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Review on Development of reliable drinking water source and/or augmentation of existing source to provide long term sustainability of water supply system.

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Abstract - Access to safe and reliable drinking water is a fundamental human right and a cornerstone of sustainable development. This review paper critically examines the development of reliable drinking water sources and the augmentation of existing sources to ensure the long-term sustainability of water supply systems. With a growing global population and increasing environmental pressures, the demand for clean and dependable water resources has never been more pressing. This comprehensive review assesses the various strategies, technologies, and approaches employed worldwide to address this vital challenge. We delve into the innovative solutions, such as groundwater recharge, desalination, water recycling, and watershed management, which are pivotal in enhancing the resilience of water supply systems. Additionally, we explore the socio-economic and environmental implications of these strategies, emphasizing the importance of community engagement, equity, and ecological preservation. By synthesizing the latest research findings and case studies, this review aims to provide valuable insights and guidance for policymakers, water resource managers, and researchers, with the ultimate goal of securing a sustainable and equitable water future for all.

Keyword - Drinking water, water supply system

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1. INTRODUCTION

The Earth's surface is comprised of almost two-thirds water, however a considerable proportion of this water exhibits elevated salt levels, making it unfit for human consumption. Only a small fraction, namely 1%, of the freshwater present in lakes, rivers, and groundwater is deemed suitable for human consumption. This is the case even though freshwater accounts for a mere 2.7% of the total water resources accessible on our planet. Only a small fraction of Earth's freshwater resources can be efficiently exploited for the purpose of producing drinkable water. The principal factor contributing to this phenomena is the significant buildup of freshwater reserves inside glaciers and deep aquifers situated under the polar ice caps. Desalination is a method through which salty water may be transformed into water that is safe for human consumption. Several nations encounter a condition known as "physical scarcity" of freshwater due to the constrained accessibility of water supplies. The increased cost of freshwater in many countries may be attributed to the scarcity of supplies.

According to scholarly research, it is widely recognized that every person has a fundamental right to get secure, plentiful, and reliably available potable water [3]. The exact delineation of the term "safe drinking water" is not immediately evident. The concept of "safe drinking water" pertains to water that does not provide significant health hazards when ingested throughout the course of an individual's lifespan [4]. The provision of safe and clean drinking water is a fundamental need in the

modern day. The assurance of water purity is not always absolute, even when it is classified as "safe." The measured concentrations of calcium, magnesium, bicarbonates, and carbonates exhibit a notable decrease. The phrase "degree of purity and safety" is ambiguous and susceptible to several interpretations, therefore lacking clarity. Pure water consists only of the chemical elements hydrogen and oxygen. Non-mineral components. According to the Joint Monitoring Programme (JMP) definition, the word "safe drinking water" pertains to water obtained from a "improved water source." This includes a range of alternatives, including domestic connections, communal standpipes, boreholes, safeguarded drilled wells, safeguarded springs, and rainfall harvesting. As per the aforementioned organization, the concept of access to safe drinking water is delineated as the provision of a minimum quantity of 20 liters per day, acquired from a "improved" source situated within a one-kilometer distance from the individual's place of residence.

Potable water, also known as safe drinking water, is characterized as water that is appropriate for dissemination to individuals and adheres to the requisite criteria for drinking and other applications [3, 4]. Full compliance with chemical, biological, and physical quality criteria for drinking water is of utmost importance when it is delivered to consumers [5]. The precise meaning of "safe drinking water" is contingent upon particular quality indicators, rendering it a relative concept that is subject to national legislation and standards.

2. ACCESS TO SAFE DRINKING WATER

Water is a fundamental need for the sustenance of all living organisms inhabiting our planetary system, namely the Earth. The importance of this entity is analogous to that of oxygen for the human species. The presence or absence of water has a profound influence on all facets of human life. The provision of clean water for fundamental everyday activities, including but not limited to food preparation, drinking, personal hygiene, and sanitation, is of utmost importance for persons. Therefore, it may be deduced that guaranteeing regular availability of clean and drinkable water is a basic human right [8]. The declaration by the United countries and other international organizations affirms that the provision of clean drinking water is a basic and essential step in improving the overall well-being of persons across all countries. The promotion of accessible access to potable water emerged as a central objective within both the United Nations Sustainable Development Goals (UN-SDGs) and the United Nations Millennium Development Goals (UN-MDGs). In accordance with the National Water Act of 1998, Article 9 of the Constitution of South Africa reaffirms the primary goal of guaranteeing equitable and widespread availability of water and food across the nation. Marginalized populations, such as persons experiencing poverty, women, and children, face an inequitable burden as a result of persistent discrepancies in their ability to obtain clean drinking water, both inside South Africa and on a worldwide scale. Inequalities are present in both local and international contexts [6]. As shown by a research done in 2002, the proportion of persons with access to potable water in rural parts of the Democratic Republic of the Congo was found to be 17%, while the rural population with such access was reported to be 77% [6]. The unequal distribution of water and sanitation resources is often seen as morally wrong and a breach of international legal obligations [3, 4]. According to a scholarly source, the worldwide estimate for the accessibility of drinkable water is at 89% [10]. According to the research published by the United Nations Development Programme (UNDP) [11], an estimated 1.1 billion persons, constituting nearly one-sixth of the global population, now have inadequate access to potable water. In some nations, notably inside the African continent, a notable segment of the populace faces the absence of secure potable water, consequently posing a threat to their well-being [12]. The earlier assessments by the United Nations Development Programme (UNDP) have been shown to have overestimated the population of those who do not have access to clean drinking water [11]. This phenomenon may be attributed to the observation that a substantial proportion of the water supply infrastructure in developing nations, constructed in accordance with the Millennium Development Goals (MDGs), is now not functioning at its maximum efficiency.

3.BENEFITS OF SAFE DRINKING WATER

The provision of clean water is a critical factor in the advancement of a country, as it serves as a pivotal determinant in evaluating the welfare and economic advancement of its inhabitants. The existence of water that is polluted not only presents a possible hazard to the physical and mental health of humans, but also has the capacity to impede their ability to perform tasks effectively [13]. Based on data provided by the World Health Organization (WHO), it is estimated that around 1.1 billion people globally ingest water that has been subjected to contamination via several means. Each year, an estimated 1.7 million deaths and 54.2 million cases of disability are attributed to inadequate water consumption and limited access to basic sanitation and hygiene practices. Water fulfills several roles and presents a multitude of benefits for both persons and the ecosystem. The limited attention given to water-related issues in the political domain and the subsequent lack of investments in water infrastructure may be attributed to the absence of strong evidence demonstrating the advantages of water, as shown by the results of the OECD [15]. In accordance with the aforementioned language, it is observed that many technical publications prefer to downplay the benefits associated with water. Based on current research, the ratio of benefits to costs related to water access is routinely reported to exceed two, and in some cases, it has been seen to reach a maximum of seven. The benefit-cost ratio of

improving water accessibility in developing areas like Africa is shown to surpass 5:1 due to the complex interdependencies across several sectors of development, including agriculture, energy, and industry. Estimates pertaining to the return on investment in water services in these regions exhibit variability, with reported values ranging from $5 to $28 for each $1 spend [7]. In addition to the economic advantages, water distribution projects provide a range of technical, environmental, and political benefits. The water sector exhibits deep interconnections with other development sectors, including agriculture, energy, and industry, among others. Furthermore, it is important to note that this phenomenon also connects with several other factors, such as social, economic, environmental, health, education, legal, and political issues, across multiple levels of analysis, including the local, national, regional, and global scales [16]. The supply of clean water has several advantageous effects across different areas, including poverty reduction, education enhancement, improvement of health conditions, and protection of the environment, among others. The United Nations World Water Development Report [7] has identified a notable connection between water and sustainable development that transcends its social, economic, and environmental dimensions. The research findings indicate that the availability of uncontaminated water is crucial for effectively tackling a wide range of urgent developmental concerns, including but not limited to human well-being, the security of food and energy resources, the process of urbanization and industrial expansion, and the phenomenon of climate change. The interdependence of water, energy, and food has been well recognized [3]. One of the key aims of the United Nations' Millennium Development Goals (MDGs) from 1990 to 2015 was to achieve a 50% reduction in the population without access to clean drinking water and basic sanitation. Based on the findings of the Joint Monitoring Programme (JMP) for water supply and sanitation, a joint initiative established by the World Health Organization and the United Nations Children's Fund [17], it is now estimated that almost 2.3 billion people have access to improved drinking water sources. The findings suggest that despite notable advancements achieved in the last twenty years, there still exists a substantial quantity of unfinished tasks. The efficacy of the Millennium Development Goals (MDGs) is subject to scrutiny given the constrained availability of potable water in several developing countries, especially among socioeconomically disadvantaged communities. Based on research findings [18], the issue of accessing clean water is primarily a prevalent concern in less developed countries. This highlights the fact that a considerable proportion of persons living in underdeveloped countries, namely in Africa, consistently suffer from waterborne diseases as a result of consuming water that is polluted. Annually, a considerable quantity of lives are regrettably lost as a consequence of illnesses disseminated by water pollution, encompassing, but not restricted to, cholera, diarrhea, malaria, and dengue fever. On a daily basis, a considerable number of persons, over 25,000, experience the unfortunate outcome of water-related diseases [12]. Among this population, a notable proportion consists of youngsters who endure water-related ailments, mostly diarrhea, leading to a staggering daily death toll of over 5,000 individuals. Each year, an estimated 1.8 million children, mostly residing in underdeveloped countries, die as a result of diarrhea and related diseases [19]. Escherichia coli is often acknowledged as a sign of fecal contamination, with about 1.8 billion humans eating water that has been polluted by this bacteria [20]. Waterborne illnesses have a substantial role in the death rates seen in different places around the globe, with a special emphasis on developing countries. The enhanced availability of potable water has resulted in a significant reduction in the incidence of waterborne diseases among the population. The reduction in the occurrence of health concerns aggravation leads to an increased likelihood of better health outcomes. In 2014, the United Nations recognized water as Sustainable Development Goal (SDG) 6, citing its multitude of benefits [21]. Water is widely acknowledged as a crucial issue within the framework of the United Nations Millennium Development Goals. As per the United Nations Sustainable Development Goal 6, water is a fundamental need for the preservation of life, and the accessibility of uncontaminated and potable water is a pivotal determinant for the advancement of a cultured community. The importance of a specific Sustainable Development Goal (SDG) centered on water has been underlined by the United Nations, specifically in SDG 6. This goal encompasses five essential areas: water, sanitation, and hygiene (WASH); water resources; water governance; water quality and wastewater management; and water-related catastrophes. The diverse array of advantages linked to water, including social, economic, financial, and environmental dimensions, underscores its substantial ratio of benefits to drawbacks. The achievement of Sustainable Development Goal 6 set by the United Nations presents considerable obstacles, especially in economically disadvantaged regions like Africa. There are a multitude of concerns and impediments that require attention in order to effectively surmount these hurdles. The many benefits of water include a range of sectors and activities that are integral to development, including health, education, energy, agriculture and food production, industry, as well as other social and economic pursuits. There exists a pronounced need for considerable improvements in both life expectancy and total well-being [7]. The provision of required infrastructure, assistance, and knowledge is a common duty that must be undertaken to accomplish Sustainable Development Goal 6. This objective underscores the notion that the availability of uncontaminated and secure potable water is an inherent entitlement of every individual. The building of competent government is

crucial for ensuring the availability of clean water in underdeveloped countries [22].

4. BASIC PRINCIPLES OF SAFE DRINKING WATER SUPPLY

Numerous protocols, accords, criteria, and metrics have been implemented to ascertain the appropriateness of water for human ingestion. In the section entitled "Safe Drinking Water," readers will find supplementary methods, projects, and recommendations. Bos et al. (year) have proposed explanations for these beliefs, which are outlined as follows: The user has provided a numerical reference. The word "norm" is used to describe the typical amount of advancement found among a substantial community. A criterion is defined as a set of criteria that constitute the basis for making well-informed judgements. The quantified value of each metric is often known as an indication of the quality of water. The word "standard" is often used to refer to the minimum criteria or common purpose set by an authorized entity. There are a multitude of rules and standards that apply to water quality on a worldwide scale.

5. WATER REGULATIONS AND ACT

Legislation Governing the Utilization of Water Resources The proper execution of water rules is crucial for ensuring the availability of sufficient quantities of safe, reliable, affordable, and socially acceptable drinking water. One of the primary duties of drinking water law is to supervise the regulation of several facets associated with the supply of potable water. This include the administration and supervision of water resources, treatment methodologies, distribution networks, water consumption patterns, as well as the management of wastewater and gray water. Different nations have enacted a range of restrictions pertaining to water use, which are dependent on the quality of their own water sources. As stated before, the restrictions pertaining to the use of drinking water within a nation are formulated based on the quality of its water resources.

Each person has an intrinsic right to get safe, plentiful, and reliably available drinking water [3]. Ensuring equal access to drinkable water is of utmost importance, regardless of persons' age or various degrees of ability. The concept of water availability refers to the existence of a sufficient and reliable supply. In the present situation, the adequacy of both the volume and the characteristics of water may be considered adequate. In order to guarantee the constant supply of services for both current and future generations, it is crucial to emphasize the principles of sustainability, system robustness, and resilience. The word "acceptability" pertains to the comprehensive assessment of water quality based on its taste, odor, and visual characteristics. The lack of widely acknowledged objective criteria for determining acceptability may be attributed to the subjective aspect of this norm, which is significantly shaped by variables such as impressions of the local ecosystem, culture, education, and personal experience. The provision of accessible water access necessitates the availability of water at all times and in various settings, such as residential premises, educational establishments, businesses, and public spaces. The matter concerns a spatial separation of 0.2 kilometers (equivalent to a 30-minute travel time) between the water source and the area where it is needed. This suggests that people across different age cohorts and skill levels should be granted unimpeded access to drinks at their own discretion. To get a thorough comprehension of the aforementioned water factors, one might consult the study undertaken by Bos et al. [3]. The principal responsibility of a drinking water provider is to guarantee the uninterrupted provision of potable water to inhabitants, therefore ensuring them access to a sustainable supply of clean water. This necessitates the implementation of stringent procedures to minimize the potential for contamination throughout the whole of the water distribution process. Ensuring the provision of clean and aesthetically pleasing water for consumer use is of utmost importance. Water pollution prevention, management, and eradication are often addressed by water companies and regulatory agencies. The establishment of water laws is a crucial factor in ensuring the accessibility of safe, cheap, dependable, and sufficient drinking water sources. Different nations have enacted a range of restrictions pertaining to water use, which are dependent on the quality of their own water sources. In accordance with the research conducted by the US Environmental Protection Agency [24] and the World Health Organization [23], it is crucial that water designated for human consumption satisfies predetermined standards and complies with defined principles to guarantee its safety.

6. POTENTIAL FACTORS CHALLENGING WATER SUPPLY SYSTEMS

The establishment of a comprehensive water supply system (WSS) is important for the provision of water to urban and industrial regions. This entails the development of an intricate network including hydraulic and hydrologic components. The system is composed of multiple components, which encompass raw water collection basins, drainage networks, water collection and transportation pipes, treatment plants, pipelines for conveying treated water, drinking water adduction systems, pumping stations, storage tanks, and distribution networks [25-27]. Traditional water supply systems consist of a range of interrelated components, such as the water distribution network, water treatment plant, storage reservoir, and water supply catchment [26]. The water supply and distribution system is composed of many crucial elements, which include source works, treatment facilities, service reservoirs, pumping stations, pipelines, and valves [25].

7. SUSTAINABLE WATER SUPPLY AND CHALLENGES

According to the ambitious Sustainable Development Goals (SDGs) vision for 2050, it is expected that there would be a realization of universal access to clean water, which will cater to both individual daily needs and ensure environmental sustainability [7]. In light of the interdependence of water resources, it is crucial to prioritize the promotion of water sustainability as a means to ensure the enduring viability of our planet in the long run. In a more precise manner, it requires progress in the social, economic, and environmental dimensions of sustainable development [7]. Therefore, the water vision articulated in Sustainable Development Goal 6 emphasizes the need of proficiently overseeing current water resources and their related components by using an integrated, inclusive, and participatory methodology. Considerable financial resources are need to be devoted towards the advancement of infrastructure, treatment plant systems, and water recycling efforts. The user provided a numerical citation [29]. There are several obstacles that might hinder the attainment of the Water Supply System's (WSS) goal of delivering a water supply that exhibits superior quality, efficiency, reliability, resilience, and sustainability for present and future generations. Rural regions pose a higher magnitude of technical and financial obstacles in comparison to their metropolitan counterparts. According to the research conducted by da Silva et al. (2019), it has been shown that rich urban areas have a greater ability to create the requisite financial means for water infrastructure in comparison to disadvantaged rural communities. The development of energy-intensive infrastructure is necessary for establishing dependable and consistent water supply systems (WSS) in rural regions characterized by high hydrologic variability and dry conditions. The research done by Chung et al. [30] demonstrates the advantages of using the robust optimization technique for the development of reliable WSSs under conditions of uncertainty. This strategy successfully reduces the likelihood of system failure to a predetermined extent. Impoverished nations have considerable obstacles in their pursuit of the Sustainable Development Goals (SDGs) as a result of limited financial investments and inadequate governance. The allocation of significant financial resources is crucial for the advancement of infrastructure, treatment plant systems, and water recycling programs [28]. The sustainable expansion of the water business is contingent upon the progress made in many areas. The existence of development activities that are not sustainable poses a substantial threat to the availability and quality of freshwater resources. The sustainability of water and sanitation services (WSS) is at risk due to various factors, including population growth, urbanization, changes in land cover and climate patterns, the demand for alternative energy sources, and governance deficiencies. The aforementioned elements that serve as sources of motivation (28) have given rise to a range of serious problems, including but not limited to water shortages, depletion of aquifers, detrimental runoff, coastal hypoxia, as well as occurrences of floods and droughts. There has been a continuous discourse around the attainment of the Millennium Development Goals (MDGs), and it is anticipated that this dialogue will endure when the current set of MDGs are put into practice. An further challenge in attaining a sustainable water supply is to the lack of appropriate policies and programs that effectively cater to the many needs and circumstances present in rural regions. The presence of water pollution presents a substantial hazard to tiny populations situated in rural areas. Furthermore, the company is now facing difficulties in meeting regulatory requirements for the quality of their potable water. This predicament arises from the restricted allocation of resources towards the improvement of their water transportation and treatment systems. The provision of water to rural communities is increasingly being recognized as a collective duty on a worldwide level. Despite the diverse array of rural geographical settings and water resources, strategies tend to have a similar approach. A thorough investigation was undertaken to examine four rural water sources situated in the Andes region of Colombia. The research examined many elements, such as infrastructure, training of human resources, revenue collection, water quality, and post-construction assistance. The user's text does not contain any information to rewrite. The study's results indicate that it is crucial to implement policies and programs that specifically target the distinctive characteristics of rural regions in order to construct water delivery systems that are sustainable. According to the findings of Kot et al. (32), it is essential for planners to consider the contextual and cultural variations present in rural locations while striving to develop appropriate water quality criteria for small communities. The frequency of using adaptive capacity indicators in urban sustainable water supply systems is limited, hence posing a difficulty in effectively managing the dynamic and unexpected characteristics of urban water supply systems in metropolitan regions. The present scenario gives rise to apprehensions over the level of development achieved by urban water systems in terms of variety and adaptability [33]. Moreover, it presents a significant risk to the long-term viability of urban water delivery systems. Spiller (33) argues that it is crucial for future study to give precedence to the advancement of techniques and metrics in order to identify, evaluate, and quantify indicators associated with adaptive capacity within the domains of economic, environmental, and technological facets of sustainable development. Therefore, it is crucial to use metrics that measure adaptive ability. Moreover, it is crucial for metropolitan regions to adopt sophisticated water systems that are distinguished by their reliability and ecological sustainability. Concerns including as leakage, mismanagement, poor quality, and difficulty in disaster and drought management are significant factors that jeopardize the sustainable functioning of urban water delivery systems [34]. The

implementation of smart water networks, including information and communications technology, has been suggested as a possible approach to tackle these aforementioned difficulties [34]. This methodology encompasses the incorporation of monitoring and control devices through networking and automation. Despite notable progress in computational capabilities, smart water systems have not received much attention, especially in underdeveloped countries. Accurate anticipation of water demand and supply of paramount significance in places undergoing rapid development. The precise prediction of future water demand has significant significance for water utilities in terms of system design, building, and maintenance of existing infrastructure. Accurately predicting outcomes may provide a significant challenge, especially in the context of forecasting models that need to account for the simultaneous effect of several variables on water demand and supply patterns. There are other variables that need study, such as changes in consumer behavior, population expansion, patterns of migration, economic progress, and the ramifications of climate change [35].

8. CHALLENGING FACTORS FOR WATER SUPPLY SYSTEMS

The World Security Society (WSS) faces several difficulties that arise from a wide array of sources. Some of the factors are aging infrastructure, water service provision thinking horizons, catchment (mountain)-specific issues, climate change, knowledge gaps with respect to present and future hydrology, accurate water demand prediction, land use/cover change, optimal operation of water supply systems, cost recovery, operating cost, water quality (water pollution), water scarcity, water leaks, low water pressure, over-use, response to drought and natural disasters, rapid urbanization, population growth, migration, demographic changes, economic development, consumer behavioral patterns, efficiency and reliability of a water supply system, self-sufficiency through use of alternative water sources, dynamic and uncertain urban water systems, complex dynamic human-environment coupled systems (non-holistic or siloed management), lack of adaptive capacity indicators to assess sustainability of water systems, scant attention of smart water grids (not supported by information and communications technology), lack of policies and programs that consider rural diversity and cultural differences and neglecting wastewater management are mentioned as challenges to water supply systems for provision of sustainable and reliable water services, which meet acceptable standards for present and future generations [14, 25, 26, 28–49]. The World Security Summit (WSS) has faced several worldwide difficulties in the current century, as shown by the research conducted by Berg and Danilenko (38). Some of the key obstacles that are widely recognized include the phenomenon of population expansion, the volatility of climatic patterns, concerns related to social and environmental issues, the lack of water resources, economic downturns, and the aging of the population. Age-related concerns cover a variety of difficulties, including diminished water pressure, water depletion, and degradation in water quality (36). The worldwide supply of clean drinking water and proper sanitation encounters several substantial problems. The user's content does not include any information to be rewritten. The concerns that necessitate attention encompass water pollution within distribution systems, the exhaustion of water resources, the adoption of inventive and economically efficient sanitation systems, the provision of sustainable water supply and sanitation to densely populated urban areas, the mitigation of disparities in access, and the establishment of financially viable water and sanitation services.

9. DRINKING WATER QUALITY

The presence of water is of utmost importance in the shaping of terrestrial landforms and the maintenance of atmospheric conditions. This particular asset bears considerable significance in the context of daily existence. The cleanliness of water has significant relevance when evaluating the health of both people and animals. According to research undertaken by the World Health Organization (WHO) [23], there exists a clear correlation between water and nearly 80% of all human illnesses. The assessment of water quality encompasses the examination of a range of biological, physical, and chemical characteristics that are intricately linked to the particular intended use of the water. Ideally, potable water should be devoid of any deleterious compounds or microbes [3]. One of the primary difficulties now confronting the people of South Africa revolves on the pollution of their freshwater resources, namely the groundwater in regions where it significantly contributes to their economic viability [52]. Groundwater plays a crucial role as the predominant water supply for a substantial proportion of the worldwide populace, fulfilling diverse needs across sectors including agriculture, industry, and household consumption. Therefore, the issue of naturally occurring pollutants in freshwater is a prominent worldwide environmental problem, especially in developing countries (53). The preservation of groundwater has paramount significance owing to the considerable difficulties included in remedying water quality post-contamination. The discourse and theoretical framework pertaining to water quality are comprehensive, since they contain a multitude of elements that have the ability to influence it. The wide range of uses for water requires strict adherence to certain criteria in order to guarantee its appropriateness. In order to conduct a comprehensive water quality study, it is necessary to determine the appropriate ranges of acceptable and unacceptable values for each variable pertaining to the quality of water. If the quality variables conform to the predetermined requirements, it is considered to be safe for all uses.

9.1 Physical parameters

Physical quality parameters are related to total solids content, which is composed of floating matter, settleable matter, colloidal matter and matter in solution. The following physical parameters are determined in water [12].

Color: Caused by dissolved organic materials from decaying vegetation or landfill leachate.

Taste and odor: Can be caused by foreign compounds such as organic compounds, inorganic salts or dissolved gases.

Temperatures: The most desirable drinking water is consistently cool and does not have temperature fluctuation of more than a few degrees. Groundwater generally meets these criteria.

Turbidity: refers to the presence of suspended solid materials in water such as clay, silt, organic material, plankton, and so on.

9.2 Chemical parameters

The potential health hazards associated with chemical pollution found in water sources surpass those presented by its physical constituents. Consequently, designations for unfavorable attributes are sometimes assigned with more emphasis on visual appeal rather than on promoting well-being. Nevertheless, there are certain chemical compounds that are considered undesirable due to concerns related to safety and aesthetics. There exists a prevailing worry over the potential adverse effects on human health resulting from extended exposure to certain substances [54]. The study demonstrates the cumulative impact of chemical constituents on human beings. Alkalinity, dissolved gases, nitrogen compounds, pH, phosphorus, and organic solids represent a limited selection of chemical criteria that may be used to quantitatively assess the quality of water. Occasionally, concealed chemical features may be unveiled by the examination of visible reactions [12, 54]. Examples of chemical reactions include redox reactions, reactions that occur during the process of washing, and several other types of reactions. The following enumeration of elements and compounds is a non-exhaustive list of substances that might potentially be found in water.

Arsenic has the potential to occur naturally in many rock formations throughout the environment. In the context of South Africa, agricultural chemicals are mostly used. The presence of this substance in water sources has been associated with a heightened susceptibility to bladder and lung cancer.

Chloride may be present in all aqueous environments. It is possible that the amount in question has been depleted due to the infiltration of sewage originating from residential or industrial sources. The concentration of chlorine in domestic water sources should not surpass 100 mg/L.

Fluoride may be present in water due to its natural occurrence as a contaminant. According to the World Health Organization [14], there exists a chemical that has significant adverse effects on human health. Excessive consumption of fluoride in one's dietary intake has the potential to result in the development of dental and skeletal fluorosis. There is a known association between dental fluorosis, which is characterized by tooth discoloration, and long-term consumption of fluoride [12]. On the other hand, excessive intake of fluoride (>2 mg/L) has been associated with the development of skeletal fluorosis. On the contrary, it may be seen that youngsters whose F levels are below 2 mg/L are more likely to have dental decay.

Certain natural streams may contain zinc due to historical mining activities that resulted in the extraction of zinc deposits. Although the potability of the water is assured, its flavor may be deemed unpalatable.

The prevalence of iron inside the Earth's crust results in its frequent occurrence in water at very low levels. The outcome will manifest as a deep scarlet hue in the water.

Due to its natural origin, manganese is often seen at elevated levels within groundwater. Examples of anthropogenic contamination include the production of steel alloys, the use of pesticides in agricultural practices, and the inadequate disposal of batteries.

Frequently found deleterious chemicals include a range of metallic elements, organic compounds, and inorganic substances. Potentially dangerous inorganic substances include heavier-than-air metals, cyanide (CN_), and nitrates (NO3). Exposure to these toxins in the water supply poses a significant hazard to human health. The phenomenon of oxygen deprivation seen in individuals with CN exhibits similarities to the condition of methemoglobinemia observed in neonates who have been exposed to elevated levels of NO3, sometimes referred to as "infant cyanosis" or "blue baby syndrome" [12]. A study has identified over 120 chemical compounds that are considered toxic [24]. The bulk of these compounds are often used as pesticides, insecticides, and solvents. These compounds may potentially have both immediate and prolonged impacts on human health. Several heavy metals have been identified as posing potential risk to human health. These include arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver [12]. Certain compounds, such as arsenic (As) and chromium (Cr), have the potential to induce acute poisoning, but chronic illness may be attributed to other chemicals, including lead (Pb), cadmium (Cd), and mercury

(Hg). This distinction also applies to organic molecules.

10s. CONCLUSION

The provision of clean and safe drinking water is considered a fundamental human right due to its essential role in sustaining human life. One essential requirement is the availability of potable water that adheres to the criteria of adequacy, dependability, purity, acceptability, and safety, catering to a diverse range of users. Furthermore, it is imperative to ensure an adequate supply of potable water for individuals to utilize within their households and localities, catering to their various daily water requirements such as culinary activities, hydration, and personal cleanliness. The United Nations has identified water availability as a crucial element in the attainment of sustainable development. Notwithstanding these findings, the global distribution of safe drinking water continues to exhibit disparities. There exist multiple factors that pose a threat to the viability of the WSS. Various factors contribute to the challenges faced in water management and delivery, including aging infrastructures, issues related to clean water such as quality and scarcity, natural factors such as climate change, floods, and droughts, as well as human factors like population growth, migration, demographic changes, economic development, willingness to pay for water supply services, and overuse. These challenges manifest in problems such as inadequate water pressure, leakages, absence of smart water meters, difficulties in cost recovery, and high operation costs.

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