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Review Article

Complexities of Water Pollution: A Review of Surface Water Contamination in Sri Lanka

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Abstract: Water is indispensable for sustaining life, food production, economic growth, and well-being. However, the growing population and industrialization have intensified the demand for freshwater, posing significant challenges to water resources in Sri Lanka. This review paper focuses on understanding the types and causes of water pollution, with a particular emphasis on surface water pollution, as well as exploring preventive measures in the context of Sri Lanka. Given its severe consequences and the global issue of water scarcity, water pollution has gained attention from researchers, scientists, and organizations. Surface water bodies, such as lakes and rivers, face pollution primarily due to inadequate management of sewage and industrial effluents. Insufficient sanitation facilities in low-income settlements further exacerbate the problem, affecting the country. Despite existing regulations, the lack of monitoring allows improper waste disposal practices to persist. Rural areas experience groundwater contamination from agrochemicals, while urban areas suffer from pollution caused by domestic sewage. Considering the limited resources, prioritizing pollution prevention proves to be a cost-effective approach. Effective control measures are required to address marine pollution, adversely impacting fisheries and tourism. Recognizing the interconnected nature of all types of water pollution is crucial, as they contribute to ecological degradation. To safeguard water resources, several measures must be implemented. These include improving sewage treatment systems, implementing better management practices for industrial effluents, prioritizing pollution prevention strategies, and strengthening monitoring mechanisms. Prioritizing water resource preservation will safeguard ecosystems, support sustainable development, and ensure well-being.

Keywords: Surface Water Pollution; Pollutants; Prevention Measures; Water Pollution

1. Introduction

The existence of Earth relies on three fundamental resources: water, air, and soil. Water is a vital natural resource, especially within the mentioned group. It serves as a critical resource for both ecosystems and human survival. Various industries heavily rely on the nation's surface water and groundwater resources. Included in this category are the industries of agriculture, hydropower generation, livestock production, industry, forestry, fishing, navigation, and recreation. [1]–[3].

Surface water, groundwater, and saltwater are the three most common types of water. Contamination from various sources is a serious problem, especially in developing countries where surface water is more readily available. However, groundwater is typically safer from pollution than surface water. However, due to the high costs of treating seawater, its use as a viable water resource is limited [4]. Both the availability and purity of drinking water are critical concerns for every country.

Specific water issues can vary from region to region and country to country. Due to high population growth rates, many developing countries are experiencing water

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pollution that exceeds the capacity of their resources to sustain traditional uses. Before the 19th-century industrial revolution, people coexisted harmoniously with their immediate environment without anticipating pollution becoming a significant problem. However, as industrialization and the global population increase, pollution has become a pressing issue [5]. With approximately 7 billion people now inhabiting the planet, it is evident that humans have exceeded certain boundaries; pollution is one indication of this.

The problem has been further exacerbated by rapid urbanization and industrialization, which have created significant point sources of pollution. As water consumption continues to rise, water quality faces severe challenges. The degradation and pollution of water bodies such as rivers and oceans, which are crucial for life, have been caused by industrialization, agricultural production, and urban life. These factors harm human health and sustainable social development [6]. Over the past few decades, the demand for freshwater has significantly increased due to population growth and accelerated industrialization [7].

Water pollution is when natural water sources become contaminated, rendering them unsuitable for various purposes such as drinking, cooking, cleaning, swimming, and other activities. Pollutants encompass many substances, such as chemicals, waste materials, microorganisms, and other agents. Different types of pollution eventually contaminate water sources. The deposition of atmospheric pollutants occurs in lakes and oceans, whereas land pollution has the potential to infiltrate subterranean streams and rivers, ultimately leading to their discharge into the sea. Consequently, the disposal of waste in a vacant area has the potential to pollute the water source. Water pollutants can be classified into several categories, including oil and derivatives, carbonic compounds, thermal variations, heavy metals, suspended particles, changes in algae and bacteria as a response to water pollutants, silts and sediments, and others [8]. It is important to note that pollution originates from various sources (Figure 1).

Water quality is being compromised on a global scale due to the presence of different forms of water pollution. Chemical pollution is a prevalent type due to its ability to infiltrate underground and surface water sources. Using pesticides and fungicides in agricultural practices substantially contributes to chemical contamination. The presence of metals and solvents originating from industrial sites also plays a significant role in this issue. As previously stated, agriculture is an important contributor to water pollution, specifically impacting groundwater and leading to groundwater pollution. Applying fertilizers and pesticides to crops has the potential to infiltrate the soil, contaminating subterranean rivers and aquifers. This contamination poses a significant risk to wells, boreholes, and other groundwater sources utilized for human consumption.

Microbiological pollution, a naturally occurring form of water contamination, represents an additional category within the broader spectrum of water pollution. Bacterial, protozoan, and viral pathogens have the potential to contaminate water sources, thereby contributing to the transmission of diseases such as bilharzia and cholera. Regions that do not possess adequate water treatment infrastructure are particularly susceptible to this form of contamination. Nutrient pollution arises when an overabundance of nutrients disrupts the intricate equilibrium of aquatic ecosystems. Nutrients play a crucial role in sustaining the growth and development of aquatic flora and fauna.

However, excessive concentrations of these nutrients can lead to algal blooms in marine environments such as rivers, lakes, and coastal areas. The proliferation of these floral formations results in the obstruction of solar radiation, thereby impeding the development of various organisms. In addition, the occurrence of algal blooms has the potential to exhaust oxygen resources, leading to the extinction of species that rely on oxygen and the proliferation of anaerobic organisms. Certain anaerobic microorganisms can generate noxious toxins, such as ammonia and sulfides, contributing to water quality deterioration and threatening various organisms, including humans, due to oxygen depletion.

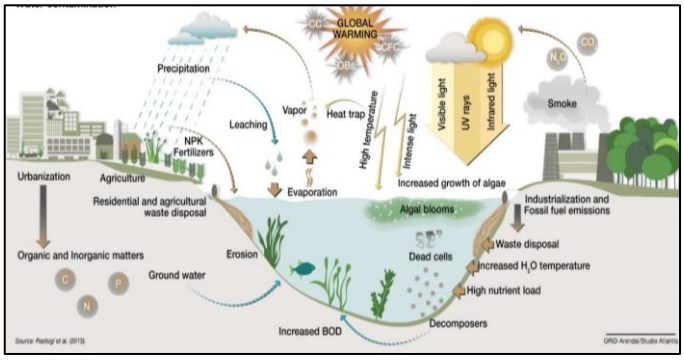

Figure 1. Process of Water Pollution [10].

Surface water pollution can arise through natural processes, unintentional incidents, or deliberate actions affecting all water bodies above the ground, such as rivers, lakes, seas, and oceans. Effective monitoring is paramount, especially in natural flood management, due to its potential to result in suboptimal water quality. Accidental oil spills and improper waste disposal by negligent industries contribute significantly to surface water pollution. The suspended matter is another factor influencing surface water pollution. Improperly discarded

materials like plastic and rubber can end up in water sources, persisting for extended periods. These materials float on the water's surface, impeding the penetration of oxygen and sunlight. They are resistant to dissolution and too large to effectively mix with water molecules.

Water pollution can harm all living organisms that rely on water, regardless of their type. The Environment President Science Committee stated in 1965 that the undesirable changes in water's chemical and physical properties could be harmful. Gupta et al. [9] further categorize water pollution into two primary forms: the alteration of the types and quantities of materials transported by water and the modification of the physical attributes of a water body. These forms of pollution pose significant threats to the ecological balance and the well-being of organisms dependent on water resources.

Furthermore, the legal definition of water pollution is provided as follows: "Such contamination of water, or alteration of its physical, chemical, or biological properties, or discharge of any sewage or trade effluent, or any other liquid, gaseous, or solid substance into the water, as may or is likely to create a nuisance or render such water harmful or injurious to public health or safety, or domestic, commercial, industrial, agricultural, or other legitimate uses, or the life and health of animals or aquatic organisms" [11]. Water pollution is excessive amounts of pollutants in water, rendering it unsuitable for drinking, bathing, cooking, and other purposes [12].

Surface and groundwater are the two most vital water resources in South Asia. The region's rivers, streams, creeks, lakes, and reservoirs hold significant surface water resources essential for our daily existence. Surface water is primarily utilized for irrigation, cooling thermoelectric power plant equipment, and supplying drinking water, among other benefits for the general public. The availability and quality of surface and groundwater profoundly impact the region's environment, economy, growth, and development [5].

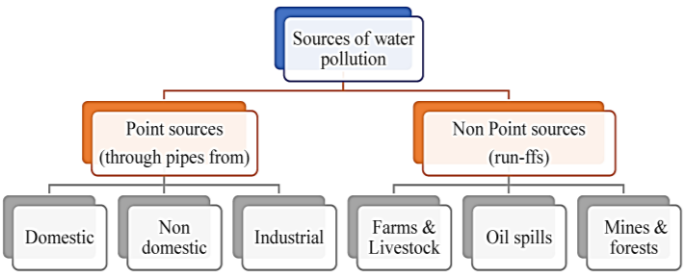

Figure 2. Sources of Water Pollution

Water pollution arises from two primary sources, namely point source (PS) and non-point source (NPS), as depicted in Figure 2 [13]. The term "point source" describes pollution originating from a singular source. Illustrative instances encompass a conduit affixed to a manufacturing facility, petroleum discharges from a vessel, and waste discharges from industrial establishments. Point sources of pollution contain wastewater effluent and storm sewer discharge, exerting their primary influence on the immediate vicinity. Non-point sources of pollution refer to the diverse origins and multiple pathways through which contaminants infiltrate groundwater or surface water, thereby entering the environment from unidentified sources. Instances include the discharge of water from agricultural fields and the disposal of waste in urban areas. At times, introducing pollutants into the environment at a specific location can have far-reaching consequences, impacting areas spanning hundreds or even thousands of miles [14].

2. Surface Water Pollution

2.1. World

Human activities have been the primary cause of a dramatic change in the hydrological cycle of rivers and lakes worldwide in recent decades. The global water budget, water quality, and available water resources have all been significantly impacted by this change [15]. Current estimates place the total water volume in the Earth's hydrosphere at around 1386 million cubic kilometers. Only 2.5% of this water is considered fresh because of its low salt levels. About 68.7 percent of the world's freshwater is found as ice and snow in the Antarctic, the Arctic, and high mountain regions. Groundwater recharged with fresh water accounts for 29.9 percent of the total water supply. Only 0.26 percent of the world's freshwater is stored in lakes, reservoirs, and river systems, but this tiny amount is enough to meet all of humanity's immediate needs and is essential for maintaining aquatic ecosystems [15].

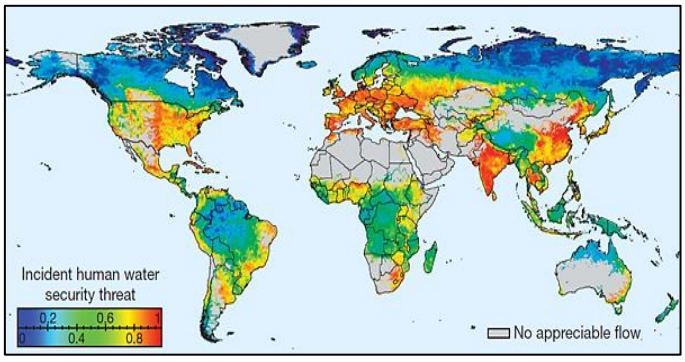

Figure 3. Human Water Security in the World [16].

The escalating pollution of freshwater systems with various industrial and naturally occurring chemical compounds poses a significant environmental challenge for humanity. Waterborne diseases contribute significantly

to illness and mortality worldwide, prompting governments to express concerns about the impact of contaminated drinking water [17], [18]. According to the United States Environmental Protection Agency (EPA), approximately 33% of the global water supply is contaminated [19]. This report emphasizes pollution as a significant contributor to the degradation of water's chemical, physical, and aesthetic properties [20].

According to the United Nations World Water Development Report (2015), a significant global issue persists, with approximately 1.1 billion individuals lacking access to safe drinking water. This problem predominantly affects continental Asia and Africa, where about 90% of the affected population resides [21]. Chapman (1996) defines pollution of the aquatic environment as the direct and indirect introduction by humans, and its effects include harm to living resources, hazards to human health, a hindrance to aquatic activities such as fishing, impairment of water quality for agricultural, industrial, and economic use, and reduction of amenities [22].

2.2. Sri Lanka

Approximately half of the water received from rainfall in Sri Lanka is lost through evapotranspiration. Only around 20% of the remaining water seeps into the ground, making a mere 30% available as inland waters. The country features a radial network of 103 river basins in the central hills, riverine marshes, 20 significant wetlands, irrigational and multipurpose reservoirs, and flooded paddy fields, amounting to approximately 1,570 km2 of inland waters. In most regions of the country, groundwater resources are sufficient.

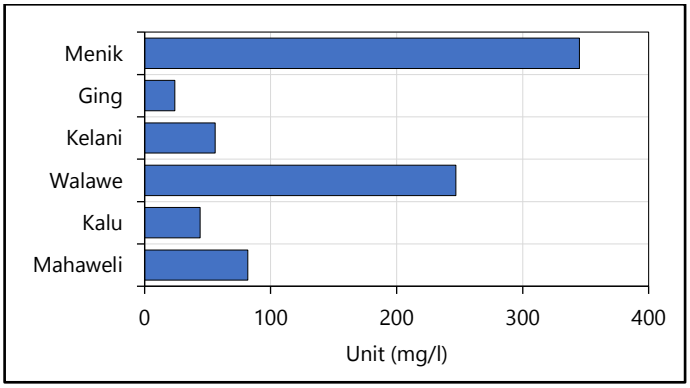

Figure 4. Total Residue (Total Suspended Solids) of 6 (Six) Rivers in Sri Lanka [23].

The government manages approximately 225 springs, with 120 of them located in the central highlands. Sri Lanka's maritime waters span an area of 489,000 km2. The surface waters are heavily utilized, and due to increasing demand, mean annual discharge rates are projected to decline. Sri Lanka's water supply is also diminishing, with long-term studies indicating a steady reduction in rainfall, particularly in the country's Central Province. Changes in land use are associated with alterations in water run-off rates and yields. The loss of forest cover and topsoil has significantly decreased the water absorption capacity.

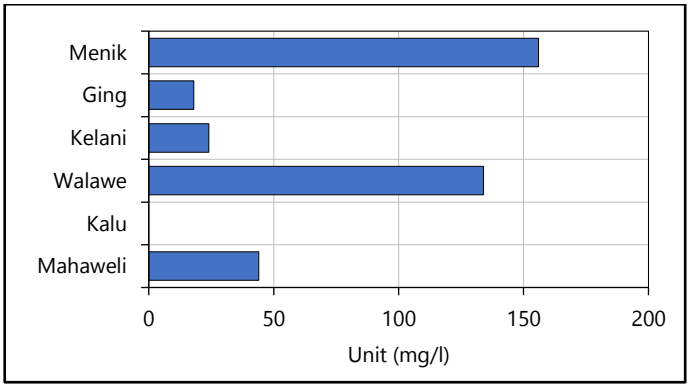

Figure 5. Total Hardness of 6 (Six) Rivers in Sri Lanka [23].

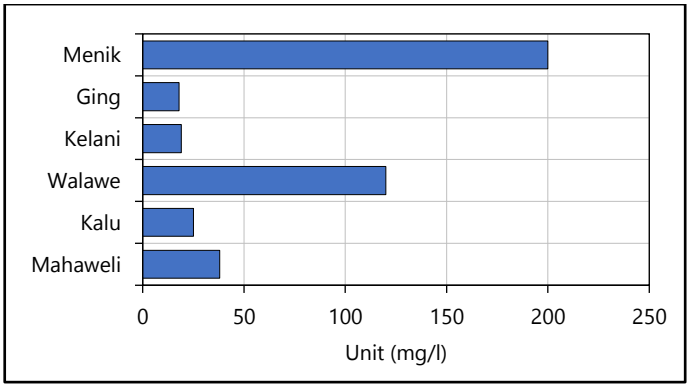

Figure 6. Total Alkalinity of 6 (Six) Rivers in Sri Lanka [23].

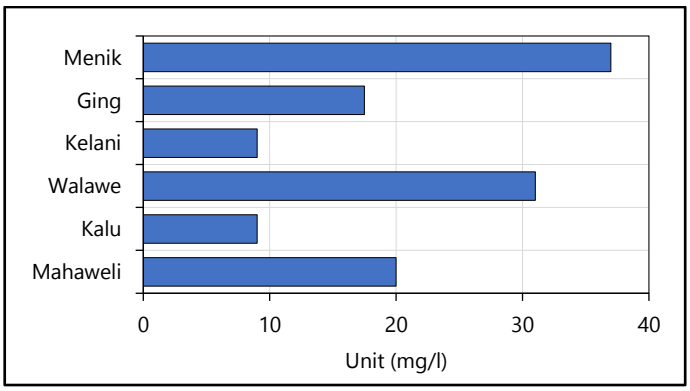

Figure 7. Total Chloride of 6 (Six) Rivers in Sri Lanka [23].

Furthermore, Sri Lanka faced severe droughts in 1982-1983, 1994-1995, and 2001, significantly impacting agricultural production and hydropower generation capacity. Over time, water pollution has increased in the country due to the growing number of industries that release substantial amounts of environmental contaminants, leading to the pollution of Sri Lanka's water

bodies. Addressing water pollution is crucial, as only 25% of households in Sri Lanka have access to clean water [24].

Some of the most polluted surface water bodies in Sri Lanka include Beira Lake, Bolgoda Lake, Boralesgamuwa Lake, Kesbewa Lake [25], Kandy Lake, River Kelani, River Manik Ganga, Mahaveli River, and Walawa River [23]. These water bodies suffer from heavy pollution, including outbreaks of algal blooms caused by eutrophication and frequent fluctuations in the chemical and physical qualities of the water (Figure 4 – 7).

In addition, the improper disposal of garbage poses a significant environmental challenge due to inadequate infrastructure. Toxic waste is often dumped into sewers, polluting the water bodies it enters. This contributes to various health problems and atmospheric pollution [26]. The unplanned growth of urban populations in developing countries like Sri Lanka puts pressure on water supply, sewage disposal, waste management, and surface drainage in cities and their surrounding areas [27], [28].

3. Causes of Surface Water Pollution in Sri Lanka

The river Kelani is a notable cause for concern among the various polluted water bodies in Sri Lanka. As per the Central Environmental Authority (CEA) findings, pollution in the area is predominantly attributed to the discharge of liquid waste from rapidly growing industries along the river, agricultural run-off, and domestic and municipal waste. Approximately 3,000 businesses along the river banks must possess an environmental pollution license. Water tests conducted by the CEA near industrial sites consistently show that critical safe water quality limits are exceeded. For example, the levels of chemical oxygen demand are 36-37% above acceptable standards, dissolved oxygen levels are 27-43% above good standards, biological oxygen demand is 7-13% above, and heavy metal concentrations are 7% higher than allowed. The hazardous impact of industrial waste on the environment was highlighted in August 2015 when a significant diesel leak from a multinational carbonated drinks manufacturer occurred, affecting the river.

Improper sewage disposal is another major contributor to water pollution in Sri Lanka. Colombo, the central city, has a functional sewage system, with 80% of the municipal population connected to it in 1994 (National Water Supply and Drainage Board, 1994). However, the collection system only collects and discharges untreated sewage into the sea through 1.5 km ocean outfalls from the city. Outside of Colombo, small sewage systems serve a few housing schemes and industrial estates, while individual households in suburban and rural areas rely on septic tanks. In most low-income settlements near streams and canals, sewage is discharged directly into surface water bodies or drainage canals.

Improper discharge of industrial effluents is another significant source of water pollution in Sri Lanka. The country has 80 categories and 300 polluting industries (Ministry of Forestry and Environment, 1998). Many industries release liquid effluents into water bodies with little or no treatment. However, there are exceptions, such as industries in the Biyagama and Katunayake export processing zones, which have central treatment systems and a few medium and large operations that can afford treatment facilities. An issue of concern is the concentration of industries in densely populated suburbs, such as the Ratmalana-Moratuwa area, with over 225 industries, and the Ekala-Jaela area, with approximately 140 enterprises, which have severely degraded water bodies [29]. The deterioration of water quality in the Lunawa Lagoon and Bolgoda Lake in the Ratmalana-Moratuwa area, which threatens fisheries, is particularly significant. It is worth noting that Beira Lake is located in the heart of Colombo's municipal area, Kandy Lake is situated in the center of Kandy city, and Bolgoda Lake and the Labugama reservoir, which supply water to Colombo, are found in the suburbs of the Colombo district. Generating and disposing of hazardous waste is another primary concern in Sri Lanka, contributing to environmental challenges.

4. Prevention of Water Pollution in Sri Lanka

The government of Sri Lanka has implemented multiple measures to address issues related to water resources effectively. The country has approximately 50 legislative measures focused explicitly on water-related matters, and there are 20 government entities responsible for overseeing and managing water resources. However, there has been a notable lack of coordination among these agencies. The National Water Supply and Drainage Board (NWSDB) monitors drinking water quality. The National Standards Institution establishes standards to ensure drinking water quality and water extracted for public supplies.

The Central Environmental Authority (CEA) is primarily responsible for mitigating water body contamination caused by industrial effluents. The CEA achieves this by formulating pollution control guidelines, establishing pollution control standards, implementing monitoring activities, and issuing Environmental Protection Licenses (EPL) to industries contributing to pollution. In 1993, regulations concerning Environmental Impact Assessment (EIA) were implemented. These regulations classify

industries based on pollution levels and determine the required permits.

Additionally, in 1994, a program was launched to introduce cleaner technologies to local industries, which continues to this day. A National Industrial Pollution Management Policy was enacted in 1996, focusing on pollution prevention at the source and clustering industrial units in designated estates. Regulations for hazardous waste management were published in the Gazette on May 23, 1996. The government is also promoting an industrial estate management strategy to facilitate the location of new industries (Ministry of Forestry and Environment, 1998). To address pollution caused by agrochemical use, the government has encouraged organic farming and integrated pest management while restricting the import of agrochemicals. However, there has been a lack of effective regulation regarding the use of agrochemicals, particularly pesticides.

5. Conclusion

In conclusion, this review paper provides a concise overview of water pollution, focusing on surface water pollution and the current state of surface pollution in Sri Lanka. The article highlights that many surface water bodies in the country, particularly urban lakes and downstream sections of rivers, suffer from severe pollution. Inadequate sewage collection and treatment systems and poor management of industrial effluents are the primary contributors to this pollution. The lack of proper sanitary facilities in low-income settlements is a significant concern affecting these areas' residents and has broader implications for the entire country.

Although new regulations such as Environmental Impact Assessment (EIA) and Environmental Protection Licenses (EPL) have been introduced to manage industrial effluents, insufficient monitoring practices have led to the continuation of unacceptable waste disposal methods. Groundwater resources in Sri Lanka also face challenges, including overuse and contamination by agrochemicals in rural areas and sewage in urban areas. Given the country's financial constraints, pollution prevention is the most cost-effective approach to safeguarding groundwater quality. Implementing a comprehensive management strategy and establishing proper monitoring mechanisms for groundwater extraction is crucial.

Furthermore, marine pollution significantly threatens Sri Lanka's fisheries and tourism industries. Effective measures must be taken to control and mitigate marine pollution. It is essential to recognize that all forms of water pollution—surface water, groundwater, and marine pollution—are interconnected and contribute to extensive ecological degradation.

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