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NEED OF ESTABLISHING DESALINATION PLANTS TO MITIGATE WATER SCARCITY IN DRY ZONES OF SRI LANKA

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ABSTRACT

This research study aims to explore the necessity of implementing desalination plants as a solution to address water scarcity in the dry zones of Sri Lanka. Water sustainability is crucial for ensuring the availability and preservation of water resources to meet the needs of current and future generations. Various innovative methods, including rainwater harvesting, irrigation efficiency, sewage water treatment, and desalination, have been employed to minimise water scarcity. Desalination, in particular, plays a vital role in meeting the growing water demands by removing salt and harmful elements from drinking water, making it safe for consumption. The primary objective of this research is to identify the specific need for desalination plants in the dry zones of Sri Lanka, while also examining the underlying reasons for water scarcity in the region. The methodology employed in this study involves template analysis, utilising data collected through expert surveys. Six experts were selected for semi-structured interviews, ensuring saturation in information gathering. The findings of this research reveal nine crucial factors that necessitate the implementation of desalination plants in the dry zones of Sri Lanka. These factors include irrigation inefficiency, groundwater depletion, the prevalence of waterborne diseases, insufficient rainwater harvesting systems, limitations in current water distribution methods, the impact of climate change, population growth, and challenges faced by industries operating in the region. The findings underscore the importance of implementing appropriate strategies to mitigate water scarcity and ensure a reliable and secure water supply for the region's present and future needs.

Keywords: *Desalination; Diseases; Dry Zone; Irrigation; Water Scarcity.*

1. INTRODUCTION

One of the most critical problems of the twenty-first century is water scarcity (Food and Agriculture Organisation [FAO], 2018). Water scarcity arises when the demand for fresh water in a given domain exceeds the supply (FAO, 2012). White (2014) stated that water scarcity is insufficient water availability for human and environmental uses and it is being recognised as a serious and growing problem in the world. Water scarcity currently affects more countries worldwide (Srinivasan et al., 2012). South Asia is a hotspot of water scarcity (Asia Development Bank [ADB], 2017). Abeysingha and Rajapaksha (2020) identified that water scarcity had been the most significant and natural hazard in the DZ

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of Sri Lanka in terms of the people affected. The DZ of Sri Lanka faces a range of water-related issues due to environmental and socio-economic complexities (Bandara, 2003). The authors highlight the presence of extreme water scarcity in the DZ and attribute it to various factors. Irrigation inefficiency is a major reason for water scarcity in DZ (Jayasekara, 2017). Climatic changes are one of the reasons for water scarcity in Sri Lanka (Dissanayake, 2005). Jayasekara (2017) argues that harvesting is only done seasonally, which is not a good solution for a DZ situation because water scarcity only occurs during the dry season. Moreover, consuming contaminated groundwater could cause various illnesses, some of which can be deadly, such as dental fluorosis and chorionic kidney diseases (CKD) (World Health Organisation [WHO], 2004).

Introduces large-scale, water sustainable innovative methods for minimising water scarcity (Islam et al., 2018). Rainwater harvesting systems, desalination, sewage treatment, and irrigation efficiency as currently using innovative water sustainable methods (Islam et al., 2018) However, some problems were identified related to the innovative techniques. Desalination is becoming a more efficient method of supplying fresh water in many countries where it is scarce (Islam et al., 2018). Desalination of salt water is the most practical method for solving water scarcity because seawater contains 97% of the world's water and 3% of the world's water resources are immediately accessible drinking water (Islam et al., 2018). Desalination can produce water for drinking purposes and agricultural purposes (Jayasekara, 2017). So, as a result, Sri Lanka is an island covered in oceans. Hence this study will identify the need for desalination for the DZ.

2. LITERATURE REVIEW

2.1 WATER SUSTAINABILITY

Water sustainability can be defined as the ability to manage water resources in a manner that meets the needs of present and future generations while ensuring the preservation of ecosystems (United Nations Educational, 2018). Solarimpulse Foundation, (2021) stated that water scarcity could be significantly reduced if there is a focus on making large-scale, innovative methods like rainwater harvesting systems, desalination technology, sewage treatment, and irrigation efficiency, which are discussed below.

- **Rainwater Harvesting System**

Rainwater harvesting refers to the technique of diverting, capturing, and storing precipitation that falls on a site for on-site consumption rather than allowing it to run off, evaporate, or infiltrate into the soil (Bottom, 2016). Raheem (2020) argues that rainwater harvesting is limited for the countries because of insufficient rainfall, mosquito growth and waterborne diseases.

- **Sewage Treatment**

Wastewater reuse is the process of turning wastewater into water that may be reused for various uses while removing contaminants from sewage (Kümmerer et al., 2016). Shakir et al. (2017) argue that because of health concerns, water-borne infections and skin irritations can occur in those who come into direct contact with reused wastewater. However, sewage water is not suitable for drinking purposes; that water is only suitable for agricultural and irrigation uses.

- **Irrigation Efficiency**

In the agriculture industry, simply switching from flood irrigation to sprinkler or drip irrigation could save a large amount of water (Waterlogic, 2017). When combined with improved soil management practices, which reduce evaporation from the soil, efficient irrigation systems can significantly reduce water usage (Waterlogic, 2017). Hansen (2020) argues that some health concerns developed due to irrigation efficiency technology, and water is best suited for agricultural needs, not for humans.

- **Desalination**

Desalination is a broad term for removing dissolved particles and producing freshwater from various feed fluids, including seawater (Islam et al., 2018). Seawater provides a seemingly limitless, consistent supply of high-quality water while preserving natural freshwater ecosystems (Elimelech & Phillip, 2011; Islam et al., 2018). Desalination is one of the water sustainability methods (Islam et al., 2018).

2.2 DESALINATION AS THE WATER SUSTAINABILITY

Sustainable water management refers to meeting current water needs without compromising future generation's ability to do so (Saavedra et al., 2021). Natural and artificial activities are quickly depleting freshwater supplies; however, Desalination is becoming a more popular water sustainable method of supplying fresh water in many countries (Peñate & García-Rodríguez, 2012). Elimelech and Phillip (2011) stated that several large-scale sustainable desalination facilities had been developed in water-stressed countries in recent years to supplement limited water resources, and additional desalination plant building is likely to expand in the near future. Around the world, seawater desalination is used at 67% of the installed capacities (Islam et al., 2018). The number of desalination plants and daily water production grew by 12.4% to 41.2% between 2016 and 2019 (Saavedra et al., 2021).

2.3 NEED OF DESALINATION TO MINIMISE THE WATER SCARCITY IN THE DZ OF SRI LANKA

According to Sri Lanka, the country is divided into two principal divisions based on annual precipitation of 1,875 mm: DZs, which account for around 70% of the country, and wet zones, which account for the remaining 30% (Ichikawa, 2012). Here discussed the needs of desalination for Sri Lanka.

2.3.1 Irrigation Inefficiency

Agriculture, forestry, and fisheries produce about 8.4% of the country's GDP, with agricultural workers accounting for 58% of the workforce involved in economic activities in 2020 (World Bank [WB], 2020). The DZ's produce around 40% or more of Sri Lanka's annual agriculture production (Ministry of Agriculture & FAO, 2017). Abeywardana et al., (2019) stated that the tank-based irrigation system is one of the world's oldest irrigation techniques used in Sri Lanka.

In 2002, there were 15,373 tanks in the DZ (Panabokke et al., 2002). By 2006, there were less than 14,950 minor tanks (Imbulana et al., 2006). In 2017, approximately 14,200 tanks were used for irrigation in agricultural areas (Ministry of Agriculture & FAO, 2017). Most of the farmers face water problems because of irrigation inefficiency (Burchfield &

Gilligan, 2016). During dry seasons, a significant number of irrigation systems experience drought conditions, resulting in inadequate water availability for daily activities and agricultural purposes (Burchfield & Gilligan, 2016). As a consequence, many individuals face numerous challenges and difficulties due to the inefficiency of irrigation systems in dry zone.

2.3.2 Rainwater Harvesting

Numerous technologies and techniques are available to help a country's water sector, such as the 3R process (Reuse, Reduce, and Recycle), including rainwater harvesting (Sayanthan et al., 2017). In 1998, Rainwater harvesting was promoted by the Sri Lankan government and non-governmental organisations, and the technology has since spread to Sri Lanka (Ariyananda et al., 2011). In 1998, the president was personally involved in rainwater collecting, and the water board built 73 rainwater collection systems in Kandy and Yatinuwara (Ariyananda et al., 2011; Jayasekara, 2017). However, there are currently 23 institutions involved in this, with nearly 32000 projects in operation (Jayasekara, 2017). Jayasekara (2017) argues that harvesting is only done seasonally, which is not a good solution for a DZ situation because water scarcity only occurs during the dry season. Further, Sayanthan et al. (2017) argue that Sri Lanka's population is growing day by day, and rainwater collecting is insufficient to meet the needs of the DZ of Sri Lanka. The harvesting water could be stagnant and infected with microbial activity, and in such instances, a preventative strategy should be implemented (Jayasekara, 2017).

2.3.3 Groundwater Depletion

Groundwater is a critical natural resource for life, and it is used extensively in the drinking, industrial, agricultural, and domestic sectors. In Sri Lanka, over 60% of the population drinks groundwater from shallow drilled wells (Mahagamage & Chinthaka, 2015). According to Sri Lanka, water pollution and overexploitation intrusion are the leading causes of groundwater depletion (Chandrajith et al., 2012). The former is highly transparent in DZ, and nitrate concentrations exceeding 200 mg per litre are reported (United Nations Educational, 2018). In the regions of Puttalam, Mannar, Kilinochchi, and Mullaithivu, overexploitation and saltwater intrusion are prevalent issues. This is because the wells in these areas are currently yielding low-quality groundwater, rendering it unsuitable for drinking and agricultural purposes (United Nations Educational, 2018). Additionally, the rapid exploitation of groundwater has exacerbated the strain on these already vulnerable water sources (Sayanthan et al., 2017).

2.3.4 Climate Change

Sri Lanka is divided into three main agro-climatic zones, namely wet zone (>2,500 mm), intermediate zone (2,500-1,750 mm), and DZ's (< 1,750mm) (Punyawardena, 2010). The amount of rain that falls varies significantly between seasons and years (Dissanayake, 2005). Climate change has a significant impact on human well-being and will continue to do so in the future (Esham & Garforth, 2013). Jayasekara (2017) identified some districts in Sri Lanka that received an annual average rainfall of less than 1,000 mm, classifying them as areas with extreme water scarcity districts in DZ. Drought has affected the DZ in years such as 2001, 2004, 2016, 2017, and 2018 (Alahacoon & Edirisinghe, 2021).

2.3.5 Diseases

Groundwater is essential for rural water supply (Chandrajith et al., 2012). However, water quality is poor in some districts, such as the DZ and near coastal areas (Jayasekara, 2017).

Because of that, calcium, fluoride, magnesium, sodium/potassium type, and non-dominant are found in Sri Lankan groundwater (Dissanayake, 2005). Consumption of contaminated water can cause various illnesses, some of which can be death (Jayasekara, 2017).

- **Dental fluorosis**

Dental fluorosis is a disorder in which the look of tooth enamel deteriorates (National Center Chronic Disease Prevention and Health Promotion [NCCDPHP], 2019). Dental fluorosis may occur if children drink fluoride regularly during their teeth-forming years, ages eight and younger (NCCDPHP, 2019). In the beginning, teethes are discolouration and even browning becomes obvious, and the enamel becomes eroded, pitted, rough, and difficult to clean (Jayasekara, 2017).

Table 1: WHO guideline for fluoride in drinking water

Concentration of fluoride (mg/L)	Impact on health
0.0 − 0.5	Limited growth and fertility, dental caries
0.5 − 1.5	Promotes dental health, prevents tooth decay
1.5 − 4.0	Dental fluorosis (mottling of teeth)
4.0 − 10.0	Dental fluorosis, skeletal fluorosis (pain in back and neck bones)
> 10.0	Crippling fluorosis

Source: (WHO, 2004)

The optimal fluoride level in Sri Lankan groundwater for caries protection is 0.6 - 0.9 mg/L (Chandrajith et al., 2012). Due to the use of high-fluoride groundwater, millions of people in Sri Lanka's DZ are at risk of developing some diseases Dental fluorosis skeletal fluorosis (Chandrajith et al., 2012; Jayasekara, 2017).

- **Chronic kidney disease (CKD)**

Around 500 people die each year in DZs of Sri Lanka from chronic kidney disease (CKD), which is thought to be caused by arsenic and cadmium contamination in groundwater due to agricultural pesticides (Jayasekara, 2017). CKD is a common serious health problem, with 3 - 4% of the population suffering in several villages (Jayasekara, 2017). In Sri Lanka, the emergence and prevalence of CKD with Unknown Aetiology among residents of North Central (Gunatilake et al., 2015).

2.3.6 Contemporary Water Distribution Methods

Some DZ areas are in the courtyards during the draught season to compete for water (Ariyananda et al., 2011). Water availability decreases due to population growth, limited water resources, and climatic changes, while water demand increases (Ariyananda et al., 2011). The National Water Supply and Drainage Board (NWSDB) developed a distributing of fresh, pure water by trucks and storing it in tanks of 100 litres capacity for common use by people in DZ districts, which is high in fluoride and suffers from Chronic Kidney Disease (Jayasekara, 2017). This is not a long-term solution for a community water supply because water distribution is uncontrollable and on a first-come, first-served basis (Jayasekara, 2017).

2.3.7 Population Growth

Between 2012 and 2016, the total population of Sri Lanka grew at an increasing rate of 0.42% (Sayanthan et al., 2017). As a result, water and food production demands are also increasing (Ministry of Agriculture & FAO, 2017). Groundwater is under additional stress due to the growing population (Sayanthan et al., 2017).

2.3.8 Industries Related Problem

The water scarcity problem in the DZ region affects various industries including hotels, commercial, manufacturing, and residential buildings (Chandrajith et al., 2012). Most sectors used ground water, which is under additional stress due to rapid exploitation and growing population (Sayanthan et al., 2017). The hotel industry is the most affected by water scarcity in DZ (International Finance Coorporation (IFC), 2013). Some hotels use bore wells and wastewater treatment plant water for gardening and laundry because that NWSDB supplied water is insufficient (IFC, 2013). However, there are health concerns associated with the reuse of wastewater (Shakir et al., 2017). The hotels also spend more money on purchasing bottled water for drinking (IFC, 2013). Therefore, plastic bottles are harmful to health, wildlife, and the environment (Mers, 2019). Some buildings have implemented rainwater harvesting (Lo & Koralegedara, 2015). During the dry season, hotels have to restrict their water consumption due to water scarcity (IFC, 2013). Desalination is a common solution for both people and industries to minimise water scarcity in the DZ region (Dasinaa & Delina, 2016)

3. METHODOLOGY

The comprehensive literature review to explore innovative water sustainable methods and propose desalination as a viable solution for addressing the water needs of the DZ. To conduct the literature review, books, journals, conference proceedings, dissertations, reports, newspapers, magazines, websites and government publications were used as sources. An expert survey was conducted to gather data from professionals with extensive experience in the field of water resource management in Sri Lanka. Six experts were chosen for the interviews, as they indicated that the information provided by additional participants would likely yield redundant findings, reaching a point of saturation. These experts collectively possessed over 20 years of experience in the field, with specific expertise in desalination spanning 5-10 years. These experts are directly involved with the Jaffna desalination plant, which is the first and only largest plant installed in Sri Lanka. Semi-structured interviews were selected as the data collection method to allow for flexibility in exploring participants' knowledge, insights, and experiences related to the need for desalination plants. A qualitative research approach was adopted to gain an in-depth understanding of the complex factors contributing to water scarcity and the need for desalination plants in Sri Lanka's dry zones. This approach enabled the exploration of participants' perspectives, experiences, and expert knowledge, providing valuable insights into the research problem. By employing qualitative methods, this study aimed to capture nuanced information that quantitative methods alone may not fully capture. Template analysis was chosen as the analytical framework for analysing the expert survey data. This method involves developing a coding template or a set of pre-established themes based on the research objectives and relevant literature. The template served as a structured guide to organise and categorise the data obtained from the interviews. Table 2 presents a profile of experts of the expert survey.

Table 2: Profile of experts

No	Interview code	Designation	Year of experience	Year of experience for the desalination
1	R1	Assistant General Manager	21	10
2	R2	Water Treatment Specialist	29	9
3	R3	Water Treatment Specialist	23	9
4	R4	Engineer	25	10
5	R5	Engineer	24	9
6	R6	Engineer	26	10

4. DATA ANALYSIS AND FINDINGS

4.1 IDENTIFY THE NEED OF IMPLEMENTING DESALINATION FOR THE DZ OF SRI LANKA

The need for implementing desalination was first identified from the literature (Section 2.4) and then refined based on the expert's opinions. Water scarcity is a growing problem in the DZ of Sri Lanka. Interviewee R1 stated, "*Most North and North-Central provinces face huge effects because of water scarcity"*. Currently, on top of a breakdown at the Norochcholai coal power plant, there are insufficient water levels in reservoirs for hydropower generation because of water scarcity (Jayasinghe, 2022). Interviewee R2 identified DZ districts with extreme seasonal or year-round water scarcity, such as Ampara, Anuradhapura, Batticaloa, Kurunagala, Hambantota, Jaffna, Killinochchi, Kurunegala, Mullaitivu, Polonnaruwa, Puttalam, Trincomalee, Mannar and Vavunia. According to experts, DZ currently has a water scarcity problem. In the future, it will be badly impacted to Sri Lanka. Interviewee R5 suggested, "*If the government wants to minimise water scarcity, Government should consider new technologies like desalination"*. Currently, Sri Lanka needs more alternative methods to minimise water scarcity. Interviewee R4 stated, "*Desalination is most suitable for Sri Lanka because of the location*". Sri Lanka is an island and Sri Lanka has open access to seawater. Hence, desalination is one of the best solutions to minimise the water scarcity of DZ. Through a comprehensive literature review, the criteria necessitating the implementation of desalination in the dry zone of Sri Lanka have been identified. This section examines the expert opinions and ideas concerning the identified needs outlined in the literature.

4.1.1 Irrigation Inefficiency

In ancient times, irrigation systems were designed to save rainwater collected during the short rainy seasons to maintain water supplies for human needs. Interviewee R2 identified, "*In 2007; there were 33,000 tanks in Sri Lanka's DZ; by 2021, the remaining tanks would be less than 10,000"*. According to that, most of the irrigations were left. Interviewee R5 stated "*The reason for the irrigation inefficiency is the government's poor water storage, poor maintenance, and poor water management"*. The interviewee R5 identified, most of the tanks in DZ are mostly maintained by village-level farmer organisations, not the government. The government implements several projects to increase irrigation efficiencies, such as the Mahaweli Authority of Sri Lanka, Malwathuoya, Daduru Oya, Manik Ganga and Rambukanaoya projects. Further, Interviewee R6 mentioned that "*The government started several projects to cover several*

areas of the DZ, but until any projects are not completed. The previous government started some projects, but projects were not complete until then". MASL is the largest irrigation project in Sri Lanka. Currently, MASL project's primary purpose is the provide water for the hydropower plant. Interviewee R3 mention that "*If government improve the MASL project and Malwathu Oya project can minimise the water scarcity of Anuradhapura, Polonnaruwa and Mannar districts".* The Asian Development Bank (ADB) is assisting Sri Lanka with a large government water resources project to redirect untapped water from the Mahaweli River. This is the country's largest river basin, with headwaters in the southern wet zone. The government hopes to finish the MASL project in 2024. Interviewee R6 specified that "*If the government increased the efficiency of Manik gaga project, can be covered some districts of the southern province which faced water scarcity".* According to the interviewees, when developing the irrigation system of Sri Lanka, the government can minimise the inside of the country's water scarcity.

4.1.2 Rainwater Harvesting

The government established the rainwater harvesting project in 1998. Rainwater harvesting is collecting and storing rainwater rather than letting it flow off. Interviewee R6 explained, "*The NWSDB is responsible for over 32,000 rainwater collection systems in the DZ of Sri Lanka".* Interviewee R1 mentioned that "*Rainwater harvesting plants are established in the wet zone. It pumps to the DZ for consumption".* Interviewee R2 argues that *"It is not 100% acceptable for minimising water scarcity for the DZ".* Further, Interviewee R3 specified that "*Most people in DZ establishing domestic rainwater plant to fulfil their requirements".* Rainwater harvesting is not the 100% supportive method for the DZ of Sri Lanka. The interviewees R1 and R2 argue that Rainwater harvesting is insufficient for living in one year because the rainy season is coming in once a year for the DZ. According to the DZ, the rainy season is coming from December to March. Interviewees R1, R2, and R6 stated that rainwater harvesting could cover basic human needs and is insufficient to do agriculture. Additionally, Interviewee R6 stated that "*When using the rainwater harvesting method needs to be a supporting method like developing irrigation".* As a result of the final discussion, rainwater harvesting is not a 100% possible solution for minimising the water scarcity in DZ.

4.1.3 Groundwater Depletion

Groundwater is used for drinking, industrial, agricultural, and domestic purposes in the DZ. Over 60% of Sri Lanka's population drinks groundwater from the wells. Interviewee R6 mentioned that "*Water quality is considerably low in the DZ and coastal areas".* All interviewees identified that salinity, hardness, fluoride, and agricultural pesticides lead to poor groundwater quality in the DZ of Sri Lanka. Interviewee R5 confirmed that "*There would be groundwater depletion in the future".* Interviewee R1 identified "*Population growth and the complexity of human needs"* as reasons for groundwater depletion. Interviewee R2 identified, *"Deforestation is the main reason for groundwater depletion in Sri Lanka".* Interviewee R3 stated "*Most industries discharge their wastewater into water sources".* Groundwater is water that seeps into the earth and collects. The leading cause of ground depletion is water pollution. According to the final discussion, there will be groundwater depletion in the future because of deforestation, population growth, increasing human needs and water pollution.

4.1.4 Diseases

Many people have faced some diseases because of the lack of pure groundwater. Most people in DZ consume groundwater for drinking purposes. Interviewee R3 stated "*Kidney illness is frequent in many Sri Lanka's DZ regions, particularly in the North Central Province. Recently, chronic renal failure has risen in Anuradhapura and Polonnaruwa districts".* Interviewees R1, R2, R4 and R5 indicated that most people are affected by Dental fluorosis, skeleton fluorosis and skin allergies because of the lack of pure water. Interviewee R3 stated, *"CKD has affected around 150,000 people in Sri Lanka".* Interviewees R2, R3 and R6 identified one of the reasons for the diseases is the high Total Dissolved Solids (TDS) rate of the groundwater and drinking fluoride water without filtration. Calcium, fluoride, magnesium, sodium, potassium type, and nondominant are all present in Sri Lankan groundwater; as a result of this, contaminated water can induce a variety of illnesses, some of which can be dangerous.

4.1.5 Current Distribution Methods

Interviewee R3 stated that "*Some people walk too far to find pure water".* People are time-consuming to find pure water sources in DZ. Currently, the NWSDB uses several methods to fulfil human needs. Interviewee R6 stated, *"The NWSDB supplies fresh water to villagers via trucks, which were then stored in tanks with a capacity of 100 litres".* Interviewee R5 argues that *"NWSDB supplying water is insufficient to fulfil all needs of the people and it was just temporary solution".*

4.1.6 Population Growth

The population growth rate of Sri Lanka is 0.39%. Interviewee R1 identified that *"Population growth and the complexity of human needs are reasons for water scarcity in DZ of Sri Lanka".* According to the interviewees, population growth is increasing day by day. As a result, basic human needs will increase. Due to groundwater depletion, deforestation, and water pollution, water demand will increase in Sri Lanka.

4.1.7 Climate Change

Climate change is the main reason for the water scarcity in Sri Lanka. Interviewee R3 identified that *"The DZ got the rain from December to March".* That water is insufficient to fulfil their human needs. Most of the people do agriculture in the DZ. Interviewee R6 mentioned that "*The Mannar district and a part of the Hambanthota district receive less than 1000 mm of rainfall on average, and are classified as places of severe water scarcity".* According to the interviewees, the main reason for water scarcity is climate change.

4.1.8 Water Problem in Industries

The water scarcity affected the industries which are situated at the DZ. Interviewee R6 stated, "*Most hotels, hospitals, and manufacturing companies are affected by water scarcity".* However, interviewees R1, R2, R5 and R6 explained most industries were affected by water scarcity in the past, but nowadays, many industries established minor BWRO (Brine Water Reverse Osmosis) or SWRO (Sea Water Reverse Osmosis) to supply their water requirements in the dry season. According to the discussion, several issues are identified regarding the water scarcity of the DZ of Sri Lanka. Interviewee R5 mentioned that "*The government should need to follow new technology to minimise water scarcity".* When considering the new technologies, desalination is the most upcoming

method globally. Interviewee R6 confirmed that "*Desalination is one of the best methods to minimise the water scarcity of Sri Lanka".*

5. DISCUSSION

One of the most significant worldwide challenges is water scarcity. By 2025, nearly two-thirds of the world population may face water scarcity (Gao et al., 2018). With the increase in the population, the scarcity of water resources to meet food production demands is a significant issue that will increase in the future (Porkka et al., 2016). Water scarcity currently affects more countries worldwide (Srinivasan et al., 2012). Currently used innovative methods to mitigate water scarcity, including rainwater harvesting, irrigation efficiency, sewage water treatment, and desalination have been identified in the literature. Desalination is widely used as it is seen as a sustainable, cost-efficient and energy-efficient method (Islam et al., 2018).

Abeysingha and Rajapaksha (2020) identified that water scarcity had been the most significant and natural hazard in the DZ of Sri Lanka in terms of the people affected. The Interviewee R2 identified some districts experiencing extreme seasonal or year-round water scarcity in the DZ, such as Ampara, Anuradhapura, Batticaloa, Kurunagala, Hambantota, Jaffna, Killinochchi, Kurunegala, Mullaitivu, Polonnaruwa, Puttalam, Trincomalee, Mannar and Vavunia. The literature, identified the need of desalination for DZ of Sri Lanka such as irrigation inefficiency, insufficient rainwater harvesting, groundwater depletion, climate change, population growth, and industries-related issues. According to the irrigation efficiency, Interviewee R5 stated "*The reason for the irrigation inefficiency is the government's poor water storage, poor maintenance, and poor water management"*. All interviewees mentioned that when developing the irrigation system of Sri Lanka, the government can minimise the inside of the country's water scarcity. The Literature review identified rainwater harvesting in Sri Lanka. Interviewee R1 mentioned that "*Rainwater harvesting plants are established in the wet zone. It pumps to the DZ for consumption".* Interviewee R2 argues that *"It is not 100% acceptable for minimising water scarcity for the DZ".* The interviewees R1 and R2 argue that Rainwater harvesting is insufficient for living in one year because the rainy season is coming in once a year for the DZ. Groundwater depletion is another reason for water scarcity in Sri Lanka. According to the interviewees, there will be groundwater depletion in the future because of deforestation, population growth, increasing human needs and water pollution. Many people have faced some diseases because of the lack of pure groundwater. Most people in DZ consume groundwater for drinking purposes. According to the interviewees, some diseases arise in the DZ, such as dental fluoride, skin allergies, chronic kidney diseases (CKD), renal failure, and skeleton fluorosis. Interviewee R3 stated, *"CKD has affected around 150,000 people in Sri Lanka".* When discussing about the current distribution methods, Interviewee R6 stated, *"The NWSDB supplies fresh water to villagers via trucks, which were then stored in tanks with a capacity of 100 litres".* Interviewee R5 argues that *"NWSDB supplying water is insufficient to fulfil all needs of the people and it was just temporary solution."* Interviewee R1 identified that *"Population growth and the complexity of human needs are reasons for water scarcity"*. Climate change is the main reason for the water scarcity in Sri Lanka. Interviewee R3 identified that *"The DZ got the rain from December to March"*. That water is insufficient to fulfil their human needs. Interviewee R6 stated, "*Most hotels, hospitals, and manufacturing companies affected water scarcity"*. R1, R2, R5 and R6 explained most

industries affected water scarcity in the past, but nowadays, many industries established minor BWRO or SWRO to supply their water requirements in the dry season. According to the discussion, several issues are identified regarding the water scarcity of the DZ of Sri Lanka. Interviewee R5 mentioned that "*The government should need to follow new technology to minimise the water scarcity"*. Additionally, all interviewees highlighted the significant challenge faced by Sri Lanka in establishing desalination plants, which is the high cost involved. The economic crisis further exacerbates the difficulty for the government in establishing such plants. However, it is important to note that the establishment of desalination plants has the potential to generate future income for the government.

Table 3 summarises the factors that have been identified through the data analysis and findings.

Table 3: Summary of research findings

Literature Findings	Data Collections Findings
Irrigation inefficiency	▪ The reason for the irrigation inefficiency is the government's poor water storage, poor maintenance, and poor water management. ▪ Most of the tanks in DZ are mostly maintained by village-level farmer organisations, not the government. ▪ The government started several projects to cover several areas of the DZ, but until any projects are not completed. The previous government started some projects, but projects were not complete until then. ▪ If government improves the MASL project and Malwathu Oya project can minimise the water scarcity of Anuradhapura, Polonnaruwa and the Mannar districts. ▪ If the government increased the efficiency of Manik ganga project, can be covered some districts of the southern province which faced water scarcity.
Rainwater Harvesting	▪ Rainwater harvesting is not 100% acceptable for minimising water scarcity for the DZ. ▪ Most people in DZ establish domestic rainwater plants to fulfil their requirements. ▪ Rainwater harvesting is insufficient for living in one year because that rainy season is coming in once a year for the DZ. ▪ rainwater harvesting could cover basic human needs and is insufficient to do agriculture. ▪ When using the rainwater harvesting method needs to be a supporting method like developing irrigation
Groundwater depletion	▪ Water quality is considerably low in the DZ and coastal areas ▪ salinity, hardness, fluoride, and agricultural pesticides lead to poor groundwater quality in the DZ of Sri Lanka ▪ salinity, hardness, fluoride, and agricultural pesticides lead to poor groundwater quality in the DZ of Sri Lanka. ▪ There would be groundwater depletion in the future. Because of Population growth and the complexity of human needs, Deforestation and water pollution
Current distribution methods	▪ The NWSDB supplies fresh water to villagers via trucks, which were then stored in tanks with a capacity of 100 litres. ▪ NWSDB supplying water is insufficient to fulfil all needs of the people and it was just a temporary solution."

Literature Findings	Data Collections Findings
Population Growth	▪ Population growth and the complexity of human needs are reasons for water scarcity in DZ of Sri Lanka
Climate change	▪ The DZ got rain from December to March. That water is insufficient to fulfil their human needs ▪ The Mannar district and a part of the Hambanthota district receive less than 1000 mm of rainfall on average and are classified as places of severe water scarcity. ▪ Identified DZ districts with extreme seasonal or year-round water scarcity, such as Ampara, Anuradhapura, Batticaloa, Kurunagala, Hambantota, Jaffna, Killinochchi, Kurunegala, Mullaitivu, Polonnaruwa, Puttalam, Trincomalee, Mannar and Vavunia.
Water problems in (industries)	▪ Most hotels, hospitals, and manufacturing companies are affected water scarcity. ▪ most industries affected water scarcity in the past, but nowadays, many industries established minor BWRO (Brine Water Reverse Osmosis) or SWRO (Sea Water Reverse Osmosis) to supply their water requirements in the dry season.

6. CONCLUSIONS

Water scarcity is insufficient water for human and environmental uses. It is increasingly recognised as a serious and growing problem in many countries (White, 2014). Through the literature reviewed identified rainwater harvesting, desalination, sewage treatment, and improving irrigation efficiency as a current innovative method used for minimise the water scarcity. Desalination is a most sustainable innovative method used in all over the world. Desalination is becoming a more efficient method of supplying fresh water in many countries where it is scarce. Currently, seawater desalination is deployed at 67% of the existing capacity around the world. Through the literature identified, water scarcity is a growing problem in Sri Lanka. The need for establishing desalination plants in the DZ was identified due to various factors (09) such as irrigation inefficiency, insufficient rainwater harvesting, groundwater problems, climate change, population growth, and industries related issues. These nine factors are discussed with the experts. According to an interviewee R5, identified the reason for irrigation inefficiency in Sri Lanka is due to poor water storage, maintenance, and management by the government. All interviewees agreed that by improving the irrigation system, the government could minimise the inside of the country's water scarcity. Rainwater harvesting has been identified in literature review, but interviewee mentioned it is not considered a complete solution to water scarcity due to the limited rainy season. Identified the depletion of groundwater another reason for water scarcity. The interviewees are identified, Groundwater depletion in the future is a concern due to factors such as deforestation, population growth, increasing human needs, and water pollution. Lack of pure groundwater has resulted in health issues, including dental fluoride, skin allergies, chronic kidney diseases, renal failure, and skeleton fluorosis, with CKD affecting around 150,000 people in Sri Lanka. The current supply of fresh water from NWSDB is considered insufficient. Population growth, complexity of human needs, and climate change are also contributing to water scarcity. The government is advised to adopt new technology and desalination is seen as the best method to minimise water scarcity.

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