Journal of Geography, Environment and Earth Science International

Volume 28, Issue 1, Page 38-49, 2024; Article no.JGEESI.111906
ISSN: 2454-7352

Water Contamination and Its Effects on Human Health: A Review

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JGEESI/2024/v28i1743

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/111906

Review Article

Received: 06/11/2023
Accepted: 10/01/2024
Published: 15/01/2024

ABSTRACT

The study was done on the effect of water contamination on human health. The review revealed a complex network of factors contributing to water contamination, including home sewage, industrial discharges, pesticides, plastics, and systemic management deficiencies. The study highlighted the widespread effects on human health, including skin disorders, serious illnesses like cancer and diarrheal infections, particularly affecting children. It emphasized the need for synchronized efforts to alleviate pollution sources, focusing on sustainable farming methodologies and responsible waste management. The study also explored advanced wastewater treatment techniques, highlighting the urgent need for their widespread use worldwide. However, the study acknowledged limitations, such as geographical scope and contamination origins. Recommendations included a comprehensive strategy involving sustainable behaviors, strict laws, and advanced treatment technology. The study emphasized the need for governments, companies, and communities to work together to implement strong legislation, improve infrastructure, and increase knowledge about water quality. Addressing these challenges requires a holistic approach, focusing on mitigating constraints through ongoing research, innovation, and international collaboration.

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Keywords: Water pollution; source; effects; treatment; human health.

1. INTRODUCTION

Pollution of waters is the introduction of undesirable substances into water, resulting in a deterioration of water quality [1]. The issue of water pollution caused by drinking water has emerged recently due to the rapid population expansion, urbanization, and industrialization that have occurred during the 1990s. This has led to increased levels of stress on the environment [2]. Detrimental to both the environment and human well-being [3]. Water is a vital natural resource that is utilized for drinking and many developmental activities in our daily life [4]. Water sourced from alternative natural reservoirs has the attribute of a consistent quantity inside the Earth, and is replenished within a defined timeframe as a result of the water cycle [5].

As a result of fast industrialization and urbanization, coupled with a lack of knowledge regarding the importance of water as a vital resource, approximately 80% of the global population is currently experiencing issues pertaining to water supply and security [6]. Despite the vast amount of water on planet Earth, only around 2% of it is suitable for use, while the remaining 98% consists of seawater that is unfit for drinking owing to its high salt content [7]. Out of the total amount of fresh water, only 0.036% is available for usage, while the remaining 1.96% is found in polar ice caps, subterranean wells, and aquifers. In addition, the availability of freshwater resources is increasingly diminishing as a result of significant contamination in drinking water sources caused by the negligence of human, manufacturing and authorities in government [8].

The water supply systems are being contaminated by emergent pollutants such as pesticides, synthetic fertilizers, chemical compounds like dyes, heavy metals, hormones, personal care products, detergents, and pharmaceuticals. These pollutants can enter the aquatic system and ultimately have an impact on human health [9]. In addition, waterborne pathogenic microorganisms are introduced into the water system through research laboratories, hospitals, untreated sewage, septic tanks, tanneries, food processing facilities, and meat packing enterprises [10]. Additional natural phenomena that exert a significant influence on the purity of water include floods, storms, eruptions of volcanoes, quakes and other similar events [8].

Water contamination is caused by the discharge of household and industrial effluent wastes, leakage from water tanks, marine dumping, and atmospheric deposition [11]. Some of the most significant pollutants that endanger human health have been identified by the World Health Organization. These pollutants include heavy metals, organic compounds, microbial pathogens, and lead and arsenic [12]. Furthermore, the occurrence of medicines and personal care items in water has emerged as a growing worry in recent times, given that these substances possess the capacity to have adverse health impacts on both people and animals [13]. Water pollution may result in a wide range of health issues [14], including immediate ailments like diarrhea and cholera, as well as long-term conditions such as cancer and developmental difficulties. Exposure to water pollution may result in skin irritations, as well as harm to the liver, kidneys, and neurological system. Water contamination poses a heightened risk to the health of young children and pregnant women.

2. FACTORS CONTRIBUTING TO WATER POLLUTION

2.1 Domestic Sewage and Industrialization

Approximately 75 to 80% of water contamination, in terms of volume, is attributed to residential sewage. The remaining substance is industrial effluent, which may possess a higher level of toxicity. Industries such as distilleries, sugar production, textile manufacturing, electroplating, pesticide production, pharmaceuticals, pulp and paper mills, tanneries, dye and dye intermediate production, petrochemicals, and steel factories are the main contributors to water pollution. Nonpoint pollution sources, such as the runoff of fertilizers and pesticides from agricultural fields in rural regions, are increasingly becoming a significant cause for worry. Only 60% of chemical fertilizers are effectively absorbed by soils, while the remaining amount is washed away and contaminates the groundwater through leaching. The discharge of excessive amounts of phosphate is causing eutrophication in lakes and bodies of water [15]. The release of hazardous substances from industrial activities is the primary source of contamination in both surface water and groundwater, making industries the biggest contributor to water pollution. Industrial production can result in the emission of a wide range of harmful compounds, including both organic and inorganic molecules, as well as toxic solvents and volatile organic chemicals. Insufficiently treated discharge of these wastes into aquatic habitats will result in water pollution [16].

2.2 Population Growth

Waste in the form of solids and liquids is released into rivers. Water is also polluted by human waste; Contaminated water harbours a significant quantity of germs that pose a threat to human health. The government is unable to meet the necessary requirements of its residents due to the growing population. Sanitation infrastructure is more abundant in metropolitan regions than to rural locations. Polythene bags and plastic garbage are significant contributors to pollution. Waste is disposed of by placing it inside plastic bags [17]. Approximately three-quarters of the urban population engage in open defecation. 77% of the population use flush latrines, whereas 8% rely on pit latrines. Urbanization can contribute to the proliferation ofseveral infectious illnesses. Urban regions have significant health challenges such as overcrowding, unsanitary environments, and dangerous drinking water, One-fourth of the urban population is susceptible to sickness [18]. The growing population is causing several problems, including its detrimental impact on water pollution [16]. Rising Results pertaining to the population in a corresponding rise in the output of solid waste [19].

2.3 Pesticides and Fertilizers

Nutrient transmission occurs in abundance into stationary surface water reservoirs via rainfall. The application related to Chemical fertilizers and insecticides leads to eutrophication in bodies of water. This results in excessive development consisting of algae and other plants that live in water, which deplete the available dissolved oxygen necessary for aquatic life. Consequently, the water becomes less suitable for activities such as fishing, enjoyment, and industrial use. The percolation of water contaminated with fertilizer can lead to groundwater contamination due to the mixing of various chemicals, which eventually has adverse effects on the condition of living things upon consumption [20].

According to reports, in order to provide food for a population of 6127.7 million in the year 2000, the usage of nitrogen (N), phosphorus (P), and potassium (K) - the main components of inorganic fertilizers - was 64.9, 25.9, and 18.2 kg per hectare, respectively. These figures increased to 85.8, 33.2, and 20.4 kg per hectare, respectively, in the year 2014, when the global population reached 7243.8 million [21]. Moreover, the combined use of nitrogen, phosphorus, and potassium nutrients in fertilizers was expected to be 170.7 million tons in 2010 and 175.7 million tons in 2011. The global dependence on fertilizers for food production may be comprehended by considering the projected rise in the consumption of N, P, and K fertilizers. It is anticipated that by 2050, the consumption levels of these fertilizers would grow by 172%, 175%, and 150% correspondingly, compared to the present levels.

Pesticide-laden chemicals are directly contaminating water and compromising its quality. If pesticides are present in excessive amounts or not properly controlled, they pose a significant threat to the agricultural ecology [22].

A pesticide is defined as any substance, whether used alone or in combination, that has the ability to eliminate pests or weeds. Pesticides are classified based on the specific pests or weeds they target [23].

2.4 Weak Management System and Pathogenic Microorganisms

Issues in underdeveloped countries, sanitation, hygiene, and waterborne diseases are major concerns. In industrialized nation, sanitation-related water supply infrastructure is already established and maintained. Regrettably, in developing nations, there is a significant flow of untreated sewage into water bodies. Therefore, it is imperative to enhance basic sanitation infrastructure and treatment methods. Additionally, ensuring access to safe drinking water is of utmost importance. Approximately 67% of the population in developing nations is projected to lack access to adequate sewage systems by 2030 [10].

According to the World Bank, over 10,000 individuals die daily due to illnesses associated with water, sanitation, while over 10,000 others endure severe conditions. Approximately 30% of the global population does not have access to potable water, while over 40% lack basic amenities like handwashing facilities with soap and water. Due to factors such as poverty, inequality, mishandling of public money, and a lack of financing, over 673 million people still use open-pit latrines. The 2015 sustainable development goals (SDG) for 2030 have been granted endorsement by the United Nations general assembly for the 2015 millennium development goals (MDGs) pertaining to pure water and hygienic sanitation [24,25].

Furthermore, since pathogenic microbes like E. Coli and cryptosporidiosis are spread via warm water sources and air conditioning systems in homes, buildings, and hospitals, they often cause outbreaks of sickness in developed countries. The discharge of raw sewage into the water supply system or other natural water bodies is now thought to be the cause of the link between health problems with wastewater and drinking water sources [26].

3. IMPACT OF WATER POLLUTION ON HUMAN HEALTH

The use of polluted drinking water, poor sanitation, and hand hygiene all contribute to the yearly deaths of almost 829,000 people from diarrhea, according to the UNESCO 2021 World Water Development Report. polluted water has serious negative effects on human health. Remarkably, this comprises over 300,000 children under the age of five, making up 5.3 percent of all deaths in this age group. The absence of water and sanitation services also amplifies the prevalence of illnesses such as cholera, trachoma, schistosomiasis, and helminthiasis. Polluted water poses several health risks, including respiratory disease, cancer, diarrheal disease, neurological dysfunction, and cardiovascular disease [27]. Furthermore, excessive precipitation and floods are correlated with severe climatic conditions, leading to the emergence of many illnesses in both developed and developing nations [28]. Evidence from research conducted in poor nations demonstrates a distinct correlation between cholera and water that has been polluted [29].

3.1 Effect of Water Pollution on Skin

Contrary to conventional wisdom, which suggests that swimming is beneficial for health, research conducted as early as the 1950s discovered that the prevalence of diseases among those who swim was notably greater than that among those who do not swim. Swimmers can get skin disorders due to a range of disease-causing bacteria [30]. Research has furthermore indicated that those who engage in swimming activities are more than three times more likely than non-swimmers to report skin conditions. Swimming enthusiasts may have a "risk perception bias" because they are more likely to recognize and report skin conditions since they are often aware of the possible health effects of exposure to these conditions. Swimmers may have perhaps overstated their symptoms, describing diseases that someone else would not see as genuine skin ailments [31].

3.2 Cancer and Water Pollution

Based on WHO estimates, the global incidence of cancer in 2020 amounted to 19.3 million cases, with a corresponding rise in cancer-related mortality to 10 million fatalities. Presently, 20% of the whole worldwide population afflicted with fevers will eventually get cancer in the course of their lives. Furthermore, due to the time-lag phenomena, various geographic locations are affected differently by pollution of the water in a watershed in terms of cancer risk. The mortality rate of esophageal cancer resulting from water pollution is much elevated in downstream areas compared to other regions, mostly due to the enduring effects of past water pollution [32]. Nitrates are a wide-ranging pollutant that is strongly linked to the development of human malignancies, particularly colorectal cancer. The carcinogenicity of nitrates is influenced by their concentration. The danger escalates substantially when the concentration of the Drinking water concentration is more than 3.87 mg/L, significantly less than the current 50 mg/L drinking water limit. Drinking water with nitrate levels that are within the recommended standards for consumption. Drinking water also heightens the likelihood of developing colorectal cancer [33].

Arsenic, nitrate, chromium, and other similar substances are strongly correlated with the development of cancer when considering water sources. Ingesting arsenic by drinking water may result in the development of skin cancer, as well as kidney and bladder cancer. Moreover, the correlation between increased levels of arsenic in drinking water and the occurrence of liver cancer has been shown. However, When the exposure levels are less than 0.64 mg/L, this association is not regarded as significant [34]. Consuming water that contains elevated levels of chromium can lead to increased carcinogenicity because to the presence of hexavalent chromium in people. The investigations on drinking water consumption of hexavalent chromium have demonstrated that this substance has the capacity to induce respiratory cancer in humans [35].

3.3 Diarrhea and Water Pollution

Untreated drinking water and fecal contamination are the primary factors contributing to diarrhea, Cholera is one of the common illnesses that affect children. Each year, diarrheal diseases like cholera kill 1.8 million people, with 90% of the victims being young children. The majority of this burden is placed on poorer countries, where 88% of diarrheal infections are caused by poor sanitation, hygiene, and access to water [36].

Cryptosporidiosis is a global parasitic infection caused by the organism Cryptosporidium partum. It manifests as symptoms such as diarrhea, lose or watery stools, abdominal cramps, and gastrointestinal discomfort. Cryptosporidium is highly resilient to disinfection methods and has a detrimental impact on the immune system, leading to diarrhea and vomiting in humans [37].

3.4 Child Health and Water Pollution

Water contamination is a major contributor to the prevalence of pediatric illnesses. In 2016the cumulative consequences of the global mortality of children due to soil, water, and air pollution amounted to 940,000. Children under the age of five made up around two thirds of these deaths, and the majority happened in nations with low to moderate incomes [38]. In less developed countries, baby and child death rates are directly correlated with the level of industrial organic water pollution. Industrial water pollution has a significant role in causing the death of infants and children in these countries [39]. Exposure to high levels of nitrates in drinking water can lead to the development of goiter in youngsters [40].

4. METHODS FOR TREATING AND REUSING WASTEWATER

The global focus on technologies for clean water and clean energy has been driven by concerns over water shortages, resource depletion, and global warming [41]. Water treatment technologies serve three main purposes: Minimizing water use, purifying wastewater, and engaging in recycling. The treatment and reuse of wastewater pose a significant problem, prompting scientists to aggressively seek cost-effective and appropriate technologies. Her are three steps for treatment of waste water.

4.1 Basic Water Purification Methodologies

Water in this category undergoes initial treatment by processes such as sedimentation and gravity, coagulation, flotation, screening, filtering, and centrifugation. Sedimentation and gravity separation are processes that involve the settling of particles based on their weight and density. During this procedure, the suspended particles, grit, and silt are eliminated by letting water to remain undisturbed or somewhat disturbed for varying durations in different types of tanks. The suspended solids settle due to the force of gravity [42]. Occasionally, the solid particles that are suspended in a liquid may not separate and sink using the sedimentation and gravity technique. In such cases, non-settable solids can be made to settle by introducing certain chemicals. This procedure is known as coagulation. Flotation is the process of separating particles from a liquid by making them float on the surface. The process of flotation, which includes binding other chemicals, biological materials, oils, greases, and suspended particles to air or gas, is a typical and crucial part of an ordinary purification facility [43].

Screening, filtering, and centrifugal separation are methods used to separate substances based on their size or density. The primary purpose of screening is to eliminate solid debris found in wastewater, including fabric, paper, wood, cork, hair, fiber, kitchen garbage, and fecal solids. Screening is often employed as the initial stage in the process of treating wastewater. For this, a variety of screens are used; The screen size is chosen. according to a particular need, namely the size of the solid particles presents in the wastewater [44].

During the filtering process, water is directed through a material that has small openings or pores. Typically, for this purpose, a design with pore diameters between 0.1 and 0.5 μm is used. It is used to remove bacteria, oils, greases, and suspended particles, among other things. Filters of several kinds, including membranes and cartridges, may be used. Filtration can decrease oil content of 25 mg l−1 by up to 99% and efficiently remove particles smaller than 100 mg. Purification of the water is the goal of the filtering process. The water recovered from the filtering process is used in membrane separation, ion exchange, and adsorption processes. Furthermore, filtration equipment is used to produce drinkable water. A million liters of clean water may be obtained for between $25 and $450 using filtering [44].

The removal of precipitated non-colloidal particles up to 1 μm in size are accomplished via centrifugal separation. Solid particles (sludge) are separated and removed from wastewater by introducing it into centrifugal machines and rotating it at different speeds. The densities of suspended particles directly correlate with the degree of separation between them. Furthermore, the removal of suspended contaminants is also attributed to the centrifugal machine's velocity. Uses include cutting down on and separating oils and greases at the source. Solid-bowl, basket-type, counterblow, and countercurrent flow centrifugal machines are among the several types now in use [44].

4.2 Advanced Methods for Treating Water After First Treatment

Secondary water treatment involves the use of aerobic processes and bacteria to eliminate soluble and insoluble contaminants. Aerobic breakdown of biodegradable organic matter in wastewater occurs when air or oxygen is readily dissolved and present, facilitated by aerobic and facultative bacteria [45]. A high concentration of microorganisms is maintained in a reactor by the circulation of water, the organic material is converted by the microorganisms, which are mostly bacterial and fungal species, into water, CO_2, and NH3 gas [46,47]. A biological activity that takes place in the absence of oxygen is referred to be anaerobic. Anaerobic degradation, or putrefaction, occurs when there is no free dissolved oxygen in the wastewater. Simpler organic compounds, such as nitrogen, carbon, and Sulphur, are produced via the metabolism of complex organic materials by facultative and anaerobic bacteria. N_2, NH_3, provided hydrogen, and methane are the major gases created during this process. Wastewater is treated using this technology to lessen its biological load [45,48].

4.3 Advanced Water Treatment Methods at the Tertiary Level

Tertiary water treatment technologies play a crucial role in wastewater treatment strategies by ensuring the production of clean water suitable for human use. The methods employed for this objective include: adsorption, ultra-filtration (UF), precipitation, electro dialysis, oxidation, and reverse osmosis (RO), advanced oxidation process, electrolysis, ion exchange, distillation, crystallization, solvent extraction, evaporation.

Adsorption: Optimization of water treatment by adsorption technology is influenced by several aspects, including the characteristics of the adsorbent and ad sorbates, contact duration, adsorb ate concentration, pH level, adsorbent dosage, particle size, temperature, and the presence of additional contaminants, In this technological process, equilibrium is achieved when an adsorbent substance makes contact with the contaminated water, resulting in a consistent level of adsorption of contaminants, The adsorption isotherm refers to the link between the equilibrium adsorbed quantity of a pollutant on an adsorbent and the temperature at which it is measured" [49].

Ultra-filtration (UF): Ultrafiltration is necessary to eliminate particles. It has become more prevalent in water treatment due to its exceptional efficacy in removing particles and microorganisms [50].

Precipitation: Dissolved pollutants in precipitation are transformed into solid precipitates by decreasing their solubility, allowing for easy removal of the precipitates from the water's surface [51].

Electro dialysis: Electro dialysis has been employed to lower water source concentration, achieving a maximum reduction of 90% for total dissolved solids (TDS) with a concentration of up to 200 mg/l. Membrane fouling, similar to that observed in reverse osmosis, was addressed by incorporating carbon nanotubes into the composite membranes to improve flow [52].

The term "**oxidation**" describes a chemical process when a material increases in its oxidation state by losing electrons. Aldehydes, ketones, carboxylic acids, alcohols, and other byproducts may be produced via chemical oxidation, which converts organic molecules into carbon dioxide and water. The products may be chemically oxidized using Fenton's reagent, potassium permanganate, chlorine, ozone, and H2O2. They are also easily biodegradable (H_2O_2 and Fe catalyst) and chlorine dioxides [53].

Reverse osmosis is a process that involves the movement of water molecules across a semipermeable membrane in the opposite direction of natural osmosis, resulting in the separation of solutes from Reverse osmosis (RO) is increasingly being recognized and adopted globally for water treatment, The process is powered by pressure and involves the use of a semi-permeable membrane to remove dissolved substances from the feed water, The rejection is a result of the exclusion of particles based on their size, charge, and the physical-chemical interactions between the solute, solvent, and membrane, Reverse osmosis is employed to clean wastewater originating from sources such as sanitary waste, municipal leachates, and various industrial processes [54, 55].

Advanced Oxidation Processes (AOPs): Advanced oxidation process refers to a method that involves the use of powerful oxidizing agents to break down and remove contaminants from a substance. In certain cases, a single oxidation system may not be enough to completely break down organic pollutants in wastewater. Advanced Oxidation Processes (AOPs) are methods that utilize multiple oxidation processes simultaneously, resulting in the rapid generation of the highly reactive hydroxyl free radical [56,57]. These procedures encompass methods such as Fenton's reagent oxidation, UV photolysis, and sonolysis ,They have the ability to break down organic contaminants at normal temperature and pressure conditions, An inherent benefit of the advanced oxidation method is the efficient oxidation of organic pollutants into carbon dioxide (CO2),There are several advanced oxidation processes that can be utilized, including chemical oxidation processes that involve ozone, a combination of ozone and peroxide, in addition to ultra violet accelerated oxidized techniques such catalytic oxidation of moist air (in which air is utilized as the oxidant), UV/air wet air oxidation, UV/ozone, UV/hydrogen peroxide, and UV/Fenton or photo-Fenton [58-60].

Electrolysis: Electrolysis is a process that involves the deposition or decomposition of soluble materials on the surface of electrodes through electrochemical redox reactions. In this method, metal ions are primarily deposited on the electrode surface, while organic substances are broken down into carbon dioxide and water, or other products that have low or non-toxic properties [61].Ion exchange: An ion exchange process is used to replace hazardous ions in wastewater with non-harmful ions derived from a solid material [62].

Distillation: During the distillation process, water undergoes purification by being heated to its boiling point of 100 °C. This causes the liquid water to vaporize, leaving behind the contaminants. The resulting vapors are then cooled back into liquid water.

Formation of crystals: By raising the concentration of pollutants until they reach a threshold where they start to form crystals and separate from the solution, a process known as crystallization is used to eradicate those pollutants. This phenomenon arises from either evaporation, the reduction of water temperature, or the introduction of additional solvents. This method is beneficial for treating wastewater that has high levels of total dissolved solids (TDS), which include both soluble organic and inorganic substances. The additional ingredients, such as ammonia, sulfite, bicarbonate, etc., were added throughout this procedure. Undergo decomposition into different gaseous components, Because of this, crystallization may sometimes be used to control ph. The paper and dyeing industries, cooling towers and boilers powered by coal and gas all often use crystallization to cleanse their effluent. Additionally, in order to reduce the quantity of resources used, it is used. Processes for crystallization include fluidized suspensions, surface-cooled crystallizers, forced circulation, and draft tube baffles. At a cost of between $50 and $150 US dollars per million liters, the high-quality treated water used in this method [63].

Extraction using a solvent: Solvent extraction is a process used to remove contaminants from wastewater by adding organic solvents that are unable to mix with water but have the ability to dissolve pollutants.

The process of liquid turning into vapor: Evaporation is a natural phenomenon that is commonly employed to decrease the amount of waste liquid, However, in recent advancements, it has also been utilized as a way for water purification.

5. CONCLUSION

In summarize, this review emphasizes the crucial problem of water contamination and its widespread influence on both the environment and human well-being. The review elucidates the complex network of elements that contribute to water pollution, encompassing fast urbanization, industrialization, and population increase. The ramifications of water pollution are far-reaching, spanning a range of health ailments, including dermatological disorders and life-threatening problems such as cancer and diarrheal infections, with children being especially susceptible. The study methodically analyses the main sources of water contamination, including home sewage, industrial effluents, pesticides, plastics, and inadequate management systems. These findings highlight the necessity for integrated and synchronized endeavors across several sectors to reduce pollution sources. Emphasizing sustainable farming methods and proper waste management is essential for minimizing the impact of pollutants on water supplies. Moreover, the paper examines sophisticated strategies for treating wastewater, including a thorough examination of purification methods ranging from fundamental approaches to cutting-edge tertiary treatments. Adopting these technologies is crucial to guarantee a long-lasting and secure water supply worldwide. Despite the valuable insights gained, it admits specific limitations, such as its geographical emphasis and the complex nature of pollution sources. To overcome these restrictions, continuous multidisciplinary research and collaboration are required. The review promotes a comprehensive strategy that includes sustainable behaviors, strict restrictions, and modern treatment technology. An all-encompassing plan is crucial to ensure the protection of water resources, preservation of ecosystems, and guarantee a healthy future for future generations. To tackle water pollution, it is necessary for governments, companies, and communities to collaborate in implementing strong legislation, enhancing infrastructure, and promoting knowledge regarding the significance of conserving water quality.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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