

**POLLUTION OF WATER BODIES: CHALLENGES
AND STRATEGIES**

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By:

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ABSTRACT

Water covers 70% of the earth's surface and only 2.5% is fresh water. Availability of clean and fresh water is essential for life. The water is used for drinking, irrigation and industrial purposes. Globally, the discharge of effluents in water bodies and improper water management practices contribute significantly in the water pollution problems. Human activities, especially unplanned urbanization and industrial development degrade the water quality in both industrialized and developing countries. The polluted water affects the human health, biodiversity and agricultural production. More than half of the world's major rivers are contaminated which are polluting the surrounding ecosystems, deteriorating the groundwater quality and risk for human health. About 2 million tonnes of domestic, agricultural and industrial effluents dispose off in water bodies daily. About 20% of the world population lack access to safe drinking water and it causes about 250 million cases of waterborne diseases annually, with death of 5 to 10 million people.

In Pakistan, water pollution is a major issue and water quality is not assessed regularly. The untreated effluents are indiscriminately discharged into the water bodies from industrial, municipal and agricultural sectors. The drinking water supply systems and sewer discharge systems are inefficient in most of the cities. The untreated effluents are directly discharged in the drains, from where they reach to rivers, canals or the sea and deteriorate water quality. About 20-40% patients suffer from water-borne diseases, that cause one third of all deaths.

The water quality problems can be solved by adopting pollution prevention strategies. There is a need to monitor and evaluate the water quality, strict enforcement of rules and regulations, use of effective technologies, installation of wastewater treatment plants, strengthening and capacity building of institutions and better water management practices. The linkage between research and development activities needs to be strengthened for pollution control of water bodies.

Key words: Water quality, industrial development, urbanization, water pollution, water borne diseases, effective technologies

1. INTRODUCTION

Water is an essential requirement for life which covers 70% of the earth's surface. About 97.5% water is seawater and only 2.5% is fresh water (Figure 1). Most of the fresh water is inaccessible in the polar icecaps, glaciers, atmosphere or soil while accessible fresh water in lakes, streams, rivers and groundwater accounts a small portion. It is an important resource for human consumption; ecological systems; agricultural and industrial purposes; and economic development [1].

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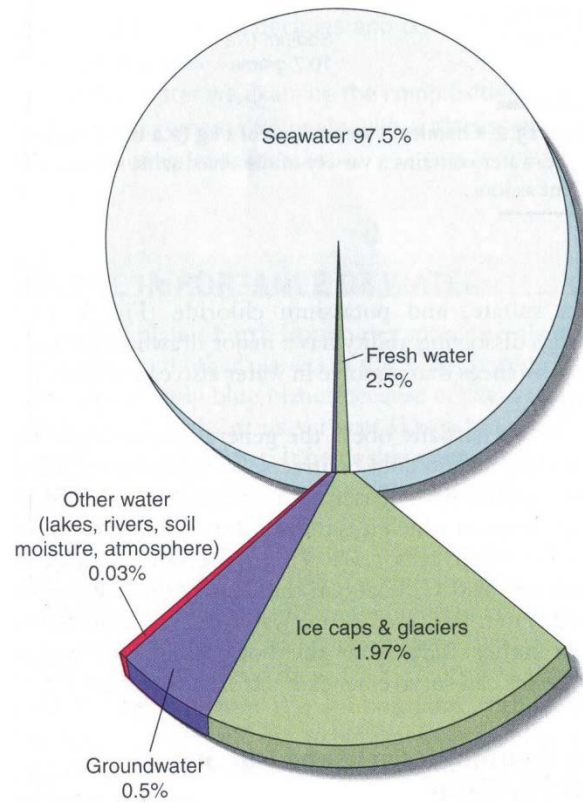


Figure 1: Global distribution of water

The water resources are unevenly distributed throughout the world and the water consumption practice varies among different countries (Figure 2). Those countries which face water shortage problem, the per capita water availability is limited as compared to those countries which possess abundant water resources.

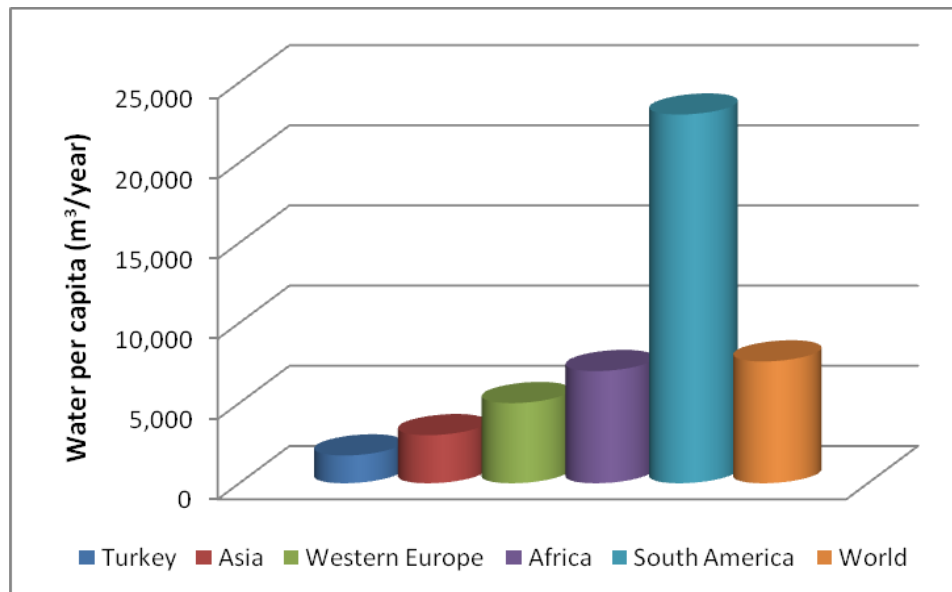


Figure 2: Average water consumption rates

Globally the largest water use sector is agriculture, where water is used for irrigation purpose. The total water consumption in different sectors is shown in the table 1 [2 &3].

Table 1: Sectoral Distribution of Water

Sector	Water Use (%)		
	World	Developed Countries	Developing Countries
Agriculture	67-70	39	52
Industry	22-23	46	38
Human Consumption	8-10	15	10

The availability of clean and freshwater is a basic necessity of life but human beings have long been dumping their wastes into the water bodies as the water is an excellent solvent and the waste material can be diluted and dispersed quickly. This self purification process was effective as long as human population density was less as compared to the available amount of water. The overexploitation and inadequate water management of water resources lead to the depletion of available water and deterioration of its quality [4].

2. WATER QUALITY

Water quality is the usefulness of water for required purposes and is affected by change in physical, chemical, and biological characteristics of water. The water quality standards vary with the required uses of water. The water quality is linked with its quantity and it can be assessed on the basis of different quality parameters. [5].

The water quality is affected due to rapid population growths, unplanned urbanization and industrialization which have raised the problem of water scarcity and water pollution [6]. Water pollution is one of the most serious environmental problems and it occurs when the water is contaminated from human and animal wastes, industrial effluents, toxic chemicals, heavy metals, metal scraps, oils etc. [7]. These pollutants enter into water bodies from natural and anthropogenic sources. The anthropogenic sources play a significant role in the deterioration of surface as well as groundwater resources. The water pollutants have no boundaries as their production at one location may affect water quality at other location located downstream [8]. The poor water quality affects the human health, environment and agricultural production [9].

2.1 Water Quality Situation in the World

The water uses and status of economic development in the country affects the water quality. Globally, the discharge of effluents in water bodies and improper water management practices contribute significantly in the water pollution problems. The water quality is deteriorated in both industrialized as well as developing countries. More than half of the world's major rivers are contaminated which are polluting the surrounding ecosystems, deteriorating the groundwater quality and a risk for human health [10]. About 2 million tons of domestic, agricultural, and industrial effluents discharge in the water bodies daily. About 1500 km³ wastewater is produced annually, which is six times more water than the water available in world's rivers. In the water bodies of US, about 1.2 trillion gallons of untreated sewage, stormwater and industrial effluents are discharged annually. About 40% of America's rivers are not fit for fishing, swimming, or aquatic life. The discharge of sewage and fertilizers has polluted about 30 % of Ireland's rivers [11 & 12].

The share of developing countries in water pollution is huge as they discharge about 70 % of the untreated industrial effluents in the water bodies [13]. The condition of Asian rivers is worse. They are the most polluted rivers in the world and contain three times as many bacteria from human waste as the global average and 20 times more lead than rivers in industrialized countries [11]. The water is severely polluted in South Asia particularly India and Southeast Asia. The world's most polluted rivers include: Yellow River in China, Ganges in India, and Amu and Syr Darya in Central Asia [10]. The situation of water pollution is worst in China as one third of the untreated industrial effluents and more than 90 % of untreated domestic sewage is discharged into water bodies [14]. About 70 % of the untreated effluent is disposed off in water bodies of India [15].

2.2 Water Quality Situation in Pakistan

Pakistan is blessed with adequate surface and groundwater resources. The water use in different sectors of Pakistan is shown in table 2 [16]:

Table 2: Water Use (%) in Different Sectors in Pakistan

Sector	Water Use (%)
Agriculture (Irrigation)	93
Industry	3
Domestic and Municipal	4

The water pollution levels have increased in Pakistan due to the discharge of untreated municipal and industrial effluents. Rapid urbanization and industrialization have resulted in increased pollution loads in the rivers and streams. The industrial units are established in and around the big cities which generate heavy pollution loads [17]. Consequently, the quality of both surface and groundwater is degrading. Groundwater is the main source of drinking water in Pakistan for more than 60% of the population. Due to over-abstraction of groundwater and high level of pollution, the quantity and quality of groundwater is degraded and the accessibility towards good quality groundwater for drinking purpose has become a serious problem, which results in:

- serious health hazards, as it causes water-related diseases;
- aquatic life at risk, due to the discharge of fresh water scarcity and discharging of toxic effluents; and
- decrease in agricultural yield due to water logging, salinity and chemical pollution [18 &19].

3. WATER QUALITY CHALLENGES

The unprecedented population growth, urbanization and industrialization, together with changes in production and consumption patterns, have placed stress on water resources. The world population is expanding by 80 million people annually, increasing the demand for freshwater by about 64 billion m³ annually. According to United Nations, the world population will exceed 9 billion people by 2050, which is an increase by nearly half of the 2000 population. The growth rate is highest in developing countries that already suffer from water stress. Growing populations, especially when concentrated in urban areas create more municipal and domestic effluent that reach to water bodies and cause water pollution. It is estimated that 42% of water used for domestic and municipal purposes is returned to the water cycle, which accounts for

11% of total wastewater. The relationship between population dynamics and water resources are shown in figure 3 [20 &21].

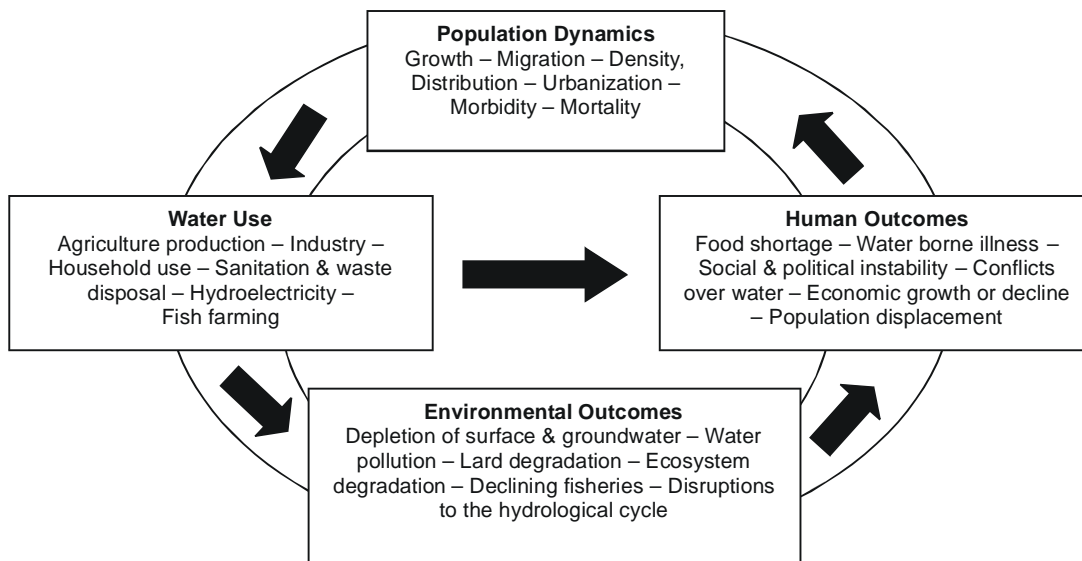


Figure 3: Water and population dynamics

The developed countries which have comparatively less population, mostly suffer from pollution problem because of their high economic levels, industrialization and mechanical lifestyle that consume more resources and energy. On the other side, the developing countries are overpopulated and municipal waste and sewage generation is high. Though these countries do not consume much resources and energy, but short finances and poor governance issue make a constraint on wastewater treatment, which is often, disposed off untreated and cause severe water pollution problem [22].

Worldwide water pollution is a leading cause of deaths and diseases, and it accounts for the deaths of more than 14,000 people daily. The harmful effects of contaminated water are not only devastating to people but also to flora and fauna. The contaminated water is unfit for drinking, recreational, agricultural and industrial purposes and it also impairs the aesthetic quality of water bodies. More seriously, it destroys the aquatic life by reducing its reproductive ability and is also hazardous for human health. Both the developing as well as industrialized countries are facing this problem of water pollution. [23 & 24]. Due to this incessant water pollution, about 20% of the world population lack access to safe drinking water and it causes about 250 million cases of waterborne diseases annually, with death of 5 to 10 million people [25, 11].

According to World Health Organization, annually 500 million diarrhea cases of less than five years are reported in children of Asia, Africa and Latin America. Commonly found water borne diseases include typhoid fever, bacillary dysentery, infectious hepatitis and other enteric infections. The cancer may be caused by consuming polluted water containing carcinogenic substances [26].

The water quality issues are facing many challenges due to population growth, availability of resources and governance issues and the water gets polluted from the following activities.

Agricultural activities

Globally, the agricultural activities contribute significantly in water pollution problem. The concern over the increases in fertilizer and pesticide runoff into water bodies has been rising since 1970s. Agricultural activities are a leading cause of phosphorus compounds and sediment. Nitrate is commonly found in the world's groundwater and surface water resources. According to UNEP study, nitrate concentrations have increased in the last decade in watersheds in the Americas, Europe, Australasia, and most significantly, in Africa and the eastern Mediterranean. The agricultural activities also caused salinization of surface water, eutrophication (excess nutrients), pesticides in runoff, and altered erosion and sedimentation patterns [21].

Industrial activities

Industrial activities are a major cause of water pollution. These activities withdraw about 20% of total global water and this water is discharged to its source in a deteriorated condition. Globally, the effluents from industrial facilities such as power plants, paper mills, pharmaceutical manufacturers, semiconductor fabrication plants, chemical plants, petroleum refineries, and bottling facilities and processes such as mining and drilling, all contribute to poor water quality. The effluents found in industrial effluents include:

- Microbiological contaminants such as bacteria, viruses, and protozoa;
- Chemicals from industrial activities such as solvents and organic and inorganic pesticides, polychlorinated biphenyls (PCBs), asbestos, and many more;
- Metals such as lead, mercury, zinc, copper, and many others;
- Nutrients such as phosphorus and nitrogen;
- Suspended matter including particulates and of pollution-prevention and water-treatment technologies used by industrial facilities.
- Temperature changes through the discharge of warm cooling-water effluent;
- Pharmaceuticals and personal care products.

Globally, the industrial activities are responsible for disposal of 300-400 million tons of heavy metals, solvents, toxic sludge, and other waste enters into water bodies annually. The industrial water pollution varies among different countries on the basis of amount of industrial activity in the country and the types of pollution-prevention and water-treatment technologies used by industries. The developed countries paid much attention towards the treatment of industrial effluents prior to its discharge into water bodies. While the developing countries are discharging 70% of the untreated industrial effluents into the water bodies. Still, the disposal of industrial effluent on a per-capita basis is high from developed countries as compared to developing countries. The polluted water alter the water quality characteristics, such as temperature, acidity, salinity, or turbidity of water bodies, leading to altered ecosystems and higher incidence of water-borne diseases. Worldwide, industrial water pollution is a leading cause of damage to ecosystems and human health [21].

Disposal of municipal wastes

The uncontrolled disposal of municipal waste contributes significantly in water pollution. The practice of raw sewage disposal into water bodies is common in developing countries, and even in less developed countries like China, India, and Iran which is a cause of fecal contamination. Even the developed countries discharge inadequately treated sewage into water bodies

Lack of adequate sanitation facilities contaminates water bodies in the world and is one of the most important forms of water pollution. Globally, 2.5 billion people lack access to sanitation facilities. Over 70% of these people, (1.8 billion people who lack sanitation facilities) live in Asia. The Asia's rivers contain 50 times more fecal coliform bacteria than the WHO guidelines. These pathogenic microbes enter into drinking water through inadequately treated water and are a leading cause of water pollution. Over 80% of the untreated sewage is discharged into water bodies of developing countries [21].

Major challenges in Pakistan

Water pollution is one of the major issues of Pakistan. Pakistan is one of the water stress country in the world and is fastly becoming water scarce. The increasing escalating population pressure, urbanization and unsustainable water consumption practices have placed immense stress on the quality as well as quantity of water resources in the Country. The population growth rate is high i.e. 80 million in 1980 and is projected to increase 230 million in 2025 (Figure 4).

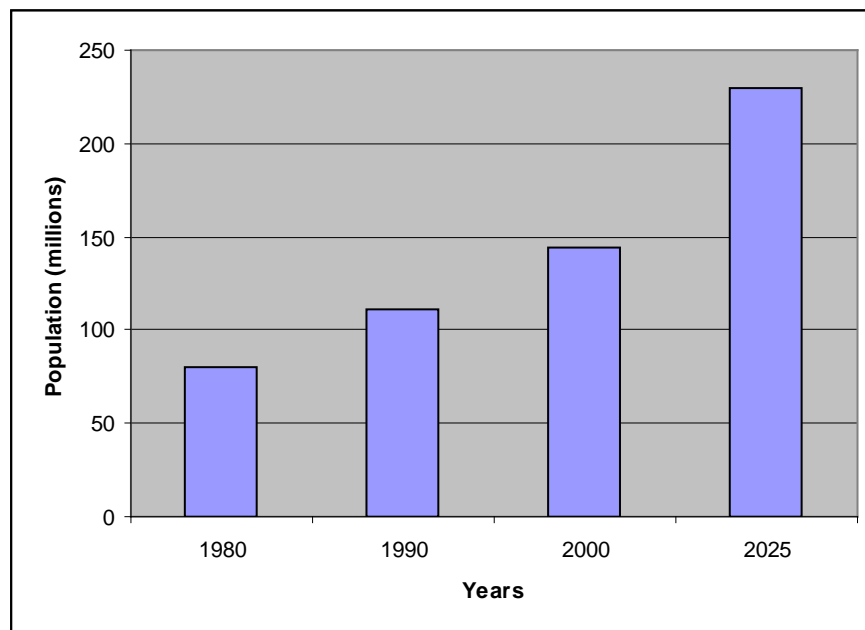


Figure 4: Population growth in Pakistan

Simultaneously, the urbanization is rapid, the percentage of population living in urban areas become double over the past twenty years. The absolute size of urban population has increased by a factor of 3.5 i.e. 20 million in 1980 to 70 million in 2000 (Figure 5).

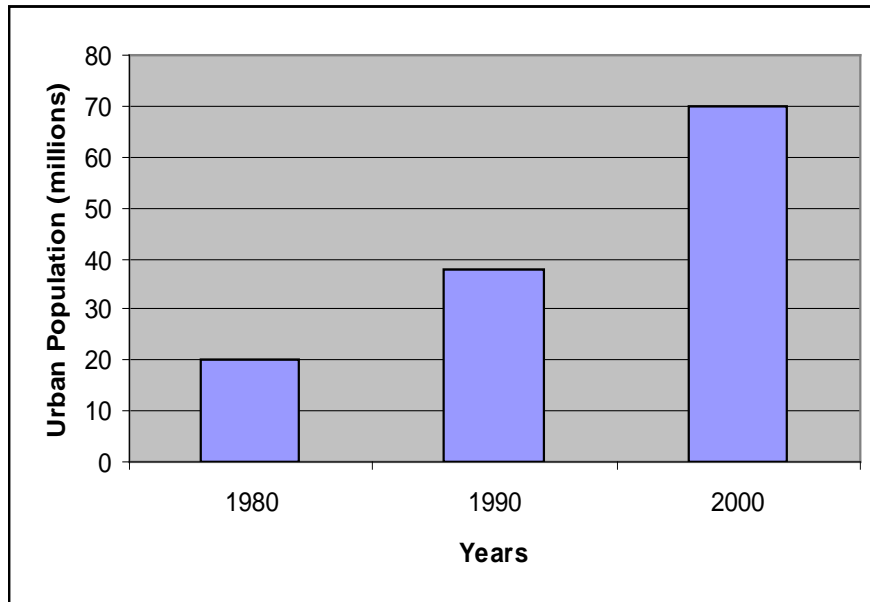


Figure 5: Urban population growth in Pakistan

The high population growth rate and urbanization reduce the per capita water availability which was 5300m^3 in 1951 and is projected to decrease and will be less than 659m^3 in 2025 (Figure 6) [27 &28].

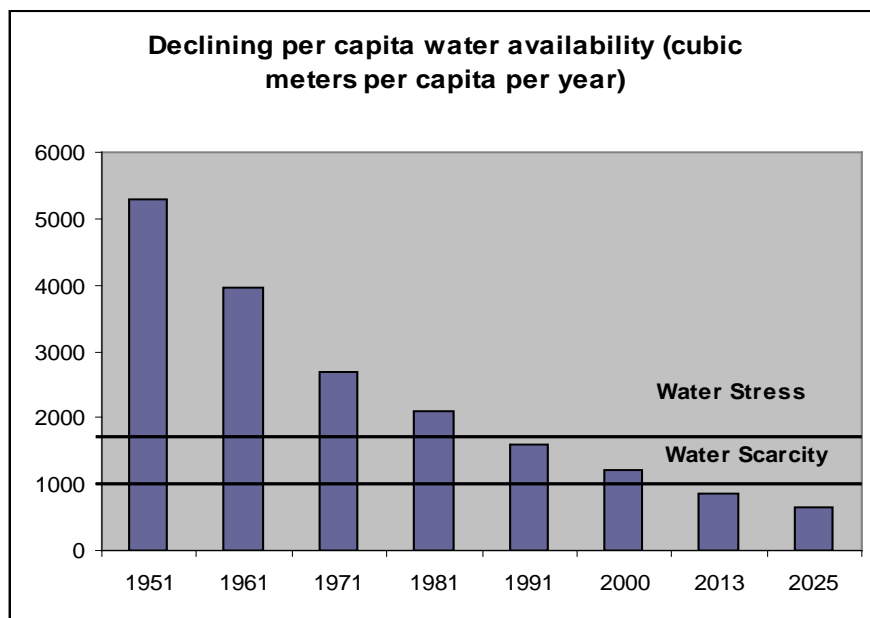


Figure 6: Per capita water availability in Pakistan

The over exploitation of water resources and discharge of untreated industrial and municipal toxic effluents has created multiple environmental, social and economical challenges. The polluted water has become a threat to various water usages including drinking, irrigation, and sustenance of aquatic life [29].

The water quality issues can be divided into following categories:

a. Technical Issues

Water scarcity

Water quality deterioration

Over extraction of groundwater

Pollution of water bodies

b. Institutional Issues

Poor system operation and maintenance (lack of funding and poor maintenance)

Poor governance

Lack of awareness

Lack of beneficiary's participation

Stakeholder's conflicts

c. Monitoring and Research Issues

Lack of monitoring and measurements

Low funding for research and monitoring

Weakening of knowledge base centers

Poor linkage between research and development [8]

The assessment of water quality is not carried out regularly. The water quality laws and regulations are present in Pakistan. Pakistan Environmental Protection Act 1997 focuses on the protection, conservation, rehabilitation and improvement of the environment, prevention and control of pollution, and promotion of sustainable development. The National Water Policy (Draft), National Environment Policy and National Environmental Quality Standards (NEQS) also exist in Pakistan, but the implementation of laws and regulations is weak [30].

The water supply and sewer discharge systems are inefficient in most of the cities. The untreated sewage directly discharges in the drains, from where it reaches to rivers, canals or the sea and deteriorates water quality [31]. This polluted surface water in turn contaminates the groundwater which is a main source of drinking water. It is estimated that about 90% of the population lack access to safe drinking water [32]. Pakistan ranks at number 80 among 122 nations regarding drinking water quality. The use of poor quality water has caused many health related problems in the Country. According to a study of UNICEF, about 20-40% patients suffer from water-borne diseases, which causes one third of all deaths [19]. About 25% adults and 40% children suffers from water borne diseases [33]. It has been reported by the World Bank that Pakistan is spending 1.8% GDP on water borne diseases [34].

The major sources of water contamination in Pakistan include:

- industrial effluents
- municipal effluents
- solid waste
- agricultural runoff

The untreated industrial effluents are discharged directly into rivers and streams as well as the Arabian Sea and are a principal source of water pollution. In Pakistan, only 1% of industrial effluent is treated before being discharged into water bodies. In Karachi, Sindh Industrial and Trading Estate (SITE) and Korangi Industrial and Trading Estate (KITE) are the biggest industrial estates of the Country, but there is no wastewater treatment plant, while in Lahore, out of hundred chemical manufacturing industries, only three industries are treating the effluents adequately. The discharge of effluent contaminates the water bodies through toxic substances, including heavy metals. The shallow groundwater pollution near industrial plants is common and once the groundwater is polluted, its remediation is a long term process as it may take hundreds or even thousands of years [35, 19].

The untreated sewage is directly discharged into nullahs and storm water drains from where it enters into rivers, canals and streams. It is found that there is the disposal of about 2,000 million gallons of sewage daily in the surface water bodies [19]. It is estimated that about 8% of the urban sewage is treated in municipal treatment plants. The contaminated water is not only hazardous for human health but also poses a threat to aquatic life and wildlife of Pakistan. There is very little separation of municipal effluent from industrial effluent and both directly disposed off in open drains which ultimately flow into nearby water body [27, 36].

About 48,000 tonnes of solid waste is produced daily in the Country and about 50% of the waste is disposed off in low-lying areas where the leachate generation is a main cause of groundwater pollution. The open dumping of solid waste also pollutes the surface water bodies and is breeding grounds for insects [37].

About 5.6 million tonnes of fertilizer and 70,000 tonnes of pesticides are used in the Country every year and their runoff is a main cause of pollution in the water bodies [19]. The pesticides and insecticides leached to the groundwater with the irrigation water and pollute the groundwater aquifers [38].

4. STRATEGIES/ THE WAY FORWARD

The water quality challenges need to be addressed in an integrated manner. The water quality problems can be solved through adopting pollution prevention strategies (Figure 6).

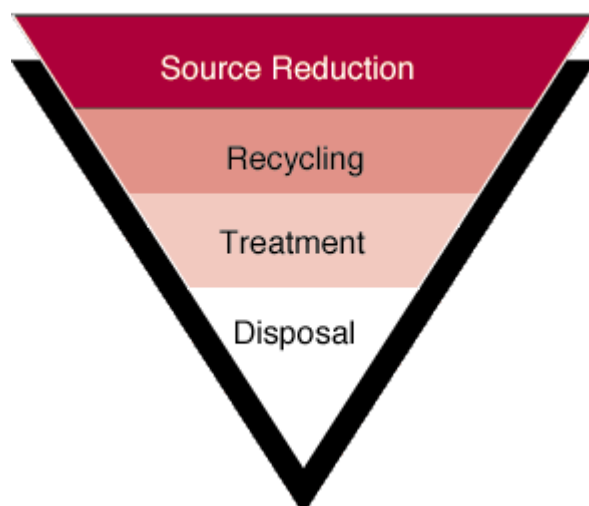


Figure 6: Pollution prevention hierarchy

The water pollution can be prevented by reducing or eliminating contaminants at the source which is the most effective way to protect water quality. The pollution prevention involves

reducing or eliminating the use of hazardous substances, pollutants, and contaminants; process modification techniques so they generate less waste; reducing leaks and fugitive releases; and reducing energy and water consumption. The prevention of pollution at source is a cost effective solution as less money is required on waste handling, storage, treatment, remediation, and regulatory monitoring. The industrial units can recycle the wastewater generated from one process into other process if it satisfies water quality standards.

There are effective technologies and approaches for the improvement of water quality and wastewater treatment. The industrial units and municipal institutions should be legally bound to set up treatment plants. The local technology should be used for establishing the treatment plant rather than importing the costly equipment. The increased investment on existing water-quality systems and research to improve the water treatment methods reduce the cost of treatment, and increase the reliability of existing methods.

The water-quality solutions include:

- The ongoing monitoring of water quality is required at government level on regular basis. For this purpose, capacity building of staff, fully equipped laboratories, recurrent budgets, latest technologies, data-sharing and management institutions should be provided.
- The development of new technologies and effective water quality monitoring is required. This may be useful for the successful deployment, maintenance, and operation of systems to collect, transport, and treat human wastes, used water, stormwater, industrial wastes and agricultural runoff.
- Strict enforcement of water quality rules and regulations need to be adopted in order to prevent the discharge of untreated effluents from the industries and municipalities.
- Improve and preserve the water quality at international, national, and local level. There is a need to reset global priorities, funding, and policies towards improving water quality.
- The industries are required to install wastewater treatment plants. The technologies need to be scaled up rapidly to deal with the tremendous amount of untreated wastes entering into water bodies daily; and water and wastewater utilities need financial, administrative, and technical assistance to implement these approaches.
- Appropriate solid waste management system should be in place to prevent the dumping of solid waste into the water bodies and leachate generation.
- Proper sanitary landfill sites should be constructed and the open dumping of human excreta and animal waste should be prohibited.
- A sustainable pollution control strategy needs to be devised in order to reduce the wastewater volumes. This approach may include the segregation of wastewater streams, process modification techniques and recycling and reuse of wastewater.
- Conduct epidemiological study in the areas close to contaminated water bodies in order to assess the affect of polluted water on health of the consumers.
- The global education and awareness campaigns about the importance of water-quality needs to be launched. Media and non-governmental organizations (NGOs) can play a vital role in this aspect.

- Integrated water resource management approach should be adopted by involving all stakeholders for the protection of water quality. The linkage between research and development needs to be strengthened.

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