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CONDENSATION, DESALINATION, AND WATER RECYCLING TO ENCOUNTER WATER STRESS

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***Abstract* –** Water is a gift of life from Allah. In Al-Quran, it is stated "And We sent down from the sky water (rain) in (due) measure, and We gave it lodging in the earth, and verily, We are able to take it away." (1). Though water is indispensable for life and livelihoods, it is becoming a world-pressing societal and geopolitical critical issue, knowing that 800 million people worldwide cannot afford primary access to potable water and that nearly 2.2 billion people lack access to a safe water supply. As a result, freshwater scarcity is now the world's second most pressing concern, after the prompt population increment issue. If the problem of freshwater scarcity persists, 'the world will miss water-related SDGs by a wide margin'; more than 40% of the world's population will be living in ever-seriously water-stressed regions by 2035 (2); ecosystems will become weakened and will be unable to meet population freshwater supply ; and developing countries will be the most affected, with 80% of their illnesses caused by a lack of access to water as well as poor water quality. To tackle the increased water shortage, reasonable water management methods are required. This article proposes three efficient sustainable water techniques for producing fresh water and thus meeting water scarcity's massive demand, along with their benefits and drawbacks. They are Condensation, desalination, and water recycling.

Keywords – Water Scarcity, Drivers, Condensation, Desalination, Water Recycling

I. INTRODUCTION

Water is an essential source of life, not only for human survival and development but also for ecosystem support. Because of the intrinsic value of water, researchers have paid close attention to the issue of water scarcity, which has become the 21st century's second pressing concern after the rapid population increase. It is estimated that over one billion people worldwide lack access to safe drinking water. There are several drivers of water stress. The three key ones: are climate change, rising population growth, and increased demand for safe drinking water sources. It is necessary, thus, to find efficient and sustainable alternatives to meet global water demand to overcome water scarcity.

DEFINITION OF WATER SCARCITY

Even though water scarcity is broadly defined as the need for access to adequate amounts of water for human beings and the environment and is increasingly considered a crucial concern in several countries, the term hence becomes frequently utilized by mass media, governmental and non-governmental organizations, and by scholar, studies to shed light on the water under pressure areas, there is no consensus on how water scarcity should be defined or measured. As a result, a reference to water scarcity in one report may measure something different than a reference to the same term in another report. This can lead to misunderstandings about what exactly water scarcity means, as well as conflicting answers to.

The question of which regions are most water-stressed. There are some methods of defining and measuring water scarcity for readers to understand what is meant in each case (64).

CRİTERİA OF WATER SCARCİTY

Aiming at eliminating confusion with respect to water scarcity indications, this article suggests three methods that indicate the criteria for water shortages :

A. First method

The 'Falkenmark indicator' or 'water stress index' is one of the most widely used measures of water scarcity. According to this method, water shortage is measured by determining the availability of water resources to a region's population and the quantity of renewable freshwater provided for each person each year. If a country's renewable water supply is less than 1,700 m3 per person per year, it is said to be experiencing water stress; less than 1,000 m3 is said to be experiencing water scarcity; and less than 500 m3 is absolute water scarcity (3).

B. Second method

A criticality ratio is another method for defining and measuring water scarcity. This method renounces the hypothesis that all countries have similar water quantity consumption. Water scarcity is measured by assessing each region's water demand regarding the quantity of available water; it is calculated as the percentage of overall yearly groundwater extraction compared to one of the available sources of water. 3. According to this approach, a country is considered water-stressed if the percentage of water withdrawals is somewhere between 20-40% of the annual national supply, and a serious water shortage if 40% is exceeded (4).

C. Third method

The International Water Management Institute created a third measure of water scarcity (IWMI). This approach seeks to address the issues raised above by incorporating: national infrastructure, like water desalinating plants as an indicator of water availability embedding water recycling by trying to limit indicators of water demand to production and consumption instead of measuring cumulative water withdrawals; and assessing a country's adaptive capacity by evaluating its infrastructure and effectiveness improvements (5).

TYPES OF WATER SCARCİTY

When a person cannot afford or obtain safe water to meet their drinking, bathing, or their livelihood, this is referred to as that person's lack of access to water. Consequently, we can refer to an area as being water scarce when a significant number of people live without access to water for an extended length of time (6).

Water scarcity was separated into two categories: physical and economic one:

- A- Physical scarcity : indicates that a shortage of water is a more serious issue in some areas. Physical access to water is limiting, and in desert or dry areas of the world, water demand outstands the capacity of the land to supply it (7).
- **B-** Economic scarcity: It is undoubtedly that economic scarcity is the most concerning type of water scarcity because it is due to a lack of care and effective governance that the problem is allowed to persist. Factors, including racial and political conflict and uneven water distribution, are the main reasons for economic water scarcity(8).

DRİVERS OF WATER SCARCİTY

Water scarcity is currently regarded as one of the most pressing issues of the twenty-first century. Four major factors contribute to water scarcity: demographic and economic factors, environmental factors, and governmental factors.

A-Demograpghic and economic drivers :

The link between overpopulation and economic factors and water scarcity is straightforward. As the population grows, the amount of water available decreases. In other words, demographic and economic growth increase the demand for Waterland significantly contributing to scarcity and supply and demand imbalances. The world's population is increasing at a rate of 80 million people per year. That is, in order to meet the world's water needs, we are attempting to provide an additional amount of approximately 64 billion cubic meters of water. It is worth noting that only about 3% of the water-covered surfaces are currently used as freshwater by humans. Furthermore, water scarcity affects 1.1 billion people worldwide, and approximately 2.7 billion experience water stress at least once a year. (10) (4). Realizing that economic causes can lead to water scarcity as well because people in need cannot afford or obtain water services (11). Noting that people from disadvantaged and wealthy families are denied access to water in locations with water scarcity. While excluded and poor groups cannot afford safe water in areas with abundant water supplies (12) (13). Therefore, it is crucial to pay close attention to issues such as public and private water system control, unequal distribution of water technologies and infrastructure, deep-seated social, political, religious, and racial discrimination, as well as increasing water shortage and inability to pay water expenses (14)(15)(16) (17) (18) (19) (20) (21). Furthermore, according to World Bank statistics from 2010, the agricultural sector consumes approximately 93% of water, whereas the industrial and domestic domains consume approximately 7%, as illustrated below:

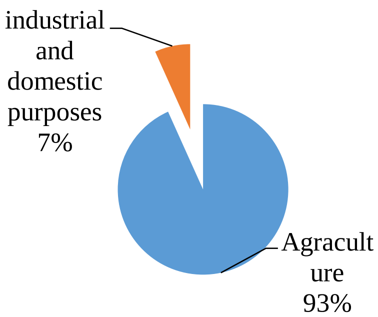


Fig. 1 Percentages of water consumption per sector

B-Govermental Management drivers

Government mismanagement leads to water scarcity, such as a lack of appropriate infrastructure, insufficient water management systems, and a dictatorship. Institutional policies may prevent populations from being satisfied with water by locating them far from water sources such as abundant watersheds, springs, rivers, and so on...... Furthermore, they reduce population water consumption while using a significant amount for other purposes such as environmental protection and ecosystem restoration, as happened in the United States in 1992. when Congress passed the Central Valley Project Improvement Act indicated a billion cubic meters of water would be dedicated to ecosystem restoration, specifically to improving the health of anadromous fish populations. As a result, farmers' water allocation was limited, groundwater surfaces were degraded, and California water disputes arose and were still unsolved for three decades. Besides, some political regimes impose dictatorship on their people to control them by denying them access to water. (22) (4).

C- Envoronmental Drivers

Tow Environmental fingerprints are the primary environmental drivers of water scarcity. The latter is remarked in areas that lack developed sewage systems. It has a significant impact on living things whose survival depends on water consumption (4) (22).Human-induced climate changes are becoming remarkable. They have primarily caused drastic changes in the hydrologic cycle, with evapotranspiration rates rising due to high temperatures, regional shifts in water and ice stocks and flows, severe droughts and extreme floods, freshwater imbalance in coastal aquifers and estuaries due to rising sea levels, and more (23). Noting that, It has recently been demonstrated that climate change impacts are to be held responsible for the seawater quantity being increased, especially by tropical cyclones that provide water, the river flows being accelerated due to snow and ice melting, augmenting evaporations emitted from reservoirs, and intense and severe droughts (50-56) Climate change also contributes to fresh water supply and demand imbalances that result in water scarcity. To sum up, as climate change worsens, the threat of water shortage for hundreds of millions of people increases, and the chances that attempt to reduce the effects of water scarcity would be successful decrease (42) (25).

TECHNIQUES TO ENQUENTER WATER SCARCİTY

There are now several techniques for expanding water access. However, due to expensive and limited investment, they are still out of reach We will concentrate on the most recent approaches to dealing with water scarcity in this study.

A- Condensation

Water droplets, which make up clouds, can also be found in clean air. Its volume is estimated to be 3,100 cubic miles, making it larger than some of the world's largest lakes. Scientists are developing extraction plans using various methods that could benefit "where water is scarce or difficult to purify" as advanced materials, making it easier to extract drinking water from thin air. Among these techniques are: (26)

Collecting water from solar energy

This method involves removing water from the air by evaporating water using solar energy and collecting the condensed vapor as purified water. This method has now been improved through the use of modern technology, and it is more efficient and effective. thanks to the efforts of engineers from two universities in the United States. They accomplished vapor condensation by employing carbon paper evaporators and polydimethylsiloxane condensers, which absorb less energy and emit more energy even when exposed to direct sunlight. Rich Groden and David Hertz's team developed the patented Adiabatic Distillation Process. Without adding or subtracting heat, the machine converts vapor droplets to liquid. After condensing, the water is filtered, ozone-treated, and stored for later use. The following illustration show how drinking water is produced from the air condensation process :

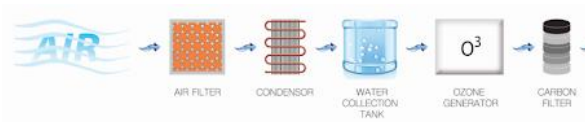


Fig. 2 Water Production From Air Condensation Process

Collecting water from desert air

Engineers at MIT and the University of California, Berkeley have also developed a system that uses metal-organic frameworks to collect water from desert air. The system functions as a network of porous crystals that can draw in and store a large amount of water. Noting that the air is drawn in at night, saturating the crystals with water from the air and that the daytime heat releases and condenses the water in the morning, as it is shown in the following illustration:

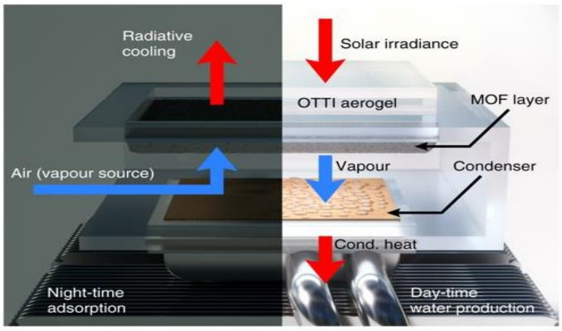


Fig. 3 water production from desert air process

Collecting water from humidity

Another method used by Arizona-based Zero Mass Water is to extract humidity from the air and condensate it into the water using solar panels. Panels are inexpensive and can be used in a variety of settings around the world, including police stations, schools, and homes. It is worth noting that after Cyclone Pam destroyed around 70% of the island's water infrastructure in 2015, panels provided 3,000 liters of clean water to Petros Primary School in Tanna, Vanuatu.

Fig. 4 Panels providing water for cyclone victims

Collecting water from air vapor droplets

Drinking water can also be produced by extracting water vapor droplets from the air, filtering it, and sterilizing it. South African company has implemented this method. The machine's process involves the vapor passing through condensing coils, which convert it into water liquid. The latter is then placed in a UV light-fitted tank capable of removing pathogens, algae, and bacteria.

Finally, the water is filtered, fed with minerals, and treated with UV-light sterilization, and the liquid can be used as drinking water.

B-Disalination

Our planet contains 98% of its water in the form of oceans. That is why seawater is regarded as an infinite source of water. To benefit from this valuable resource, desalination of marine water is the most reasonable method of providing potable water to populations. Desalination is the process of converting saline water to potable water(28) (29). Desalination processes are classified into two types: single phase (membrane processes) and phase change (thermal processes) (30) (31) :

- Single phase (membrane processes): It aims to widespread the use of membranes for desalinating saline water. It is classified into several types, including commercial desalination processes such as Electro Dialysis (ED) (32) (33) (34). and Reverse Osmosis (RO) processes(32) (31) (35) (36).
- Phase change (thermal processes: It depends on the thermal energy sources such as fossil fuels, solar energy, or nuclear energy would be employed for saline water vaporization followed by condensation to produce fresh water. Multi-Stage Flash (MSF) distillation , Solar distiller, Vapor Compression (VC) distillation, Multi-Effect (ME) distillation, Ultrafiltration (UF) membranes [18-22], and crystallization (Hydrate Freezing) are some examples. (32) (38) (39) (30) (40) (31) (41) (42) (24).

The methods mentioned above have proven to be effective in different situations. They do, however, have some significant side effects. Some necessitate large investments, costly maintenance, intensive energy use, inability to remove total impurities, and unaffordability, particularly in rural areas(40) (31) (44) (45). Recently, Other innovative desalination methods have been developed, with the gas hydrates method being the most appealing for several reasons, including ion exclusion, lower investment costs, and lower energy consumption (41)(43) (46) (47)(48) (49). The hydrate-based water desalination process is based on the phase change phenomenon, which converts liquid water into solid by extracting the dissolved solids from the liquid water. To put the gas hydrate desalination process into action, a hydrate former is required to mix it with the produced water in a hydrate reactor, then separated using hydrate formation in a crystallizer. The following figure depicts the phenomena of hydrate-based water desalination (50).

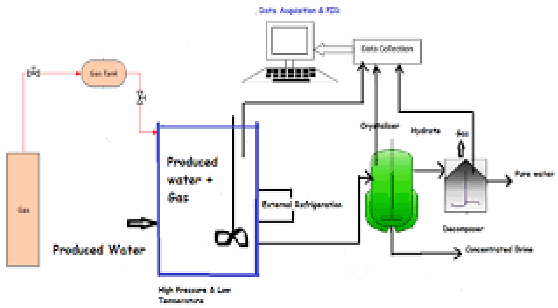
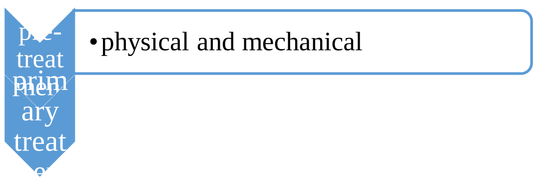


Fig. 5 Schematic flowsheet of Gas hydrate-based water desalination process(50)

D-Water recycling

When water is scarce and can be recovered from wastewater, the best purification method is required to decontaminate polluted water. In general, the purification process consists of five main steps: 1) pre-treatment (physical and mechanical); 2) primary treatment (physicochemical and chemical); 3) secondary treatment or purification (chemical and biological); (4) tertiary or final treatment (physical and chemical); and (5) sludge treatment (supervised tipping, recycling, or incineration) (51). The type of wastewater to be recycled determines how water reuse methods are implemented. There are two types of wastewater treatment techniques: non-conventional wastewater treatment techniques and conventional wastewater treatment techniques, as illustrated bellow



Conventional techniques

Conventional techniques

Conventional techniques for extracting pollutant metals are increasingly unable to respond to recent waste parameters and are prohibitively expensive in some areas. Thus, further advancements are being made to find alternatives. These techniques are based on several factors, including waste type and fixation, profluent heterogeneity, and the required size of cleaning up. There are several waste treatment conventional techniques, including (52) :

Activated Sludge: "activated sludge" refers to suspending developed organisms to remove pollutant solids and BOD. The technique does not necessitate a large installation area and produces good waste treatment results. However, the only side effect is the retention of a large amount of BOD in tank (53).

Trickling Filter: Trickling filters are regarded as an expert technique due to their exceptional ability to remove pollutant substances such as solids and BOD. The technique is not as complex as activated sludge, but it is more expensive because it requires electrical power for maintenance and operation, as well as skilled labor to keep the trickling filter operation free of problems such as "prevent clogging," "ensure adequate flushing," and "controls filter flies" (53).

Rotating Biological Contactor: The aerobic Rotating Biological Contactor (RBC) is a biological wastewater treatment method. The RBC, unlike other wastewater treatment techniques, has biological applications because it is linked to biological fixed-film: "short hydraulic retention time," "high biomass concentration," "low energy cost," "easy operation," and "insensitivity to toxic substance shock loads." As a result, the RBC method is widely used in industrial and residential wastewater treatment (55)(56).

Membrane Bioreactors: The membrane bioreactors technique necessitates more than one treatment phase. By implementing biological wastewater-treatment systems, MBRs distinguish themselves by combining aerobic and anoxic biological treatment with an integrated membrane organism that can be used with the most suspended pollutant growth (55).

Non-conventional techniques

Non-traditional biological methods require more land than conventional methods because they use low-tech, low-cost hardware and less sophisticated tools for maintenance and biologically treating municipal wastewater. They will always be effective at extracting pollutants and pathogens if carefully planned and not overutilized41. Here are some examples: There are a few unusual techniques (57).

Waste Stabilization Ponds :Wastewater Stabilization Ponds (WSPs) are large open basins in which domestic wastewater, septage, sludge, and animal or industrial wastes are treated and processed naturally in centralized or semi-centralized sewerage systems and under the influence of solar light, wind, microorganisms, and algae. The technique can be used individually or dependent on improved treatment series. There are three common types with different characteristics and designs are three: (1) anaerobic, (2) facultative, and (3) aerobic (maturation) (58). However, studies have confirmed that WSPS are ineffective in cold climates and may necessitate more land or longer detention times. In addition, odor can be a nuisance during algal blooms, anaerobic lagoons, and poorly maintained lagoons (59).

Constructed Wetlands :Constructed wetlands (CWs) are engineered structures that mimic natural simultaneous physical, chemical, and biological wetlands and are used to treat various types of wastewater. Natural removal mechanisms from wetland wetlands plant vegetation, soil, and associated microbial populations are used to implement CWs. The three types of constructed wetlands are: 1) constructed wetlands with horizontal subsurface flow, 2) constructed wetlands with horizontal free water surface flow, and 3) constructed wetlands with the vertical flow.CWs methods are tools for removing suspended solids, organic materials, nutrients, heavy metals, pathogens, and toxic pollutants from industrial and municipal wastewater, as well as environmentally friendly alternatives for secondary and tertiary treatment. They are, however, woefully inadequate for raw waste treatment and industrial wastewater pre-treatment (60) (61).

Oxidation Ditches:Oxidation Ditches (OD) are a process that is composed of a variety of comprehensive aeration processes. The latter are efficient wastewater recovery systems. They can operate in a single channel or multiple channels, reaching depths of 6 to 12 feet in general and with 45-degree sloping or straight sidewalls. Nonetheless, only oxidation ditches #2 and #3 are operational, as opposed to oxidation ditch #1, which has been out of service for three years due to aeration pipe failure. (62). Nonetheless, the OD technique has environmental drawbacks because water is moved through ditches by rotors powered by electricity, which emits sulphur dioxide and other contaminants into the atmosphere from coal-burning power plants (63).

II. CONCLUSION

Water scarcity is gaining attention among scientists due to its serious consequences for human health and the environment. This paper provides an overview of water stress, focusing on scarcity indicators, social, economic, and environmental drivers, as well as some conventional and non-conventional solutions to the water shortage problem. Future research must concentrate on other solutions to overcome the lack of access to potable water.

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