, treatment and use. Wastewater: Economic asset in an urbanizing world. 15-38.
[28] A. Ashfaq, R. Nadeem, S. Bibi, U. Rashid, M.A. Hanif, N. Jahan, Z. Ashfaq, Z. Ahmed, M. Adil, M. Naz. (2021). Efficient Adsorption of Lead Ions from Synthetic Wastewater Using Agrowaste-Based Mixed Biomass (Potato Peels and Banana Peels). Water. 13(23): 3344.
[29] Y. Chauhdary, M.A. Hanif, U. Rashid, I.A. Bhatti, H. Anwar, Y. Jamil, F.A. Alharthi, E.A. Kazerooni. (2022). Effective removal of reactive and direct dyes from colored wastewater using low-cost novel bentonite nanocomposites. Water. 14(22): 3604.
[30] R. Antil, R. Narwal. (2008). Influence of sewer water and industrial effluents on soil and plant health. Groundwater resources: conservation and management. 37-46.
[31] M. Ashraf, M.E. Safdar, S.M. Shahzad, A. Aziz, M.A. Piracaha, M. Suleman, M.B. Ahmad. (2018). Challenges and opportunities for using wastewater in agriculture: a review. Journal of Applied Agriculture and Biotechnology. 2(2): 1-20.
[32] G. Murtaza, A. Ghafoor, M. Qadir, G. Owens, M. Aziz, M. Zia. (2010). Disposal and use of sewage on agricultural lands in Pakistan: A review. Pedosphere. 20(1): 23-34.
[33] M.A. Hanif, H.N. Bhatti. (2012). Bioremediation of nickel from wastewater using immobilized Phanerochaete chyrsosporium biomass. Int. J. Chem. Biochem. Sci. 2(1): 54-59.
[34] E.R. Jones, M.T. van Vliet, M. Qadir, M.F. Bierkens. (2020). Spatially-explicit estimates of global wastewater production, collection, treatment and re-use. Earth System Science Data Discussions. 2020: 1-29.
[35] G.Z. Teklehaimanot, I. Kamika, M. Coetzee, M.N.B. Momba. (2015). Population growth and its impact on the design capacity and performance of the wastewater treatment plants in Sedibeng and Soshanguve, South Africa. Environmental management. 56: 984-997.
[36] M. Riaz, M. Hanif, S. Noureen, M. Khan, T. Ansari, H. Bhatti, Q. Imran. (2012). Coagulation/flocculation of tannery wastewater using immobilised natural coagulants. Journal of Environmental Protection and Ecology. 13(3A): 1948-1957.
[37] M. Zahid, N. Nadeem, M.A. Hanif, I.A. Bhatti, H.N. Bhatti, G. Mustafa. (2019). Metal ferrites and their graphene-based nanocomposites: synthesis, characterization, and applications in wastewater treatment. Magnetic Nanostructures: Environmental and Agricultural Applications. 181-212.
[38] O.F. Kayode, C. Luethi, E.R. Rene. (2018). Management recommendations for improving decentralized wastewater treatment by the food and beverage industries in Nigeria. Environments. 5(3): 41.
[39] J. Okereke, O. Ogidi, K. Obasi. (2016). Environmental and health impact of industrial

wastewater effluents in Nigeria-A Review. Int J Adv Res Biol Sci. 3(6): 55-67.
[40] M. Ravina, S. Galletta, A. Dagbetin, O.A.H. Kamaleldin, M. Mng'ombe, L. Mnyenyembe, A. Shanko, M. Zanetti. (2021). Urban Wastewater Treatment in African Countries: Evidence from the Hydroaid Initiative. Sustainability. 13(22): 12828.
[41] Q. Imran, M. Hanif, M. Riaz, S. Noureen, T. Ansari, H. Bhatti. (2012). Coagulation/flocculation of tannery wastewater using immobilized chemical coagulants. Journal of applied research and technology. 10(2): 79-86.
[42] M.I. Jilani, R. Nadeem, M.A. Hanif, T. Mahmood Ansari, A. Majeed. (2015). Utilization of immobilized distillation sludges for bioremoval of Pb (II) and Zn (II) from hazardous aqueous streams. Desalination and Water Treatment. 55(1): 163-172.
[43] M. Khalil, M.A. Hanif, U. Rashid, J. Ahmad, A. Alsalme, T. Tsubota. (2022). Low-cost novel nano-constructed granite composites for removal of hazardous Terasil dye from wastewater. Environmental Science and Pollution Research. 1-19.
[44] A. UNEP. (2016). A snapshot of the world's water quality: towards a global assessment. Nairobi, United Nations Environment Programme.
[45] A.E. Evans, M.A. Hanjra, Y. Jiang, M. Qadir, P. Drechsel. (2012). Water pollution in Asia: The urgent need for prevention and monitoring. Water Qual. 9: 1-4.
[46] water.org. (2022). Water in India-India's Water Crises & Sanitation Issues in 2022.
[47] B. Sarker, K.N. Keya, F.I. Mahir, K.M. Nahiun, S. Shahida, R.A. Khan. (2021). Surface and ground water pollution: causes and effects of urbanization and industrialization in South Asia. Scientific Review. 7(3): 32-41.
[48] S. Kumar, H.M. Meena, K. Verma. (2017). Water pollution in India: its impact on the human health: causes and remedies. International Journal of Applied Environmental Sciences. 12(2): 275-279.
[49] N.B. Jadeja, T. Banerji, A. Kapley, R. Kumar. (2022). Water pollution in India–Current scenario. Water Security. 16: 100119.
[50] G. Lai. (August 12, 2022). Why Indian cities are still struggling with their need for clean water.
[51] G. Singh, B. Kumari, G. Sinam, N. Kumar, S. Mallick. (2018). Fluoride distribution and contamination in the water, soil and plants continuum and its remedial technologies, an Indian perspective–a review. Environmental pollution. 239: 95-108.
[52] M.S. Sankhla, R. Kumar, P. Agrawal. (2018). Arsenic in water contamination & toxic effect on human health: Current scenario of India. J Forensic Sci & Criminal Inves. 10(2): 001-5.
[53] A. Anju, P. Ravi S, S. Bechan. (2010). Water pollution with special reference to pesticide contamination in India. Journal of Water Resource and Protection. 2010.
[54] P. Goel. (2006). Water pollution: causes, effects and control. New age international: pp.
[55] S. Mantey. (2017). Galamsey, pollution destroying water bodies in Ghana—Water Company, March 22, 2017. The Head of Communications at the Ghana Water Company.
[56] D. Vashisht, A. Kumar, S.K. Mehta, A. Ibhadon. (2020). Analysis of emerging contaminants: A case study of the underground and drinking water samples in Chandigarh, India. Environmental Advances. 1: 100002.
[57] G. Bora. (2022). A Case Study of Water Contamination in Bharalu River, Guwahati, Assam. Ijraset Journal For Research in Applied Science and Engineering Technology.
[58] S. Ahmed, S. Ismail. (2018). Water pollution and its sources, effects & management: a case study of Delhi. Shahid Ahmed and Saba Ismail (2018)'Water Pollution and its Sources, Effects & Management: A Case Study of Delhi', International Journal of Current Advanced Research. 7(2): 10436-10442.
[59] W.-Q. Lu, S.-H. Xie, W.-S. Zhou, S.-H. Zhang, A.-L. Liu. (2008). Water pollution and health impact in China: a mini review. Open Environmental Sciences Journal. 2(1).
[60] C. Wu, C. Maurer, Y. Wang, S. Xue, D.L. Davis. (1999). Water pollution and human health in China. Environmental Health Perspectives. 107(4): 251-256.
[61] J. Qu, M. Fan. (2010). The current state of water quality and technology development for water pollution control in China. Critical Reviews in Environmental Science and Technology. 40(6): 519-560.
[62] X. Shi. (2020). The Safety of Drinking Water in China: Current Status and Future Prospects. China CDC Weekly. 2(13): 210.
[63] H. Kan. (2009). Environment and health in China: challenges and opportunities. Environmental Health Perspectives. 117(12): A530-A531.
[64] J. Gao, L. Liu, X. Liu, H. Zhou, S. Huang, Z. Wang. (2008). Levels and spatial distribution of chlorophenols–2, 4-Dichlorophenol, 2, 4, 6-trichlorophenol, and pentachlorophenol in surface water of China. Chemosphere. 71(6): 1181-1187.
[65] Q. Wang, Z. Yang. (2016). Industrial water pollution, water environment treatment, and health risks in China. Environmental pollution. 218: 358-365.
[66] L. Guo, Y. Qiu, G. Zhang, G.J. Zheng, P.K. Lam, X. Li. (2008). Levels and bioaccumulation of organochlorine pesticides (OCPs) and polybrominated diphenyl ethers (PBDEs) in fishes from the Pearl River estuary and Daya Bay, South China. Environmental pollution. 152(3): 604-611.
[67] W. Zhang, F. Jiang, J. Ou. (2011). Global pesticide consumption and pollution: with China as a focus. Proceedings of the international academy of ecology and environmental sciences. 1(2): 125.
[68] X.T. Ju, C.L. Kou, P. Christie, Z. Dou, F. Zhang. (2007). Changes in the soil environment from excessive application of fertilizers and manures to two contrasting intensive cropping systems on the North China Plain. Environmental pollution. 145(2): 497-506.

[69] M.J. Currell, D. Han, Z. Chen, I. Cartwright. (2012). Sustainability of groundwater usage in northern China: dependence on palaeowaters and effects on water quality, quantity and ecosystem health. Hydrological Processes. 26(26): 4050-4066.

[70] J. Wu. (2020). Challenges for safe and healthy drinking water in China. Current Environmental Health Reports. 7: 292-302.

[71] D. Han, M.J. Currell, G. Cao. (2016). Deep challenges for China's war on water pollution. Environmental pollution. 218: 1222-1233.

[72] G. Yang, D. Zhuang. (2014). Atlas of the Huai river basin water environment: digestive cancer mortality. Springer Science & Business Media: pp.

[73] T. Tao, K. Xin. (2014). Public health: A sustainable plan for China's drinking water. Nature. 511(7511): 527-528.

[74] A. Jabeen, X. Huang, M. Aamir. (2015). The challenges of water pollution, threat to public health, flaws of water laws and policies in Pakistan. Journal of Water Resource and Protection. 7(17): 1516.

[75] I. Hashmi, S. Farooq, S. Qaiser. (2009). Chlorination and water quality monitoring within a public drinking water supply in Rawalpindi Cantt (Westridge and Tench) area, Pakistan. Environmental monitoring and assessment. 158: 393-403.

[76] S. Aslam, F. Ali, A. Naseer, Z. Sheikh. (2022). Application of material flow analysis for the assessment of current municipal solid waste management in Karachi, Pakistan. Waste Management & Research. 40(2): 185-194.

[77] K. Nadeem, S. Shahzad, A. Hassan, M. Usman Younus, S. Asad Ali Gillani, K. Farhan. (2022). Municipal solid waste generation and its compositional assessment for efficient and sustainable infrastructure planning in an intermediate city of Pakistan. Environmental Technology. 1-19.

[78] M. Ilyas, W. Ahmad, H. Khan, S. Yousaf, M. Yasir, A. Khan. (2019). Environmental and health impacts of industrial wastewater effluents in Pakistan: a review. Reviews on environmental health. 34(2): 171-186.

[79] M. Khan. (2019). Impact of urbanization on water resources of Pakistan: a review. NUST Journal of Engineering Sciences. 12(1): 1-8.

[80] K. Khanum, M. Baqar, A. Qadir, M. Mumtaz, A. Tahir, N. Jamil, A. Mahmood. (2017). Heavy metal toxicity and human health risk surveillances of wastewater irrigated vegetables in Lahore District, Pakistan. Carpathian Journal of Earth and Environmental Sciences. 12(2): 403-412.

[81] M. Bhutta, M. Chaudhry, A. Chaudhry In *Groundwater quality and availability in Pakistan*, Proceedings of the seminar on strategies to address the present and future water quality issues, 2005; 2005.

[82] R. Sial, M. Chaudhary, S. Abbas, M. Latif, A. Khan. (2006). Quality of effluents from Hattar industrial estate. Journal of Zhejiang University SCIENCE B. 7: 974-980.

[83] R.N. Nasrullah, H. Bibi, M. Iqbal, M.I. Durrani. (2006). Pollution load in industrial effluent and ground water of Gadoon Amazai Industrial Estate (GAIE) Swabi, NWFP. Journal of agricultural and biological science. 1(3): 18-24.

[84] R. Ullah, R.N. Malik, A. Qadir. (2009). Assessment of groundwater contamination in an industrial city, Sialkot, Pakistan. African Journal of Environmental Science and Technology. 3(12).

[85] A. Mashiatullah, M. Chaudhary, M. Khan, T. Javed, R. Qureshi. (2010). Coliform bacterial pollution in Rawal Lake, Islamabad and its feeding streams/river. The Nucleus. 47(1): 35-40.

[86] M. Haq. (2005). Surface and ground water contamination in NWFP and Sindh provinces with respect to trace elements. Int J Agric Biol. 7(2): 214-217.

[87] G.F. Nordberg. (2004). Cadmium and health in the 21st century-historical remarks and trends for the future. Biometals. 17(5): 485.

[88] S. Mahmood, A. Maqbool. (2006). Impacts of wastewater irrigation on water quality and on the health of local community in Faisalabad [Pakistan]. Pakistan Journal of Water Resources (Pakistan).

[89] A. Majumder, Bangladesh River Pollution Threatens Millions. In Reuters: 2009.

[90] S. Faroque, N. South. (2022). Water pollution and environmental injustices in Bangladesh. International Journal for Crime, Justice and Social Democracy. 11(1): 1-13.

[91] K. Rahman. (2015). Contemporary environmental challenges in Bangladesh. Concern Universal: Bangladesh.

[92] T. Driscoll, K. Steenland, D.I. Nelson, A. Prüss-Üstün, D.H. Campbell-Lendrum, C.F. Corvalán, A. Woodward, W.H. Organization. (2004). Occupational carcinogens: assessing the environmental burden of disease at national and local levels. World Health Organization: pp.

[93] M. Rahman, M. Rahman. ENVIRONMENTAL ISSUES IN BANGLADESH-INFRASTRUCTURE, WATER RESOURCES AND AGRICULTURE.

[94] M.A. Arefin, A. Mallik. (2018). Sources and causes of water pollution in Bangladesh: A technical overview. Bibechana. 15: 97-112.

[95] M.K. Hasan, A. Shahriar, K.U. Jim. (2019). Water pollution in Bangladesh and its impact on public health. Heliyon. 5(8): e02145.

[96] M.A. Fazal, T. Kawachi, E. Ichion. (2001). Extent and severity of groundwater arsenic contamination in Bangladesh. Water International. 26(3): 370-379.

[97] M.A. Bhuiyan, M. Islam, S.B. Dampare, L. Parvez, S. Suzuki. (2010). Evaluation of hazardous metal pollution in irrigation and drinking water systems in the vicinity of a coal mine area of northwestern Bangladesh. Journal of hazardous materials. 179(1-3): 1065-1077.

[98] M.S. Sultana, M.S. Islam, R. Saha, M. Al-Mansur. (2009). Impact of the effluents of textile dyeing industries on the surface water quality inside DND embankment, Narayanganj. Bangladesh Journal of Scientific and Industrial Research. 44(1): 65-80.

[99] M. Halim, R.K. Majumder, G. Rasul, Y. Hirosiro, K. Sasaki, J. Shimada, K. Jinno. (2014). Geochemical evaluation of arsenic and manganese in shallow groundwater and core sediment in Singair Upazila, Central Bangladesh. Arabian journal for science and engineering. 39: 5585-5601.

[100] S.H. Rahman, S. Ahmed, M. Jakariya. (2009). Investigation of shallow tube-well water quality considering the influence of nearby latrines in a rural village of Bangladesh. IAHS publication. 20: 299.

[101] A.S. Ferguson, B.J. Mailloux, K.M. Ahmed, A. van Geen, L.D. McKay, P.J. Culligan. (2011). Hand-pumps as reservoirs for microbial contamination of well water. Journal of Water and Health. 9(4): 708-717.

[102] S. Luby, S. Gupta, M. Sheikh, R. Johnston, P. Ram, M. Islam. (2008). Tubewell water quality and predictors of contamination in three flood-prone areas in Bangladesh. Journal of applied microbiology. 105(4): 1002-1008.

[103] M.G. Rasul, I. Faisal, M.M.K. Khan. (2006). Environmental pollution generated from process industries in Bangladesh. International journal of environment and pollution. 28(1-2): 144-161.

[104] S. Rahman, F. Hossain. (2008). Spatial assessment of water quality in peripheral rivers of Dhaka City for optimal relocation of water intake point. Water Resources Management. 22: 377-391.

[105] V. Subramanian. (2004). Water quality in south Asia. Asian journal of water, Environment and Pollution. 1(1-2): 41-54.

[106] M. Islam. (2010). A Silent Icy River in Dhaka! Retrieved from The Daily Star: http://www. thedailystar. net/news-detail-135603.[Accessed 17 August 2021].

[107] A. Rahman, D. Al Bakri. (2010). A study on selected water quality parameters along the River Buriganga, Bangladesh. Iranian (Iranica) Journal of Energy & Environment. 1(2).

[108] N. Chowdhury, A. Clemett. (2006). Industrial pollution and its threat to Mokesh Beel wetland in Kaliakoir. MACH Technical Paper. (3).

[109] M.M. Ali, M.L. Ali, M.S. Islam, M.Z. Rahman. (2016). Preliminary assessment of heavy metals in water and sediment of Karnaphuli River, Bangladesh. Environmental nanotechnology, monitoring & management. 5: 27-35.

[110] A.B. Hasan, S. Kabir, A.S. Reza, M.N. Zaman, M.A. Ahsan, M.A. Akbor, M.M. Rashid. (2013). Trace metals pollution in seawater and groundwater in the ship breaking area of Sitakund Upazilla, Chittagong, Bangladesh. Marine pollution bulletin. 71(1-2): 317-324.

[111] N.T. Chowdhury. (2010). Water management in Bangladesh: an analytical review. Water Policy. 12(1): 32-51.

[112] M. Sujauddin, S.M. Huda, A.R. Hoque. (2008). Household solid waste characteristics and management in Chittagong, Bangladesh. Waste management. 28(9): 1688-1695.

[113] K.S. Akter, K. Kurisu, K. Hanaki. (2017). Water use and pollution recognition from the viewpoint of local residents in Dhaka, Bangladesh. Water. 9(5): 331.

[114] M.A. Uddin, M. Saha, M. Chowdhury, M. Rahman. (2013). Pesticide residues in some selected pond water samples of Meherpur region of Bangladesh. Journal of the Asiatic Society of Bangladesh, Science. 39(1): 77-82.

[115] M.A.Z. Chowdhury, S. Banik, B. Uddin, M. Moniruzzaman, N. Karim, S.H. Gan. (2012). Organophosphorus and carbamate pesticide residues detected in water samples collected from paddy and vegetable fields of the Savar and Dhamrai Upazilas in Bangladesh. International journal of environmental research and public health. 9(9): 3318-3329.

[116] S. Bhattacharjee, A. Fakhruddin, M. Chowdhury, M. Rahman, M. Alam. (2012). Monitoring of selected pesticides residue levels in water samples of paddy fields and removal of cypermethrin and chlorpyrifos residues from water using rice bran. Bulletin of environmental contamination and toxicology. 89: 348-353.

[117] M. Hasanuzzaman, M. Rahman, M. Salam. (2017). Identification and quantification of pesticide residues in water samples of Dhamrai Upazila, Bangladesh. Applied water science. 7: 2681-2688.

[118] J.O. Nriagu. (1992). Toxic metal pollution in Africa. Science of the Total Environment. 121: 1-37.

[119] J. Antonel, Z. Chowdhury. (2014). Measuring ambient particulate matter in three cities in Cameroon, Africa. Atmospheric Environment. 95: 344-354.

[120] H. Wang, T. Wang, B. Zhang, F. Li, B. Toure, I.B. Omosa, T. Chiramba, M. Abdel-Monem, M. Pradhan. (2014). Water and wastewater treatment in Africa–current practices and challenges. CLEAN–Soil, Air, Water. 42(8): 1029-1035.

[121] A.O. Fayiga, M.O. Ipinmoroti, T. Chirenje. (2018). Environmental pollution in Africa. Environment, Development and Sustainability. 20: 41-73.

[122] C. Diop, D. Dewaelé, F. Cazier, A. Diouf, B. Ouddane. (2015). Assessment of trace metals contamination level, bioavailability and toxicity in sediments from Dakar coast and Saint Louis estuary in Senegal, West Africa. Chemosphere. 138: 980-987.

[123] E.S. Liddle, S.M. Mager, E.L. Nel. (2015). The suitability of shallow hand dug wells for safe water provision in sub-Saharan Africa: Lessons from Ndola, Zambia. Applied Geography. 57: 80-90.

[124] Z. Zhongming, L. Linong, Y. Xiaona, L. Wei. (2020). Sanitation and Wastewater Atlas of Africa.

[125] M.A. Onu, O.O. Ayeleru, B. Oboirien, P.A. Olubambi. (2023). Challenges of wastewater generation and management in sub-Saharan Africa: A Review. Environmental Challenges. 100686.

[126] S. Dos Santos, E. Adams, G. Neville, Y. Wada, A. De Sherbinin, E.M. Bernhardt, S. Adamo. (2017). Urban growth and water access in sub-Saharan Africa: Progress, challenges, and emerging research directions. Science of the Total Environment. 607: 497-508.

[127] M. Niasse, O. Varis, Quenching the thirst of rapidly growing and water-insecure cities in sub-Saharan Africa. In *Global Water Resources*, Routledge: 2021; pp 283-305.
[128] M. Chukwuma Obeta. (2018). Rural water supply in Nigeria: policy gaps and future directions. Water Policy. 20(3): 597-616.
[129] J.O. Seyi-Olajide, E.A. Ameh. (2020). Investing in pediatric surgical research to advance universal health coverage for children in Nigeria. Nigerian Journal of Surgery. 26(1): 1-8.
[130] S. Akinde, J. Olaitan, T. Fasunloye. (2019). Water shortages and drinking water quality in rural Southwest Nigeria: issues and sustainable solutions. Pan African Journal of Life Sciences. 2: 85-93.
[131] A. Ado, A.I. Tukur, M. Ladan, S.M. Gumel, A.A. Muhammad, S. Habibu, I.B. Koki. (2015). A review on industrial effluents as major sources of water pollution in Nigeria. Chemistry Journal. 1(5): 159-164.
[132] M. Allaire, H. Wu, U. Lall. (2018). National trends in drinking water quality violations. Proceedings of the National Academy of Sciences. 115(9): 2078-2083.
[133] J.O. Ighalo, A.G. Adeniyi, J.A. Adeniran, S. Ogunniyi. (2021). A systematic literature analysis of the nature and regional distribution of water pollution sources in Nigeria. Journal of Cleaner Production. 283: 124566.
[134] A.U. Kaoje, M. Yahaya, M.O. Raji, S.M. Hadiza, A. Sylvanus, T. Musa. (2019). Drinking water quality, sanitation and hygiene practices in a rural community of Sokoto State, Nigeria. International Journal of Medical Science and Public Health. 7(11): 1.
[135] S. Aghalino, B. Eyinla. (2009). Oil exploitation and marine pollution: Evidence from the Niger Delta, Nigeria. Journal of human ecology. 28(3): 177-182.
[136] E.I. Seiyaboh, S.C. Izah. (2017). A Review of impacts of gas flaring on vegetation and water resources in the Niger Delta region of Nigeria. International Journal of Economy, Energy and Environment. 2(4): 48-55.
[137] A. Galadima, Z. Garba, L. Leke, M. Almustapha, I. Adam. (2011). Domestic water pollution among local communities in Nigeria-causes and consequences. European journal of scientific research. 52(4): 592-603.
[138] S.C. Izah, A.L. Srivastav. (2015). Level of arsenic in potable water sources in Nigeria and their potential health impacts: A review. Journal of Environmental Treatment Techniques. 3(1): 15-24.
[139] J.C. Akan, F.I. Abdulrahman, E. Yusuf. (2010). Physical and chemical parameters in abattoir wastewater sample, Maiduguri Metropolis, Nigeria. The Pacific Journal of Science and Technology. 11(1): 640-648.
[140] Y. Bello, D. Oyedemi. (2009). The impact of abattoir activities and management in residential neighbourhoods: A case study of Ogbomoso, Nigeria. Journal of Social Sciences. 19(2): 121-127.
[141] J.O. Ighalo, A.G. Adeniyi. (2020). A comprehensive review of water quality monitoring and assessment in Nigeria. Chemosphere. 260: 127569.
[142] J.A. Veil, M.G. Puder, D. Elcock *A white paper describing produced water from production of crude oil, natural gas, and coal bed methane*; Argonne National Lab., IL (US): 2004.
[143] O.A. Aghoghovwia, F.A. Miri, S.C. Izah. (2018). Impacts of anthropogenic activities on heavy metal levels in surface water of Nun River around Gbarantoru and Tombia Towns, Bayelsa State, Nigeria. Annals of Ecology and Environmental Science. 2(2): 1-8.
[144] K.O. Adebowale, F.O. Agunbiade, B.I. Olu-Owolabi. (2008). Fuzzy comprehensive assessment of metal contamination of water and sediments in Ondo Estuary, Nigeria. Chemistry and Ecology. 24(4): 269-283.
[145] S. Inyang, A. Aliyu, A. Oyewale. (2018). Total petroleum hydrocarbon content in surface water and sediment of Qua-Iboe River, Ibeno, Akwa-Ibom State, Nigeria. Journal of Applied Sciences and Environmental Management. 22(12): 1953-1959.
[146] S.O. Akporido. (2018). Effects of petroleum products spillages on the water quality of Benin–Ethiope fluvial system in Oghara, Nigeria. FUW Trends in Science & Technology Journal. 3(1): 141-148.
[147] A. Achudume. (2009). The effect of petrochemical effluent on the water quality of Ubeji creek in Niger Delta of Nigeria. Bulletin of environmental contamination and toxicology. 83: 410-415.
[148] O. Ayantobo, J. Awomeso, G. Oluwasanya, B. Bada, A. Taiwo. (2014). Gold mining in Igun Ijesha, southwest Nigeria: impacts and implications for water quality. American Journal of Environmental Sciences. 10(3): 289-300.
[149] C.E. Chukwuma, C.G. Chukwuma, I.J. Uba, C.L. Orakwe, N.K. Ogbu. (2016). Irrigation water quality index assessment of Ele River in parts of Anambra State of Nigeria. Archives of Current Research International. 4(3): 1-6.
[150] S.N. Chinedu, O. Nwinyi, A.Y. Oluwadamisi, V.N. Eze. (2011). Assessment of water quality in Canaanland, Ota, southwest Nigeria. Agriculture and Biology Journal of North America. 2(4): 577-583.
[151] S. Dan'Azumi, M. Bichi. (2010). Industrial pollution and heavy metals profile of Challawa River in Kano, Nigeria. Journal of Applied Sciences in Environmental Sanitation. 5(1): 23-29.
[152] M. Idris, B. Kolo, S. Garba, I. Waziri. (2013). Pharmaceutical industrial effluent: heavy metal contamination of surface water in Minna, Niger State, Nigeria. Bull Environ Pharm Life Sci. 2(3): 40-44.
[153] W. Nafarnda, I. Ajayi, J. Shawulu, M. Kawe, G. Omeiza, N. Sani, O. Tenuche, D. Dantong. (2012). Bacteriological quality of abattoir effluents discharged into water bodies in Abuja, Nigeria. International Scholarly Research Notices. 2012.
[154] J. Magaji, C. Chup. (2012). The effects of abattoir waste on water quality in Gwagwalada-Abuja,

Nigeria. Ethiopian journal of environmental studies and management. 5(4): 542-549.
[155] E.N. Ogamba, S.C. Izah, B.P. Toikumo. (2015). Water quality and levels of lead and mercury in Eichhornia crassipes from a tidal creek receiving abattoir effluent, in the Niger Delta, Nigeria. Continental Journal of Environmental Science. 9(1): 13-25.
[156] C.O. Akinbile. (2012). Environmental impact of landfill on groundwater quality and agricultural soils in Nigeria. Soil and Water Research. 7(1): 18-26.
[157] C.O. Akinbile, M.S. Yusoff. (2011). Environmental impact of leachate pollution on groundwater supplies in Akure, Nigeria. International Journal of Environmental Science and Development. 2(1): 81.
[158] T.A. Adesakin, A.A. Adedeji, A.I. Aduwo, Y.F. Taiwo. (2017). Effect of discharges from re-channeled rivers and municipal runoff on water quality of Opa reservoir, Ile-Ife, Southwest Nigeria. African Journal of Environmental Science and Technology. 11(1): 56-70.
[159] V.N. Ben-Eledo, L.T. Kigigha, S.C. Izah, B.O. Eledo. (2017). Bacteriological quality assessment of water from Epie creek, Niger Delta region of Nigeria. International Journal of Ecotoxicology and Ecobiology. 2(3): 102-108.
[160] E.I. Seiyaboh, S.C. Izah, J.E. Bokolo. (2017). Bacteriological quality of water from river nun at Amassoma Axises, Niger Delta, Nigeria. ASIO Journal of Microbiology, Food Science & Biotechnological Innovations. 3(1): 22-26.
[161] A. Odeyemi, A. Dada, O. Ogunbanjo, M. Ojo. (2010). Bacteriological, physicochemical and mineral studies on Awedele spring water and soil samples in Ado Ekiti, Nigeria. African Journal of Environmental Science and Technology. 4(6).
[162] I. Oboh, C. Agbala. (2017). Water quality assessment of the Siluko River, southern Nigeria. African journal of aquatic science. 42(3): 279-286.
[163] R. Duru, E. Ikpeama, J. Ibekwe. (2019). Challenges and prospects of plastic waste management in Nigeria. Waste Disposal & Sustainable Energy. 1: 117-126.
[164] E. Oparaocha, O. Iroegbu, R. Obi. (2010). Assessment of quality of drinking water sources in the Federal University of Technology, Owerri, Imo state, Nigeria. J Appl Biosci. 32: 1964-1976.
[165] J. Okereke, O. Ogidi, K. Obasi. (2016). International Journal of Advanced Research in Biological Sciences Environmental and Health Impact of Industrial Wastewater Effluents in Nigeria-A Review. Int. J. Adv. Res. Biol. Sci. 3(6): 55-67.
[166] J. Nayebare, M. Owor, R. Kulabako, L. Campos, E. Fottrell, R. Taylor. (2020). WASH conditions in a small town in Uganda: how safe are on-site facilities? Journal of Water, Sanitation and Hygiene for Development. 10(1): 96-110.
[167] D. McCole, M.J. Culbertson, M. Suvedi, P.E. McNamara. (2014). Addressing the challenges of extension and advisory services in Uganda: The Grameen Foundation's community knowledge worker program. Journal of International Agricultural and Extension Education. 21(1): 6-18.
[168] H.E. Mutikanga, S. Sharma, K. Vairavamoorthy. (2009). Water loss management in developing countries: Challenges and prospec. Journal-American Water Works Association. 101(12): 57-68.
[169] W. Osumo. (2001). Effects of water hyacinth on water quality of Winam Gulf, Lake Victoria.
[170] S.R. Nayebare, L.R. Wilson, D.O. Carpenter, D.M. Dziewulski, K. Kannan. (2014). A review of potable water accessibility and sustainability issues in developing countries–case study of Uganda. Reviews on environmental health. 29(4): 363-378.
[171] G. Bwire, D.A. Sack, A. Kagirita, T. Obala, A.K. Debes, M. Ram, H. Komakech, C.M. George, C.G. Orach. (2020). The quality of drinking and domestic water from the surface water sources (lakes, rivers, irrigation canals and ponds) and springs in cholera prone communities of Uganda: an analysis of vital physicochemical parameters. BMC Public Health. 20(1): 1-18.
[172] K. Andersson, S. Dickin, A. Rosemarin. (2016). Towards "sustainable" sanitation: challenges and opportunities in urban areas. Sustainability. 8(12): 1289.
[173] H. Lung'Ayia, L. Sitoki, M. Kenyanya. (2001). The nutrient enrichment of Lake Victoria (Kenyan waters). Hydrobiologia. 458: 75-82.
[174] J.-S. Balirwa, F.-M. Wanda, F.-J. Muyodi In *Impacts of water hyacinth and water quality change on beneficial uses of Lake Victoria, Uganda*, 13th World Lake Conference, Wuhan, China, 2009; 2009; pp 1-5.
[175] F. Mwanuzi, J. Abuodha, F. Muyodi, R. Hecky. (2005). Lake Victoria Environment Management Project (LVEMP) water quality and ecosystem status. Lake Victoria Reg. Water Qual. Synth. Rep. pp. 1-189.
[176] R.A. Tamatamah, R.E. Hecky, H. Duthie. (2005). The atmospheric deposition of phosphorus in Lake Victoria (East Africa). Biogeochemistry. 73: 325-344.
[177] F. Muyodi, M. Rubindamayugi, J. Kitamirike. (2003). Influence of water hyacinth on presence of pathogens in nearshore waters of Lake Victoria. Uganda Journal. 49: 79-87.
[178] F. Kansiime, J. Van Bruggen. (2001). Distribution and retention of faecal coliforms in the Nakivubo wetland in Kampala, Uganda. Water Science and Technology. 44(11-12): 199-206.
[179] A. Nakagiri, R.N. Kulabako, P.M. Nyenje, J.B. Tumuhairwe, C.B. Niwagaba, F. Kansiime. (2015). Performance of pit latrines in urban poor areas: A case of Kampala, Uganda. Habitat international. 49: 529-537.
[180] A. Peal, B. Evans, I. Blackett, P. Hawkins, C. Heymans. (2015). A review of fecal sludge management in 12 cities. World Bank Final Report.
[181] W.H. Organization. (2006). World Health Organization Weekly Epidemiologic Record. World Health Organization (WHO)(2007). Schistomiasis. WHO Fact Sheet. (115): 145-164.
[182] G. Bwire, M. Malimbo, B. Maskery, Y.E. Kim, V. Mogasale, A. Levin. (2013). The burden of cholera

in Uganda. PLoS neglected tropical diseases. 7(12): e2545.

[183] G. Bwire, A. Munier, I. Ouedraogo, L. Heyerdahl, H. Komakech, A. Kagirita, R. Wood, R. Mhlanga, B. Njanpop-Lafourcade, M. Malimbo. (2017). Epidemiology of cholera outbreaks and socio-economic characteristics of the communities in the fishing villages of Uganda: 2011-2015. PLoS neglected tropical diseases. 11(3): e0005407.

[184] C. Chomchoei, T. Apidechkul, P. Wongnuch, R. Tamornpark, P. Upala, M.P.N. Nongkhai. (2019). Perceived factors influencing the initiation of methamphetamine use among Akha and Lahu youths: a qualitative approach. BMC Public Health. 19: 1-11.

[185] G. Pande, B. Kwesiga, G. Bwire, P. Kalyebi, A. Riolexus, J.K. Matovu, F. Makumbi, S. Mugerwa, J. Musinguzi, R.K. Wanyenze. (2018). Cholera outbreak caused by drinking contaminated water from a lakeshore water-collection site, Kasese District, south-western Uganda, June-July 2015. PloS one. 13(6): e0198431.

[186] S. Agodzo, E. Bessah, M. Nyatuame. (2023). A Review of the Water Resources of Ghana in a Changing Climate and Anthropogenic Stresses. Frontiers in Water. 4: 222.

[187] P. Bhattacharya, O. Sracek, B. Eldvall, R. Asklund, G. Barmen, G. Jacks, J. Koku, J.-E. Gustafsson, N. Singh, B.B. Balfors. (2012). Hydrogeochemical study on the contamination of water resources in a part of Tarkwa mining area, Western Ghana. Journal of African Earth Sciences. 66: 72-84.

[188] E. Awuah, K. Nyarko, P. Owusu. (2009). Water and sanitation in Ghana. Desalination. 248(1-3): 460-467.

[189] B.K. Osei. (2023). Indigenous Water Resource Conservation Practices in Contemporary Ghanaian Society. Universal Journal of Social Sciences and Humanities. 1-10.

[190] M. Eduful, K. Alsharif, A. Eduful, M. Acheampong, J. Eduful, L. Mazumder. (2020). The illegal artisanal and small-scale mining (galamsey)'menace'in Ghana: is military-style approach the answer? Resources Policy. 68: 101732.

[191] E. Yeleliere, S. Cobbina, A. Duwiejuah. (2018). Review of Ghana's water resources: the quality and management with particular focus on freshwater resources. Applied water science. 8: 1-12.

[192] A.-B.K. Emmanuel. Physico-chemical and microbiological quality of surface waters within the Newmont Ghana Gold Mining concession areas. 2009.

[193] F.N. Nsubuga, E.N. Namutebi, M. Nsubuga-Ssenfuma. (2014). Water resources of Uganda: An assessment and review.

[194] S. Awuah-Nyamekye. (2013). Managing the environmental crisis in Ghana: The role of African traditional religion and culture—A case study of Berekum traditional area. University of Leeds: pp.

[195] M.M. Mekonnen, M. Pahlow, M.M. Aldaya, E. Zarate, A.Y. Hoekstra. (2015). Sustainability, efficiency and equitability of water consumption and pollution in Latin America and the Caribbean. Sustainability. 7(2): 2086-2112.

[196] C. Ringler, M.W. Rosegrant, M.S. Paisner *Irrigation and water resources in Latin America and the Caribbean: Challenges and strategies*; 2000.

[197] A. Mejia, Water scarcity in Latin America and the Caribbean: Myths and reality. In *Water for the Americas*, Routledge: 2014; pp 56-76.

[198] L. Chakraborti, J.P. Shimshack. (2022). Environmental disparities in urban Mexico: Evidence from toxic water pollution. Resource and Energy Economics. 67: 101281.

[199] N. CEPAL. (2017). The Outlook for Agriculture and Rural Development in the Americas: A Perspective on Latin America and the Caribbean 2017-2018.

[200] S. Vaz S. Silva, A.H.C. Dias, E.S. Dutra, A.L. Pavanin, S. Morelli, B.B. Pereira. (2016). The impact of water pollution on fish species in southeast region of Goiás, Brazil. Journal of Toxicology and Environmental Health, Part A. 79(1): 8-16.

[201] E. Smaling, R. Roscoe, J. Lesschen, A. Bouwman, E. Comunello. (2008). From forest to waste: Assessment of the Brazilian soybean chain, using nitrogen as a marker. Agriculture, Ecosystems & Environment. 128(3): 185-197.

[202] A.E. Bardach, A. Ciapponi, N. Soto, M.R. Chaparro, M. Calderon, A. Briatore, N. Cadoppi, R. Tassara, M.I. Litter. (2015). Epidemiology of chronic disease related to arsenic in Argentina: A systematic review. Science of the Total Environment. 538: 802-816.

[203] M. Onestini. (2011). Water quality and health in poor urban areas of Latin America. International Journal of Water Resources Development. 27(1): 219-226.

[204] J. Hrenovic, G. Durn, S. Kazazic, S. Dekic, M.S. Music. (2019). Untreated wastewater as a source of carbapenem-resistant bacteria to the riverine ecosystem. Water Sa. 45(1): 55-62.

[205] T. Sarwar, M. Shahid, S. Khalid, A.H. Shah, N. Ahmad, M.A. Naeem, Z. ul Haq, B. Murtaza, H.F. Bakhat. (2020). Quantification and risk assessment of heavy metal build-up in soil–plant system after irrigation with untreated city wastewater in Vehari, Pakistan. Environmental geochemistry and health. 42: 4281-4297.

[206] M.A. Owili. (2003). Assessment of impact of sewage effluents on coastal water quality in Hafnarfjordur, Iceland. The United Nations Fishery Training Program, Final Report.

[207] M. Qadir, D. Wichelns, L. Raschid-Sally, P.G. McCornick, P. Drechsel, A. Bahri, P. Minhas. (2010). The challenges of wastewater irrigation in developing countries. Agricultural water management. 97(4): 561-568.

[208] A.L. Thebo, P. Drechsel, E. Lambin. (2014). Global assessment of urban and peri-urban agriculture: irrigated and rainfed croplands. Environmental research letters. 9(11): 114002.

[209] M. Qadir, B.R. Sharma, A. Bruggeman, R. Choukr-Allah, F. Karajeh. (2007). Non-conventional water resources and opportunities for water augmentation

to achieve food security in water scarce countries. Agricultural water management. 87(1): 2-22.

[210] S.K. Dickin, C.J. Schuster-Wallace, M. Qadir, K. Pizzacalla. (2016). A review of health risks and pathways for exposure to wastewater use in agriculture. Environmental Health Perspectives. 124(7): 900-909.

[211] R. Bos, R. Carr, B. Keraita, Assessing and mitigating wastewater-related health risks in low-income countries: an introduction. In *Wastewater irrigation and health*, Routledge: 2009; pp 55-74.

[212] L. Järup. (2003). Hazards of heavy metal contamination. British medical bulletin. 68(1): 167-182.

[213] O. Akpor, B. Muchie. (2011). Environmental and public health implications of wastewater quality. African Journal of Biotechnology. 10(13): 2379-2387.

[214] T. Saliu, N. Oladoja. (2021). Nutrient recovery from wastewater and reuse in agriculture: A review. Environmental Chemistry Letters. 19(3): 2299-2316.