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A review on pollution of water resources and its impact on health in South Asian Region: Pakistan

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ABSTRACT

Water in Pakistan is contaminated by microbes and dangerous metals. Pakistan is one of the South Asian countries with the worst water pollution. The recommended limits for the various measures from the World Health Organization (WHO) are regularly disregarded. The lack of adequate maintenance and regulation of the drinking water quality in Pakistan puts the community's health in danger. The main goal of this review is to talk about water pollution by giving a general overview of the level of water pollution in Pakistan's rivers, significant sources of water pollution, significant pollutants involved in water pollution (like microbial contamination and heavy metal pollution), and significant pollutants' effects on human health. Urban areas are known to contribute to increased water pollution, health issues, river pollution, heavy metal contamination, etc. in Pakistan and other parts of the region. This hypothesis contends that urbanization and population pressures have an immediate effect on the environment, ecosystem, demand for freshwater, water supply pollution, and other issues. Because urban areas are major sources of pollution, there is a substantial interaction between urban areas and agriculture. The

review's results were derived from several research that were accepted for publication in prominent journals with high-impact factors and in government reports from throughout the country. Additionally, the goal of the evaluation is to inspire decision-makers, those responsible for creating policies, researchers, and administrative divisions to begin useful initiatives and develop cutting-edge plans for ensuring clean and pure water. To protect the neighborhood and environment from an outbreak of infectious diseases on a global scale, urgent action must be taken to reduce additional contamination and improve the existing bodies of water.

Keywords: water pollution, microbial contamination, heavy metal pollution, groundwater

1. INTRODUCTION

Water is an essential natural resource for human well-being, food production, economic growth, and the survival of all living creatures. The world doesn't have enough water. 3% of the world's water supply is made up of water. Only 0.5% of these freshwater resources are usable (USBR, 2020). The world's freshwater supply is regrettably nonetheless severely threatened notwithstanding the small percentage [1]. The population of the planet has grown swiftly, and a large portion of them have settled in cities, where the ecology cannot support the water demand and where there is less recharge due to the considerable rise in impermeable surface. Therefore, industrial, residential, and agricultural pollutants are putting a strain on freshwater [2]. According to United Nations research, while the world's population is growing quickly, freshwater supplies are shrinking. In the coming years, several nations may experience severe water shortages in developing countries, inadequate water management, and climate change, agricultural use, population increase, a lack of knowledge and funding, among other issues, that exacerbate water shortage. Pakistan suffers from a water crisis, just like many other developing nations globally. People must rely on contaminated and less contaminated sources due to a lack of fresh water [3].

Additionally, this region will undoubtedly experience water constraints in the ensuing decades. The region is already thought to be "water-stressed". The amount of water in rivers and lakes is constantly dropping since the nation's precipitation rate is often lower than its evaporation rate. In addition, groundwater is also being drained. Even though the issue is serious, a few factors, such as prolonged droughts and a dearth of new water resource development, make it worse[4]. A severe water shortage affected practically the entire country as a result of this lack of water and increased demand. People who lack access to clean water in some places are compelled to consume brackish water, as is the case in Sindh's water-scarce regions (SDNA, 2016). Baluchistan's groundwater supply is rapidly going dry [5]. As water is used more and more, its quality will deteriorate, which might adversely contaminate the water supply. The availability of clean water and its quality in terms of contamination or safety present significant issues in the twenty-first century.

Pakistan Council of Research on Water Resources provides information on the country's water quality from 2001 to 2020. According to the assessment, the quality of water resources is between 80 and 90 percent below the recommended criteria (PCRWR, 2021). People were forced to purchase alternatives in the form of readily available plastic water bottles due to the lack of pure drinking water [6]. But because it comes from unreported plants, commercially packaged water is likewise dangerous.

The average person also cannot afford expensive water filtration methods. As a result, the majority of Pakistanis drink contaminated water, which contributes to a range of ailments linked to water consumption. Therefore, the pollution issue in Pakistan cannot be disregarded. The primary objective is to draw attention to the problem of water pollution in Pakistan and concentrate on its underlying causes, water contaminants, and any potential negative impacts on human health [7]. The review also intends to motivate researchers, administrative divisions, decision-makers, and researchers to take part in constructive endeavors and develop cutting-edge strategies to deliver pure and clean water (Fig. 1).

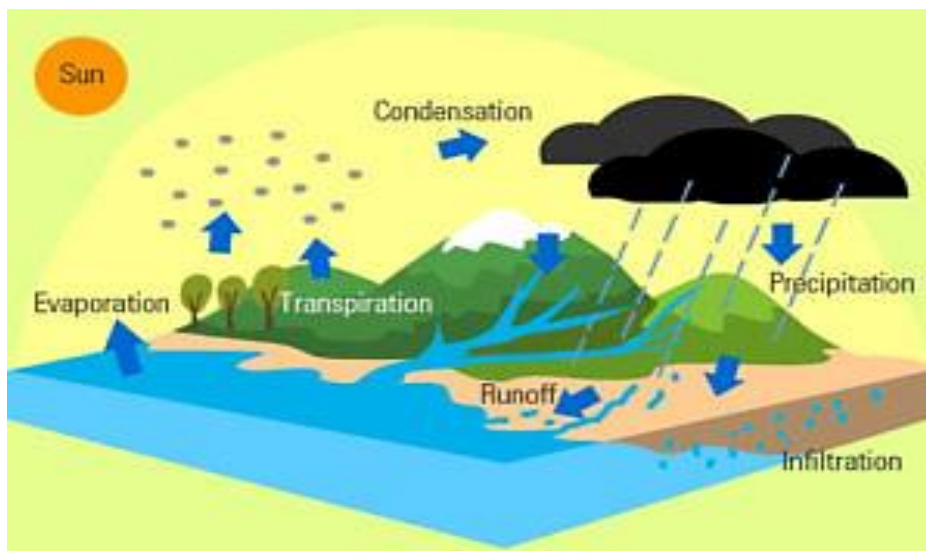


Fig. 1. Overview of water contamination [7].

1. 1. Scope and objectives

There is more room in this research evaluation for the formation of decision- and policy-makers who will monitor water pollution and its sources throughout the region. Due to the significance of water quality to ecosystem health, irrigation, and human health. According to this perspective, there is more room for development in these sectors as well as solutions for Pakistan's ongoing problems with dirty water and pollution sources. Every factor has been thoroughly addressed here [8]. The review paper's key goals are as follows:

2. PAKISTAN: AN OVERVIEW OF RIVER POLLUTION

The first national investigation on water quality in six rivers, ten reservoirs, ten lakes, and twenty-one cities was carried out by the Pakistan Council of Research in Water Resources (PCRWR). The nation has a relatively high level of bacterial contamination (PCRWR, 2021). Specifically, iron, Sulphur, and fluorites, the inorganic pollutant are also highly high [9]. (Table 1) displays the status of the water quality in various lakes, rivers, and dams. The situation is worse in areas where only minimal drinking water is available in 114 out of 130 districts, and where 40 districts have statistics that are less than 11%, with central issues in Punjab.

According to estimates, more than 45 million people are compelled to use irrigation water for residential purposes, particularly in areas where the river water is salty and brackish (GOP, 2018) [10]. In addition, Table 2 displays a comprehensive summary of river pollution in Pakistan from 1996 to 2020.

2. 1. Sources of river pollution

Several sources, both direct and indirect, as well as other sources, contribute to river pollution (Fig. 2). The term "direct pollution" refers to pollution that results from fluid discharge into rivers. Directly merged into the river or sea were hazardous solids. Due to these effects, fish and other aquatic life cannot survive in the water, which is now poisonous.

However, animals and other species that consume this water suffer ill health and eventually pass away. Humans are not immune to it. People in developed nations rely on river or stream water for drinking. Those who take a bath in contaminated water or take part in campaigns like drifting on face danger.

A few of them have the potential to be fatal [11]. Direct discharge of toxins into the water does not result in indirect pollution, only those that remain there. Such fertilizer and pesticide chemicals are gradually removed from the soil, where they follow a path into the groundwater before entering several canals. In addition, air pollution damages animals, contaminates streams, and renders water unsafe for neighboring species [11]. Four components have been provided to illustrate the preparatory aspect of river contamination. As a result, river pollution must be rapidly reduced. The additional causes of water contamination can range from man-made to natural sources, including urban.

Table 1. Dam, river, and lake water quality (Resource: PCRWR) [12].

Source	TDS (mg/liter)	pH	Turbidity (NTU)
Torkhezai Dam	145	6.9	399
Hub Dam	689	6.8	4
Hub River	698	6.5	10
Kabul River	122	6.3	766
Swat River	39	7.1	35
Lahore Canal	125	7.5	644
Khanpur Dam	23	7.7	3
Hanna Lake	299	7.3	11
Chashma Lake	130	76	180

Table 2. From 1996 to 2020, a study of river pollution in Pakistan [12-15].

Method	Results	Conclusion	Recommendations
(Spectra AA-10) Atomic intake spectrophotometer	According to the new research, fish contain metal concentrations of chromium, copper, nickel, lead, and zinc in that order. The following EPA Dietary Reference Intakes (DRI) are satisfied by a 100 g serving: 0.003 mg of arsenic, 0.014 mg of cadmium, 0.008 mg of mercury, 0.3 mg of lead, 0.01 mg of nickel, 2.6 mg of zinc, and 2.5–5 mg of iron.	The recommended daily limits for each of the five metals contained in fish oil are far exceeded by the amount found in one serving. Thus, based on this most recent research, fish oil in any form is not good to consume.	
spectrophotometer for atomic absorption	This parameter continuously gave results that were greater than the benchmark value of 159 mg/liter for effluent for the course of the low-flow sample period. In the winter, the mean was 290.5 11.81 mgO ₂ /liter, and in the summer, it was 295.67 6.66 mgO ₂ /liter.	The downstream water quality measures, such as COD and sulfides, during the low flow period, are over the national environmental quality standard's (NEQS) permissible limits just a few meters from the Warsak dam. The vicinity of Nowshera, where the river flows through densely populated cities and villages, is	Industrial effluent disposal should adhere to environmental regulations. It is crucial to educate the public on the value of properly disposing of these effluents.

		unquestionably contaminated.	
Colorimeter Technique. Method of Atomic Absorption Spectrometry. Argandometric Technique	In comparison to environmental norms, the concentration of the several examined values was extremely high. Take the concentrations of BOD5, COD, DO, and total suspended particles as an example.	The Ravi River has been thoroughly investigated, and it is extremely polluted and unfit for recreational usage.	It is highly advised that a small reservoir be constructed upstream. In the low-flow season, this will help control and maintain water levels.
Paper from Whatman Filter.	Upstream had the highest Cr concentration, which was measured at 23.54 mg/L, while downstream had the lowest, 21.12 mg/L.	Trimmu barrage has greater Cr concentrations upstream than downstream.	
Spectrophotometer for Atomic Absorption	Lead, copper, cadmium, and nickel levels are generally slightly to significantly elevated in the river's fish. Lead had the highest concentration of these metals in the worst-offending fish, at 33 mg/kg of wet weight.	According to a recent study, heavy metals like cadmium and lead are not frequently identified in the majority of freshwater fish species from the Kabul River. However, nickel, one of the metals, may be unhealthy for regular or excessive fish eaters.	Multiple factors can be linked to heavy metal contamination. The most recent findings can be used by government agencies and other interested parties as a reference for the freshwater body in the study area's severe metal contamination status.

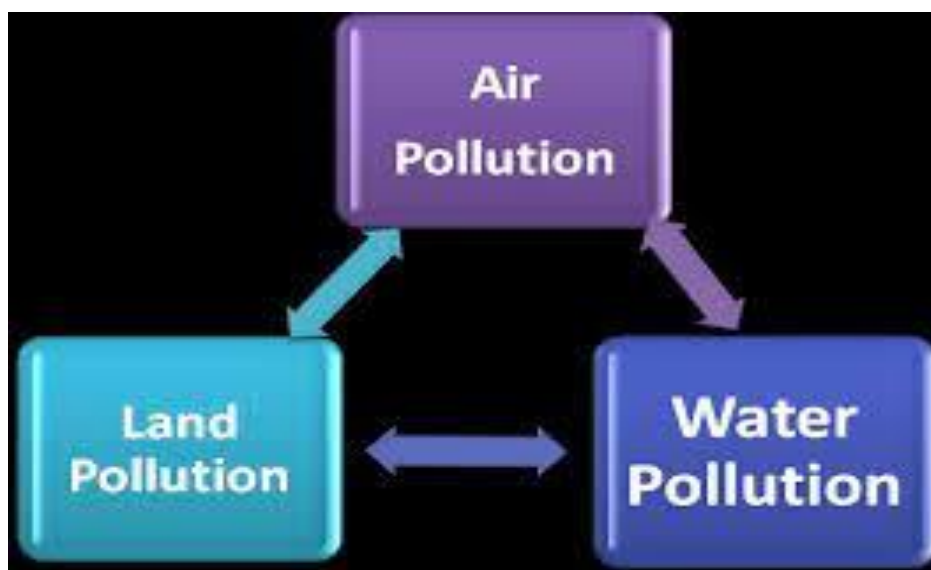


Fig. 2. River pollution sources [13].



Fig. 3. Important factors contributing to river pollution [14].

3. MAJOR POLLUTANTS

Numerous types of substances are designated as active water pollutants. The most common types of pollutants include pathogens (bacteria, viruses, and protozoa), anions and cations (phosphate, nitrate, sulfate, Ca^{2+} , Mg^{2+} , and F), and water-soluble radioactive

compounds. Inorganic pollutants include acids, salts, and hazardous metals. Additionally, it is believed that organic contaminants like oil and pesticides endanger the integrity of the water. All of these toxins become toxic and seriously harm both people and other creatures in the ecosystem when they exceed a particular threshold value [14]. Pesticides, bacterial contamination, toxic metals like nitrates and fluorides, toxic metals including arsenic, iron, cadmium, and nickel, and in some locations, nitrates and fluorides, pose severe threats to Pakistan's water quality.

3. 1. Bacteriological contamination

Water is typically subjected to microbial analysis to find total and/or fecal coliforms. Coliforms are a common environmental occurrence and are typically not dangerous to people, although their presence is utilized as an indicator. For pathogens and bacteria that might cause disease in water. Fecal coliforms and *E. coli* are additional signs that water has been contaminated by human or animal feces. For there to be no total or fecal coliforms, the WHO standard for public drinking water, which stipulates that there should be 0 counts/100 mL of the water sample, must be met; Bacterial contamination has been recognized as the biggest risk factor for Pakistan's drinking water [15].

Numerous studies have found that the nation's drinking water is heavily contaminated by bacteria, and many of the bacterium species found there are dangerous to human health. Water supplies like rivers, lakes, and underground aquifers are incredibly contaminated with germs in most of the nation's regions. In Pakistani cities like Quetta total coliform and, in certain cases, fecal coliform were detected in samples taken from water distribution networks and even treatment facilities. 567 (73.83%) and 351 (45.70%) of the 768 drinking water samples taken at Khairpur in the Sindh province were polluted with total and fecal coliforms, respectively [16]. Another study conducted in the same city discovered that total and fecal coliforms were present in all 90 (100%) water samples obtained from the main reservoir, distribution lines, and consumer taps. The scenario isn't much better in other significant cities across the nation, such as Quetta, Peshawar, Lahore, and Karachi, where it has been determined that the water is tainted with bacteria [17]. Total coliforms and *E. coli* were discovered in 100% of surface water samples in a different study carried out in key cities across the country, but only in 65% and 35% of groundwater samples (PCRWR, 2005). According to a recent analysis, Quetta Lake and its feeder streams may have had tainted water. Over 1.5 million people in Rawalpindi receive their drinking water from Rawal Lake [18].

3. 2. Water pollution sources

Pollution of water is primarily caused by human activity. The main one is the careless discharge of commercial, municipal, and household trash in lakes, rivers, streams, and other bodies of water. Every day, sewage and other effluents are thought to be released into the ocean in quantities of 2 million tonnes. In poor countries, where more than 90% of raw sewage and 70% of untreated industrial waste are dumped into surface water sources, the problem is worse, according to a survey that claims 1228 of Pakistan's 6634 recognized firms are considered to be seriously polluting [19]. Due to the massive amounts of organic and toxic compounds included in their waste effluents, industries in Pakistan are now a significant source of water pollution. The main industries that contribute to water pollution include textile, pharmaceutical, ceramic, petrochemical, culinary, steel, oil mills, sugar industries, fertilizer plants, and leather

tanning. The wastewater produced by these industries contains large amounts of hazardous metals such as arsenic, iron, lead, mercury, chromium, cadmium, copper, nickel, zinc, and magnesium as well as nitrates, nitrites, cations, and anions like Ag^+ , Na^+ , K^+ , Mg^{2+} , Ca^{2+} , Cl , and HCO_3 [20]. The vast majority of industries are found in or close to big cities. They merely dump their waste into the nearby rivers, canals, and drains. Figure 1 displays streams, ponds, ditches, and undeveloped or farmed terrain. as an example. The River Kabul in Khyber Pakhtoonkhwa is said to receive 80,000 m³ (8 107 L) of industrial effluents each day. Even in Islamabad, the capital city, rubbish is merely dumped into the Sawan River since the two industrial estates lack efficient effluent management. Only 1% of Pakistan's industrial effluent is thought to be treated before being released [21]. As a result, wastewater containing potentially harmful compounds is disposed of without considering the risks they pose to the environment.

The amount of waste effluent that various businesses in Pakistan release into water bodies each day is estimated as 40 109 L. These waste contaminants do not just stay in surface water; they also contaminate groundwater aquifers through soil percolation. Domestic and municipal wastes, in addition to industrial pollutants, pose a severe hazard to water. Domestic wastes, which include human waste and household effluent, are also dumped directly into open space or agricultural land, just like industrial wastes [22]. However, less than 50% of large cities have collecting systems, and only approximately 10% of the collected sewages are successfully treated. Sometimes, sewerage collection systems empty their contents into the nearest body of water. The majority of the nation's wastewater is produced in the biggest cities, including Quetta, Karachi, Lahore, and Peshawar. Although many of these cities have treatment plants, many of them were constructed before the completion of the related sewage networks. As a result, the plants are frequently underloaded (due to an inadequate sewage network, many municipal effluents do not reach the plant) or abandoned, and only a very limited proportion of wastewater is handled adequately [23]. Only 8% of urban wastewater is typically treated at municipal facilities before being released into freshwater sources. Stormwater drains and nullahs, which are the local term for a ravine, gully, or ditch, are often the routes via which sewage and waste from communities enter streams, rivers, and irrigation canals. Estimates state that Pakistan releases 2000 million gallons (7.5708 109 L) of sewage into surface water bodies each day.

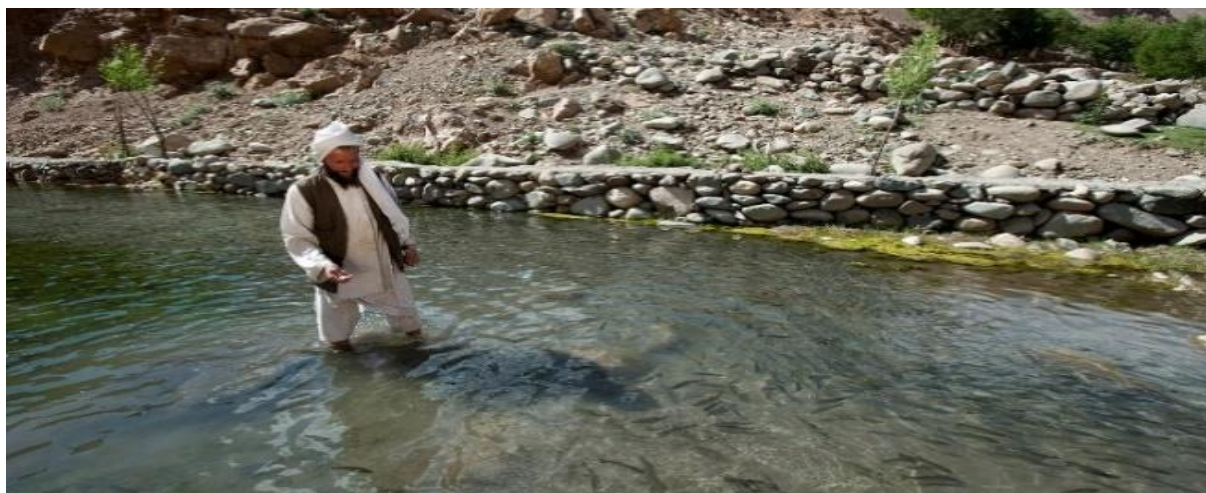


Fig 4. Effluents, and sewage turning Pakistani rivers toxic [24].

3.3. Human health and environmental toxins

One of the key factors contributing to issues with human health is contamination of the water supply. Water-related illnesses harm 2.3 billion people worldwide (UNESCO, 2003). According to estimates from WHO and UNICEF (2000), 2.2 million people worldwide die each year as a result of drinking contaminated water and neglecting to utilize sufficient sanitation facilities. Infectious and parasite disorders associated with water account for more than 60% of infant deaths worldwide [25]. The primary causes of waterborne infections in Pakistan include drinking water contamination with industrial and municipal wastes, together with a lack of water disinfection practices and quality monitoring at treatment plants[26]. It is extremely challenging to accurately estimate waterborne diseases in Pakistan since medical data are not kept up to date [27].

A UNICEF study claims that 20–40% of hospital patients in Pakistan have illnesses connected to the water supply. One-third of all fatalities in the country are caused by diseases like typhoid, hepatitis, cholera, dysentery, cryptosporidiosis, dysentery, and giardiasis. Waterborne diseases include cholera, hepatitis, typhoid fever, gastroenteritis, dysentery, rotavirus diarrhea, *E. coli* diarrhea, intestinal worms, and dysentery become more common as the monsoon season (July and August) rains begin. Since there aren't enough efficient prevention and control measures, the issue gets worse [28].

Diarrhea, an illness brought on by contaminated water, affects 7% of Pakistan's population overall and 14% of children under the age of five. Every year, 0.2-0.25 million children in Pakistan lose their lives to diarrhea and other water-related illnesses. Kidney diseases, which claim the lives of 10,000 people annually in Karachi, have been related to dirty water [29].

In this nation, polluted water has been linked to several illnesses. The Hepatitis E epidemic was discovered in a Pakistani army unit at Abbottabad in September 1988. It was discovered that a water system had been contaminated by feces. There were 800 people in the facility, and 107 of them ended up getting sick. In two localities of Islamabad, Hepatitis E (HEV) waterborne infections afflicted 3827 people in late 1993 and early 1994. In Gadap, Karachi, during the summer of 2003, an outbreak of acute gastroenteritis was linked to the consumption of fecally tainted well water [31].

The most likely culprit was the rotavirus present in the water. In the remote Nek Muhammad village outside Karachi, typhoid disease spread within a week, killing three people and infecting more than 300 more. The outbreak has been linked to the village's sole source of drinking water, a reservoir well. Interviews revealed that 98% of the patients reported weakness, 91% had a fever, 65% had diarrhea, 42% had vomiting, and 42% had other symptoms[32]. Due to a lack of sewage and water treatment infrastructure, typhoid fever is still common and a major cause of morbidity and mortality in underdeveloped countries like Pakistan, where it has almost entirely disappeared (Ahmed et al., 2006).

In the Khairpur region of Sindh Province, contaminated drinking water has been the cause of multiple epidemics of water-related ailments such as diarrhea, dysentery, and typhoid fever[33]. According to the Quarterly Report of Infectious Diseases of Civil Hospital, Khairpur, there were 25 cases of typhoid fever, 18 cases of diarrhea, and 7 cases of dysentery in the area in the years 2006–2007.

According to national press reports, hundreds of individuals in rural Sindh went through a similar situation in May 2008 after drinking contaminated water[34].

4. CONCLUSIONS

The analysis above leads to the conclusion that water pollution has reached alarming levels. The majority of the world's water supplies have declined in quality, but Pakistan's situation is more dire. The fact that the current generation consumes considerable amounts of key pollutants, such as germs and a range of heavy metals through our food including arsenic, cadmium, lead, nickel, copper, chromium, iron, and zinc is unknown. Keep those pollutants out of reach at all costs. People fought against nature to pollute it, but they were still baffled by its 10% policy. Each day, thousands of cases are recorded that discuss different ailments. Nature has no dangerous substances. Something only turns poisonous when it is exposed. The nation will therefore be required to keep an eye on the buildup of higher doses of any substance in the environment or atmosphere. Sustainable development is crucial in today's world. One needs to take into account even their generation, who still appear to be on our planet. Therefore, it is important to focus on future repairs, upkeep, and increasing the regular inspection of current treatment plants. The papers listed above give a complete overview of the main pollutants, the causes of water pollution, and the impacts of contamination on human health. It is determined that without obtaining or putting the indicated reformatory remedies into practice, all analyses of water contamination are meaningless.

It costs a lot of money to make the efforts necessary to develop solutions or techniques for particular problems or issues. More people, more money, and more priceless time are needed to discover a solution or a way around the problem. The great mindset's conclusions, meanwhile, have occasionally turned out to be calamitous. Pesticide levels in water tests from various places consistently exceed the permitted limits. Human activity is the main cause of water pollution in Pakistan, mainly the discharge of untreated industrial and municipal pollutants. Particularly in rural areas, inadequate water quality monitoring is done. If treatment facilities do exist, they do not offer the general public high-quality water, and methods of water disinfection such as chlorination are either nonexistent or insufficient. In various parts of the country, bacterial and chemical contamination of public drinking water has resulted in waterborne illnesses. However, there are very few records on illnesses linked to water due to a lack of diagnostic equipment and record-keeping. Regular nationwide surveys are required to gain a clear picture of the diseases connected to water. The recommendations made below may help Pakistan address its problems with deteriorating water quality.

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