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An Analysis on the Harmful Effects of Water Pollution in the Ravi River

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Abstract

The Ravi River, which is the major source of recharge in Lahore, is typically dry throughout the year. This issue has sparked widespread anxiety that Lahore could soon suffer a water shortage, putting the city's population in jeopardy. During the low flow season, multiple drains reach the river at various locations, discharging millions of tonnes of effluent, and the river functions almost as a "sullage carrier." The river's unclean water seeps into the groundwater, ultimately moving to a circle of depression in the aquifer created by excessive groundwater pumping in the urban area. To meet the needs of domestic and industrial water supplies, massive groundwater pumping is going place. The extraction of groundwater is expanding dramatically as the population and industry grow, and as a result, the groundwater reservoir is fast emptying, causing a dip in the underlying aquifers. With time, the quality of drain water entering the river has degraded, and as a result, comparable trends in River water quality have been documented. Before being thrown into the river, industrial and municipal effluents must be properly treated.

1. Introduction

Groundwater is a vital resource for survival on Earth; 70% of the planet is covered in water, but only 2.5 percent of it is freshwater, and 30% of it is in the form of glacial. Humans are largely reliant on clean drinking water. Groundwater is scarce, just with 1% availability. This readily obtainable Groundwater is currently the most endangered nature supply. Rivers are one such source of Groundwater. Natural materials and Groundwater abound in the subcontinent's area. Rivers abound in Pakistan, and they all run throughout Punjab province. Ravi is a river in Kashmir and Pakistan that originates in Bara Bangal, a part of the Dhauladhar Himalayan ranges in India's Himachal Pradesh region. It begins in the northwest and bends southwest towards Dalhousie (Fig. 1), on the Jammu-Kashmir state border [1].

Fig. 1: Ravi turns to south-west [1]

The river Ravi, which adds to the breathtaking grandeur of the Chamba valley (Fig. 2), has its basin between the Pir Panjal and the Dhauladhar ranges. Budha, Tundahan, Beljedi, Saho, and Sial are Ravi's right bank tributaries on the Kashmir side, whereas Chirchind is its left bank tributary on the Punjab side. After passing through Dhauladhar, the Ravi zigzags across northwestern India and northwestern Pakistan, flowing to the Pakistan boundary and along with it before reaching Pakistani Punjab.

Fig. 2: Ravi contributes the marvelous beauty of Chamba Valley [1]

The Ravi eventually unites with the Chenab River, but before that, the two rivers are linked by the Marala Ravi link canal, the Upper Chenab Canal, and the Qadirabad-Bulloki Link Canal, which meets both rivers at Bulloki headwork. The majority of wastewater flows into

Ravi in the 60-kilometer stretch between Bulloki and Lahore. Trimmer Sindhnai is the last connection canal on the Ravi, finishing at Sindhnai Barrage (Fig. 3) [2].

Fig. 3: Sindhnai Barrage on Ravi

The total water supply in Pakistan and India has decreased from nearly 5000 square meters per meter in 1950 to 1800 square meters per meter in 2005. Water accessibility per capita in Pakistan has decreased from 5600 square meters in 1947 to 1200 square meters in 2005 and is rapidly approaching 1000 square meters in 2007. Irrigation might suffer because of the decrease in the water supply. Pakistan has the world's biggest irrigation infrastructure, delivering 60% of all irrigation water. Irrigation water inflows have decreased from 140 MAF in the 1980s to an average of 100 MAF in 2005. It is expected to continue to fall as streams in the three rivers, one of which is the Ravi, are decreasing at a 6.6 percent annual rate. In 1995, the average yearly inflow into the nation via western rivers (the Indus, comprising the Kabul tributary, the Jhelum, and the Chenab) was 170.27 km3. This is retained for India by the Indus Water Treaty of 1960 [1].

The Ravi is the shortest of the major rivers of the Indus River Network and was ceded to India as part of the Indus Water Treaty [3]. It rises in the Bangahal valley and flows down the southern slopes of Dhanladhar. It leaves the Himalayas near Baseeli in India [4], after flowing northwest across the Chamba valley, parallel to the Dhanladhar range. The river streams for roughly 130 miles through the hilly terrain, falling 15,000 feet at a rate of around

115 feet per mile [5]. After passing through the Gurdaspur area, it reaches Pakistan in Jassar, some 120 kilometers upstream of Lahore [6]. It travels for roughly 520 kilometers until it joins the Chenab River. (See Fig 4).

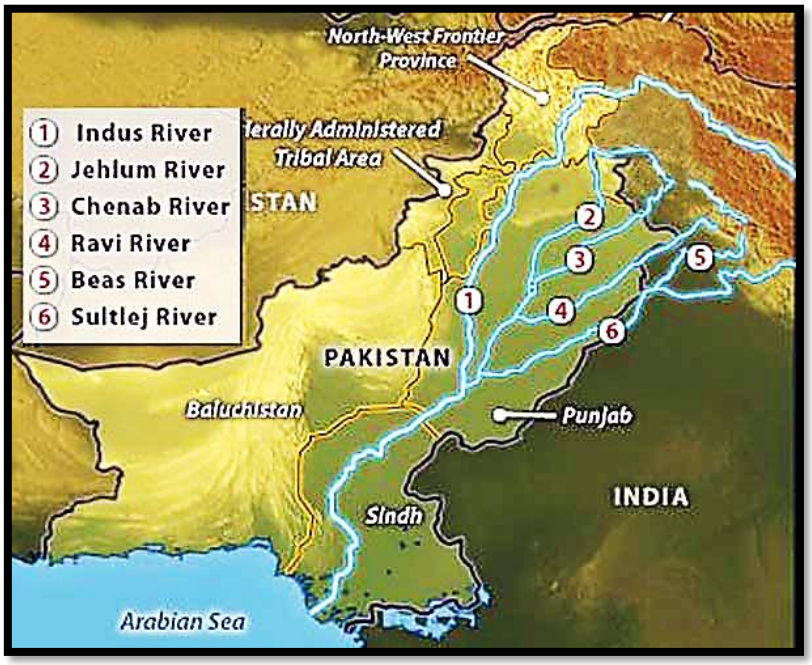

Fig 4. Major Rivers In Pakistan

As stated in Visions 2025, Pakistan may face a major water shortage crisis and the country may suffer greatly if critical water supply management measures are not implemented immediately [7]. Pakistan is the world's largest and sixth-most populous nation, with over 175 million people and a growth development rate of 2.1 percent [8]. For many years, fast population growth has led to the over-extraction of groundwater, particularly in metropolitan areas, to fulfill human requirements, causing the subterranean water tables to deplete at dangerous levels [9]. Freshwater is a critical and easily accessible resource, and reliance on it has risen considerably in recent years, particularly in South Asia [10]. More than 50% of worldwide freshwater consumption is accounted for by South Asia and China [11]. In the last 3 years [12].

South Asia has been the globe's greatest freshwater extortionist. Freshwater is the backbone of agriculture in India, Northern Sri Lanka, Pakistan's Punjab, Bangladesh, and the Northern China Plain because of rising scarcity and inconsistency in the surface water supply. Freshwater accounts for more than half of all irrigated land in India, accounting for 60% of total agricultural water consumption [13]. It is believed that 60-70 percent of Pakistan's community relies on fresh water for their survival, either directly or indirectly. Like India, the

United States, and China, Pakistan is the world's fourth-largest groundwater consumer [14]. Water is a necessity for all life and survival. It is also important for the economic development of any country. Pakistan features on the global list of water-scarce countries due to limited water resources [15].

Although there is not any reuse technology, approximately 4.43 billion m^3 of wastewater is produced annually in Pakistan and only a fraction of wastewater is processed by treatment plants before discharge into natural water sources. Pakistan lacks appropriate water storage facilities as found in other countries such as the United States of America and Australia (having the storage capacity of 5,000 m^3), and China (storage capacity of 2,200 m^3). Pakistan can only store 1,500 m^3 per capita water. In Pakistan, the per capita annual water resources are 1,305 m^3 [16]. Typical sources of water include rivers, streams, rainwater, lakes, ponds, and underground water [17]. With increasing pollution in many tropical countries, there is limited awareness about the weaknesses and strengths of different institutional frameworks to deal with pollution, ecosystems, and their effects on biota [16]. Normally in developing countries, wastewater is disposed of in water bodies without any treatment [18]. High energy consumption, process intricacy, high capital, and functioning costs have made the traditional treatment procedures difficult to implement in these countries. This situation is exasperated by a lack of trained and skilled workers.

Lahore city is situated at the bank of River Ravi, which is receiving untreated industrial and domestic wastewater daily from various domestic and industrial drains. This water invades aquifers threatening the health of residents Lahore is Pakistan's second-largest metropolis, with roughly 4,847,040 m3/d (1,981 cusecs) of sewage flowing into Ravi. The capital expense, inherent operational difficulty, and resource comprehensiveness of traditional sewage processing methods are major challenges in handling this effluent [16].

Fig 5. View of Ravi River

Ironically, river water loaded with harmful compounds, excessive metal content, and excessive arsenic concentrations are utilized for irrigated agriculture, posing a risk to humans who consume these lethal products [19].

The poisonous mixture also poses a major hazard to the freshwater aquifers that are used to recharge freshwater [20]. Freshwater is the primary supply of drinkable water in Lahore. Due to over-extraction, this resource is likewise quickly declining [21]. With a range of 422 miles in Punjab and an annual discharge of 0.94-million-acre-feet (MAF), the Ravi has become a dumping site for municipal waste and hazardous industry toxic pollution in recent decades. The Ravi arrives in Pakistan near Kot Nainan and meets the Chenab at Khanewal's Sardar Pur. In the winter, the river's normal water discharge is approximately 0.54 MAF, but in the summer, it is approximately 0.94 MAF [22].

1.1. Industrial drain

Unchecked pumping of toxic industrial and municipal waste into the Ravi, the biggest source of refilling underground water aquifer of the provincial metropolis, has posed serious health concerns to citizens, native river species, and the surrounding environment [6] With a range of 422 miles in Punjab and an annual discharge of 0.94 million acre-feet (MAF), the Ravi has become a dumping site for municipal waste and hazardous industry toxic pollution in recent decades. The Ravi arrives in Pakistan near Kot Nainan and meets the Chenab at Khanewal's Sardar Pur. In the winter, the river's normal water discharge is approximately 0.54 MAF, but in the summer, it is approximately 0.94 MAF [22] [23]. The quality of the freshwater downstream from the Ravi Syphon to Lahore has decreased [24].

Freshwater near Lahore city has changed color from colorless to yellowish, and its scents have become disagreeable, with hardness varying from 2 to 4 NTU [25]. Hazardous chemicals from industry pollutants were also discovered in freshwater specimens, with lead (Pb), nickel (Ni), and numerous E. coli percentages above the allowable drinking water quality standards [26]. Municipal landfills are additional reservoirs of contamination, particularly of freshwater, that pose a severe danger to metropolitan settings [27]. The Ravi arrives in Pakistan near Kot Nainan and meets the Chenab at Khanewal's Sardar Pur. In the winter, the river's normal water discharge is approximately 0.54 MAF, but in the summer, it is approximately 0.94 MAF [22] [23].

Fig 6. Drain in River

According to figures collected, drains of the provincial capital are throwing industrial and municipal waste into the river.

Table 1. Lahore main drains

Drain Names	**Capacity And BOD Level**	**Ref.**
Mehmood Booti Drain	(1 cusec in which BOD level is 250 mg/l).	[28]
Shadbagh Drain	(200 cusecs in which BOD level is 192 mg/l).	[29]

Shahdara Town Pumping Station	(35 cusecs in which BOD level is 140 mg/l)	[30]
Forest Colony pumping Station	(25 cusecs in which BOD level is 200 mg/l).	[31]
Furkhabad Drain	(40 cusecs in which BOD level is 382 mg/l)	[32]
Main Out Fall Drain	(102 cusecs in which BOD level is 412 mg/l).	[33]
Babu Sabu Drain	(72 cusecs in which BOD level is 312 mg/l).	[29]
Hudiyara Drain,	(512 cusecs in which BOD level is 120 mg/l)	[34]

More than 450 industrial units are pumping untreated toxic water into the drain at different points. Outside the provincial capital, drains are also throwing waste into the Ravi at Faisalabad, Sahiwal, and TT Singh district.

1.2. Comparison between TDS/BOD and NO_3-N in Districts of Lahore, Sheikhupura, and Faisalabad

Between all the waste-carrying drainage systems, the Farrukhabad and Hudaira drainages carry a large share of the pollutants. Both Sheikhupura Road and Shadra, Baradari Road, G.T. Road, and their neighboring areas transfer both industry and sewerage waste to Farrukhabad [32] [34]. Another of the biggest drainage systems is the Hudiara drain, which transports household and industrial waste from township residence regions, township industrial estates, the towns of Johar, Faisal, and WAPDA, as well as sewage from tiny drains like the Nishtar Colony drain, Sattokatla drain, and Charrier drain [34]. Usually, the city of Lahore pollutes the Ravi River the most, followed by the towns of Sheikhupura and Faisalabad (see figure 4). The Sukhrawa drain carries 0.25 percent of the pollutant burden from the Sahiwal area, which is minimal.[31]

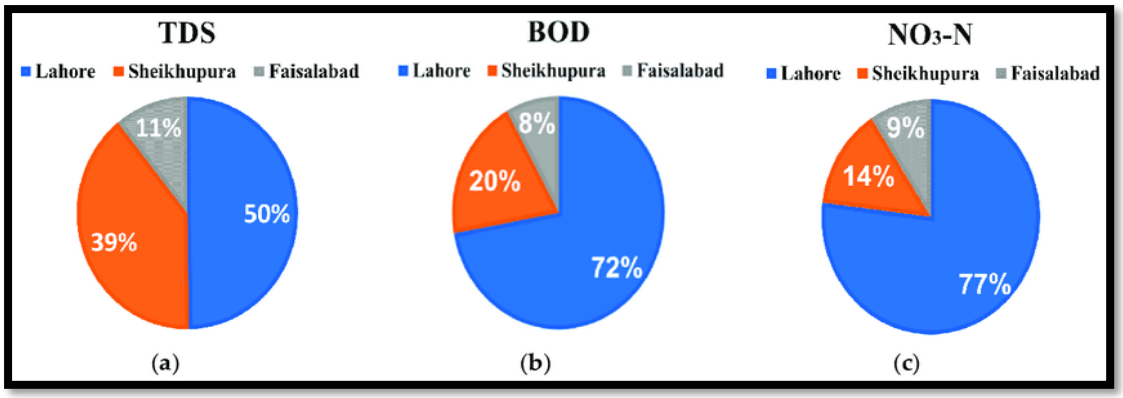

Fig 7. District-wise pollution load share of water-quality variables: (a) TDS, (b) BOD, and (c) NO_3-N along the Ravi River. [31]

1.3. Pollution Threats

Residential, agriculture and industrial waste streams released from several industries are the primary causes of contamination in the River Ravi between Lahore Siphon and Baloki headworks. Significant deterioration of river water and bed sediments occurs at Mehmood Booti, Shad Bagh, Farrukhabad Munshi Hospital, Taj Business, Bukkar Mandi, and Hadiara drains. Metal concentrations in sediments (Cu, Mn, Zn, Cr, Ni, and Pb) are often greater than in water. (See Figure 8).

Fig. 8: Shadman drain carrying sewage and solid waste into the Ravi

Using a dried material base, the quantities of the metal concentration in the sediments varied from 0.99 to 3.17 micrograms for Cd, 4.60 to 57.40 micrograms for Cr, 2.22 to 18.53 micrograms for Co, and 3.38 to 159.75 g for Cu. As the quantity of copper in the water rises, it becomes exceedingly hazardous to marine species. Planktons in marine ecosystems have a strong ability to acquire elements in their organisms from water and sediments [35]. Because phytoplankton removes elements from the atmosphere, accumulates, and stores them for a prolonged length of time, they operate as bioindicators of minerals in aquatic ecosystems [36]. Planktons have the potential to accumulate toxic metals from their aqueous surroundings, which makes them unique. Like Cd, Cu, and Pb, they can be harmful to marine biota [37]. The Ravi River, which has transformed into a sludge, is now a threat to the metropolis of Lahore.

More than 1500 cubic meters of wastewater are dumped into it without being treated. Insufficient river flows have elevated pollution quantities to unsafe levels, making marine life impossible to maintain. To reduce the ecological impact of wastewater in river ravines, either wastewater must be treated before discharge or wastewater quantities must be diluted by releasing more freshwater into the river. Under the current river flow and wastewater load, around 2000 cusecs of freshwater from the Marala Ravi Link Canal are necessary to sustain a soluble oxygen concentration of 4 to 5 mg/l. Daily, about 1307.08 tons of toxic and unprocessed trash enter Ravi. (See Figure 9). The burden of Lahore's wastewater is 728.75 tons per day. Ten sewage drainage and pumping units discharge 1810 cusecs of city sewage and harmful industrial effluents into the river.

Fig. 9: Dumping of solid and hazardous waste into the Ravi at Lahore

Hazardous waste from 10 drains, as well as five large industry sewage-carrying drains, have all contributed to the elimination of many local fish populations, as well as posing a severe danger to marine life and subterranean water levels.

1.4. Effect on the food chain

As in many locations where water for irrigation is becoming limited and people are utilizing drain water for irrigation, the issue of environmental contamination caused by toxic chemicals has begun to create worry. Geoaccumulation, bioaccumulation, and biomagnification may occur because of harmful major elements penetrating the environment. Toxic metals like Fe, Cu, Zn, Ni, and other trace metals are necessary for biological processes to operate properly, and their absence or overabundance can cause a variety of problems. Despite its potential buildup in bio stems via polluted water, soil, and air, heavy metal pollution in the food chain has become a hot topic in previous decades.

2. Water Quality Management Framework

With the city of Lahore's growing population and industrial expansion, current and future pollution loads constitute a constant danger to the Ravi River's water quality. A thorough WQM framework for the analysis of diverse options with predicted future loads (i.e., inputs) utilizing a calibrated and confirmed DO model has been developed to ameliorate this scenario. Based on the design periods of various waste management solutions, WQM programs are developed to satisfy future demands. In this respect, WQM is proposed for the year 2025 in this study. Haider calculated the ultimate CBOD (CBODU) and ultimate NBOD pollution loads in the future (NBODU) [31].

For the Ravi River, Haider and Ali built, evaluated, and tested DO and nitrification models. Haider and Ali investigated the required modifications in biokinetic rate coefficients of the Ravi River with varied levels of wastewater treatment. In this study, the same method was used to model DO and unionized ammonia profiles at various levels and degrees of treatment for various water quality control approaches under critical low-flow situations to achieve the Ravi River's needed water quality criteria (See Fig 10).

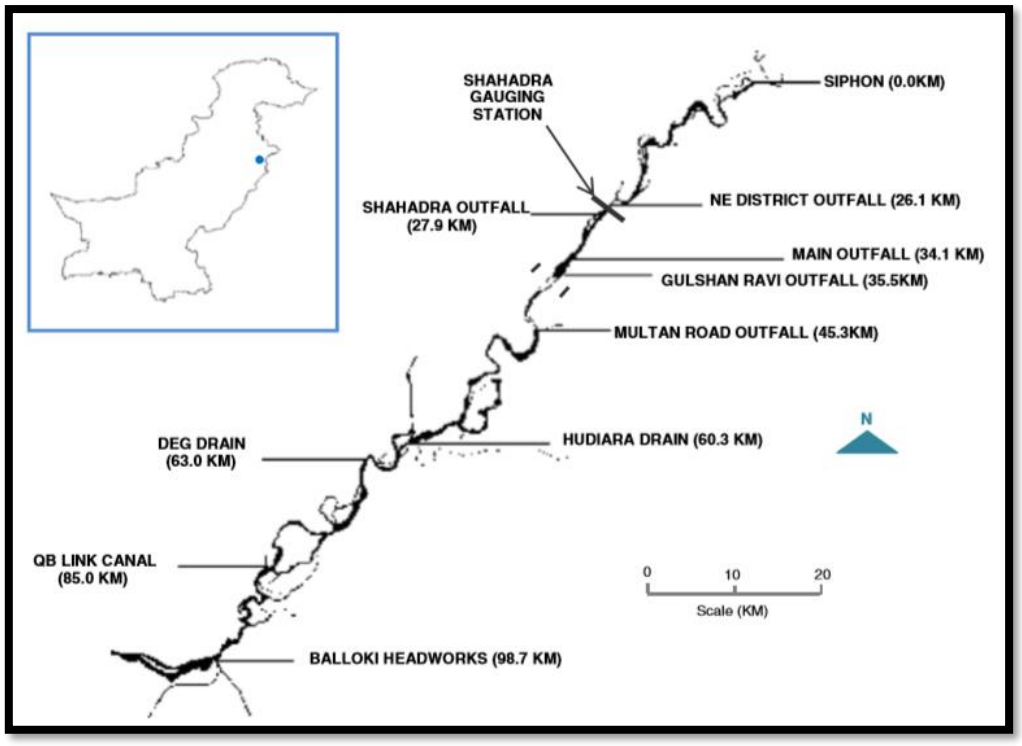

Fig 10. Location of Ravi River and study reach showing different locations of wastewater outfalls and surface drains [38]

The Ravi is irrigated by five irrigation canals: the Marala Ravi Link Canal, Upper Chenab Canal, QB Link Canal, Trimu Sidhnai Link Canal, and Haveli Main Line Canal, in addition to municipal and industrial drainage. According to activists, Ravi's water is utilized for irrigation, and hazardous chemicals that are injected into it without treatment might have disastrous implications for agricultural land that is irrigated with this harmful water. They claim that Ravi water is also utilized for drinking in some locations, posing major harm to humans and animals. According to a senior official with the Environmental Protection Department (EPD), the most polluting drains that discharge industrial and municipal trash into the river are Hadyara Drain, Main Outfall Drain, and Shad Bagh Drain.

He asserts that tens of thousands of moist tones of human excrement are produced every day in the province capital, with over half of this entering the Ravi through various pathways [31]. He claims that industrial wastewater contains harmful compounds and metals and that the lack of water treatment systems in most sectors is concerning (See Fig 11). He speaks

"They just dispose of untreated toxic waste into nearby drains which pump it into the Ravi".

According to research by WWF-Pakistan, excessive contamination of the Ravi has wiped off 42 kinds of local fish, while wildlife around the river has relocated to other locations. Small invertebrates, microfauna, and plants are also in danger of extinction.

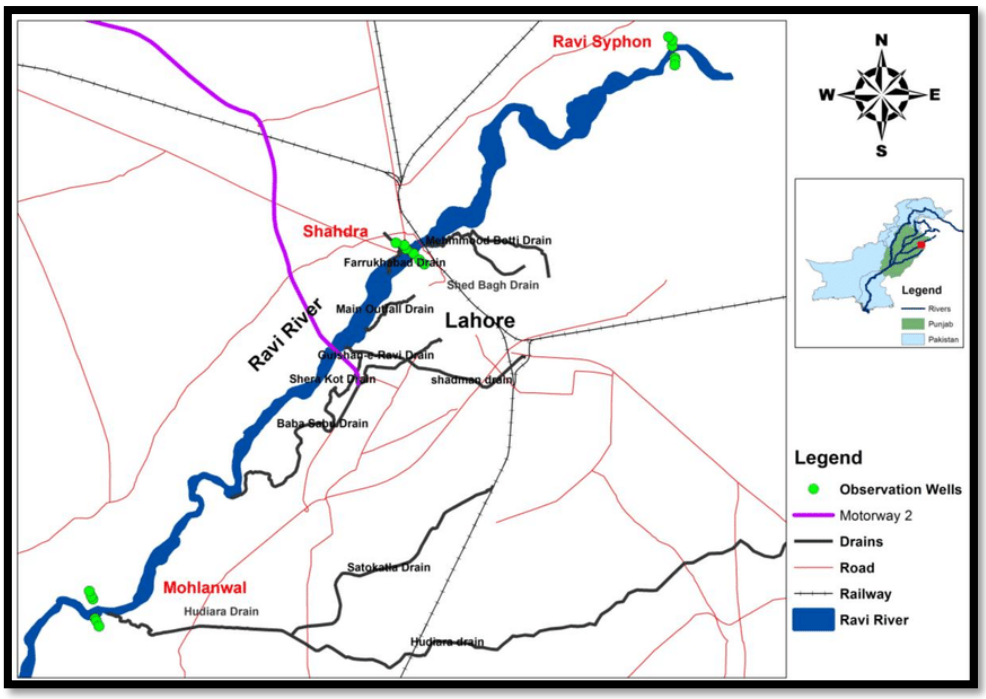

Fig 11. The layout of Drains entering the Ravi River [24]

3. Sewage and Street Runoff

The urban population of Lahore, Sheikhupura, Faisalabad, and Sahiwal is growing at an alarming pace of 4% per year, resulting in an ongoing increase in residential sewage [39]. This sewage, in combination with street runoff, poses a serious hazard to groundwater since a portion of it eventually leaches into the groundwater. The outflow of wastewater from these cities into the Ravi River was estimated to be around 990 cusecs in 2006 but has now risen to 730,000 cusecs through sewers and different pumping stations without sufficient treatment [25].

As previously said, Lahore has evolved into the country's industrial center. Textiles, chemicals, car parts, electric appliances, equipment, food, restaurants, plastic, and PVC shops, all of which are headquartered in the lovely city of Lahore, pollute the environment [40]. These industries, which are in Kala Shah Kaku, Lahore Sheikhupura Road, along Lahore Band Road,

Quaid-e-Azam Industrial Estate at Kot Lakhpat, and Multan Road in Lahore city, require a lot of groundwater to process and analyze materials and finish products. Instead of industrial parks, the city of Lahore has a high number of in-house small industrial facilities that discharge effluent into sewage systems without remediation [24].

Organic and inorganic contaminants in domestic and industrial pollutants thoroughly seep through the soil, depending on the soil's type, and eventually worsen groundwater quality [41]. During the winter, the Ravi River's flow is inadequate to wash away wastewater contamination. According to Pakistan's environmental profile, over 40% of deaths are caused by waterborne illnesses transmitted by water pollution, which is mostly caused by sewage and industrial wastewater degradation of drinking water distribution systems [42].

According to prior studies, most groundwater specimens collected near these landfill sites contain pollutants, and their concentration levels in groundwater are higher than those prescribed by the Pakistan Standards and Quality Control Authority (PSQCA), and the concentration of arsenic in drinking water exceeds WHO criteria [43]. According to UNEP statistics, 47% of drinking water in Lahore city is polluted owing to the presence of different harmful toxic components, according to the Daily newspaper (20 May 2008) [44].

Chemical fertilizers, insecticides, and herbicides are used in overabundance and uncontrollably, resulting in polluted agricultural run-off [45]. This not only contaminates the surface drains but also causes serious pollution of the natural aquifer in Lahore's neighboring districts [46]. Over-abstraction of groundwater causes replenishment from surface water drains, which are heavily polluted themselves. Different drains, such as the Hudiara drain, gather surface runoff from Indian and Pakistani farm fields and contaminate the groundwater in Lahore and its nearby areas [47].

4. Effects of Groundwater Pollution

4.1. Health Issues

Contaminated groundwater is hazardous to one's health. Human excrement may pollute water sources in situations where septic tanks are not installed appropriately [48]. Hepatitis-causing germs might be present in the excrement, causing irreparable liver damage. It can also induce dysentery, which can result in severe diarrhea, Hepatitis A, D, and E, typhoid fever, dehydration, and death in certain cases. Poisoning may occur as a result of the overuse of

pesticides, fertilizers, or natural chemicals, among other health issues. The chemicals contaminate water sources by leaching into them. Drinking water from such a source might be harmful to your health [49].

4.2. Affects economic growth

Contamination of groundwater supplies makes the region unfit for plant, human, and animal life to thrive. The population of the region decreases, and the value of the land decreases. Another impact is that industries that rely on groundwater for production suffer from reduced stability. As a result, enterprises in the impacted areas may have to rely on water from other regions, which might be costly. Furthermore, due to low water quality, they may be compelled to close [50].

4.3. Damaging impacts on the environment

Freshwater contamination has the potential to wreak havoc on the ecosystem. Another major change is the elimination of specific minerals that are necessary for the ecosphere's subconscious. Additionally, whenever contaminants mingle with water bodies, the marine environment may be altered. As a result of too numerous toxins in the bodies of water, aquatic animals such as fish may die off fast. Animals and plants that drink the tainted water may be harmed as well. Toxic compounds build up in aquifers over time, and as the contamination expands, the freshwater may become unfit for human and animal use. The consequences are severe, particularly for those who rely on freshwater throughout droughts [51].

Hazardous elements such as lead, nickel, and other toxic substances have leached into freshwater and eventually into the food supply chain in locations wherever industry drainage is located. In these places, faces contamination is also frequent. As a result, ailments including diarrhea, stomach infections, and skin problems have become more common. The river becomes a drain when the flow from India is minimal or non-existent [52]. Throughout seasons of low flow, most of the river reach (60 km) near Lahore turns anaerobic. The principal sources of oxygen deficiency in the Ravi River are nitrogenous biochemical oxygen requirements and carbonaceous biochemical oxygen consumption.

As a result, in addition to CBOD removal, NBOD removal must be addressed while assessing different WQM solutions in the Ravi River to achieve DO criteria [38]. In this regard,

un-ionized ammonia is another key water quality parameter to control to guarantee a healthy habitat for fish. Unionized NH3 in high amounts is hazardous to fish [53].

5. Solutions to Groundwater Pollution

5.1. Legislation

In most nations, there are federal rules in place to assist safeguard the quality of groundwater. Rules for Healthy Drinking and Clean Water should guarantee that drinking water is protected by setting mechanisms to make sure it meets health requirements [53].

5.2. Self-treatment of wastewater by industries

Almost all the companies in the central Punjab region discharge their dirty water into wastewater drains that eventually go into the Ravi River. These businesses should be encouraged to install water treatment plants to improve the quality of river water, which is utilized by many residents, aquatic life, and agriculture [54].

5.3. The use of water cleaning systems

At outlets that discharge water for human consumption, point-of-use treatment devices should be provided. Chemical disinfection, boiling, sun distillation, filtration, ozone water disinfection, activated charcoal absorption, and ultraviolet decontamination are among the methods employed. Arsenic removal filters (ARFs) are commonly used to filter out arsenic compounds. These filters must be maintained regularly to guarantee that the drinking water is always healthy. Another management strategy is groundwater remediation. Bioaugmentation, slurping, bioventing, phytoremediation, and sparging are the biological treatment procedures used. Ion exchange, ozone gas injection, membrane separation, and chemical precipitation are all chemical processes that can be applied [55].

5.4. Proper management of the sources of pollution

Clay and leachates should be included in the landfill design. Maintenance should be performed regularly. The landfill should also be well away from any groundwater sources. Hazardous wastes should not be dumped in landfills unless they are specifically designed for that reason. To avoid pollution or even litigation, it is critical to follow the established standards and procedures while constructing and operating subterranean storage tanks. Any unwanted

submerged tanks should be removed, and a containment system that functions as a leak backup must be installed. The establishment of underground pipelines should be done by an expert. Assessments should be performed regularly, and any corrosion or leaks should be addressed right once [56].

5.5. Recycling

Most landfills in various nations are next to a recycling plant. As a result, spent petroleum products should be transported to such locations. Other recyclable items, such as plastic, bottle, and paper trash, can be delivered to recycling operations in addition to oil. The state should construct dedicated recycling pick-up locations in regions where they do not already exist.

The state, in collaboration with other environmental groups, can motivate individuals to join in the recycling campaign. They may accomplish this by launching public awareness initiatives and teaching communities about the value of recycling. The overall outcome of the investigation suggests that groundwater quality is degrading more at Shahdara (relative to Ravi Syphon and Mohlanwal) as an outcome of sewage entering the river through various drains. Data from the Shahdara site on both sides of the river show that the quality of shallow water at 50 ft depth at R3 and L3 is declining with time [57].

6. Wastewater Transportation:

A further option for Ravi River water quality maintenance is to transfer NE-District, Main Outfall, Gulshan Ravi, Multan Road Outfalls, and Hudiara Drain flows through a collecting channel to the QB Link canal conjunction site. The advantage of diluting from the QB Link canal may be used in this way to reduce sewage processing costs. The normal yearly stream in the QB Link canal is 395.6 m3 /s, which is over 9 times larger than the expected sewage flow through the above outfalls and the Hudiara drain through 2025. Deg drain meets the UCC channel around 20 kilometers upstream and frequently uses UCC's diluting. When Deg Drain's flow joins the River Ravi during the canal closing season, wastewater remediation is already underway when the UCC confluence is the only possible possibility for Deg Drain in this situation [31].

7. Conclusions

Unregulated and unexpected over-pumping, unprocessed contaminants, a shortage of aquifer recharge, a lack of cooperation among numerous parties, and other potential dangers to Lahore's groundwater reserves have been highlighted. Groundwater levels in the city area are dropping at a pace of 2.5 feet per year on average, and up to 3 feet per year in some places, due to excessive pumping and inadequate recharging. Groundwater has plunged more than 100 feet below the normal surface level in several areas of the city. The Ravi River has become a source of contamination for the groundwater reservoir underneath Lahore (due to low flows and throwing of effluents in it).

The quality of groundwater in the aquifer is diminishing with time, and pure water is now becoming scarce and difficult to get. The quality of groundwater increases with depth below the natural surface. Groundwater quality degrades from Ravi Syphon to Mohlanwal, with the worst being at Shahdara along the Ravi river. Because groundwater levels change with the river gauge, the Ravi river can help recharge the aquifer. The quality of pollutants reaching the River through drains is degrading with time. The slope of the hydraulic gradient line was monitored from Raiwind/Kasur to Lahore, with the slope becoming steeper as the line approached Lahore. There is a lack of understanding, collaboration, and cooperation across multiple government departments/agencies and stakeholders/consumers.

8. Recommendations

Development of a National Groundwater Management Board and Provincial Boards/Cells, as groundwater contributes more than 50% of irrigation and over 90% of drinking water in Punjab. Long-term policy framework development and extensive master planning to protect rapidly decreasing groundwater supplies. Implementation of the Canal and Drainage Act of 1873 and the Punjab Environmental Protection Act of 1997 (as amended in 2012), as well as compliance with the NEQS and other related rules and regulations. Special Regulations/legal Framework for Appropriate Groundwater Use in Rural and Urban Areas. Following points of recommendations [1].

- Industry effluents are the primary source of contamination. at the origin are a viable option for commercial pollutants. This may be accomplished by supplying them with reduced loans to build treatment plants while also implementing NEQS and applying fines.

- The most effective way to reduce the environmental impact of household wastewater is to treat it before discharge. Gravity settlement, oxidation lakes, and lagoons are examples of naturally occurring wastewater treatment systems that can be cost-efficient. This will not just enhance water cleanliness, but it will also allow cleansed water to be recycled for agriculture without compromising human health.
- Approximately 2000 cusecs of freshwater from the Marala Ravi (MR) LINK canal could be discharged into the river to increase water accessibility while not affecting water levels at the Baloki pumping stations. This will keep the dissolved oxygen content in the water at 4 to 5 mg/l, which is necessary for aquaculture viability.
- A lake or reservoir could be built along the river from Siphon to Thokar Niaz Baig, which would provide several benefits such as flood management, groundwater recharge, recreational site enhancement, aquaculture propagation, and land reclamation.

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