Thirsty World: Examining the Causes and Consequences of Water Scarcity

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Abstract

Over the past few decades, human activity has increasingly accumulated pressure on clean water resources to the point where we have reached scarcity. Water scarcity has become a global crisis, not only threatening the availability of drinkable water but also impacting the stability of natural ecosystems, economic productivity, and environmental health. Specifically exploring how inefficient irrigation, nutrient runoff, textile production, and urbanization intensify water contamination and exhaustion, the paper suggests respective solutions such as precision irrigation, water recycling, and pollution control systems. Additionally, the essay recognizes the inordinate effect that water scarcity has on marginalized communities, highlighting that limited access to water can disproportionately exacerbate opportunities in health, education, and economics. This paper examines the scope of water scarcity, root causes, diverse impacts, solutions, and future visions for the problem, thus advocating for readers to recognize their role in a collective society to promote sustainable water management and an equitable future for clean water resources.

Understanding the Scope of Water Scarcity

Imagine waking up in the morning, realizing that your kitchen faucet runs dry – no water to drink, no water to shower or make coffee. According to recent statistics, water scarcity is a common occurrence, and about "1.1 billion people lack access to water, and 2.7 billion experience water scarcity at least one month a year" (Overview on Water Scarcity). More specifically, research also indicates that about 2.2 billion people lack access to clean drinking water, and 3.5 billion people lack access to safely managed sanitation.

These statistics indicate a global crisis that will soon inevitably spread to billions of people, including those in currently water-rich regions. The implications of these are concerning, especially given the importance of water in human life. Composing around 45-75% of the human body, clean water is considered one of the most essential commodities of humanity (Helmenstine). Water is vital in regulating body

temperature, eradicating unnecessary body waste, providing nutrients to our cells, and protecting our organs and body structures (Rozen-Rechels). It widely supports the survival and growth of plants and animals, playing the biggest role in biodiversity preservation between the natural resources that are common in our societies (Water Scarcity).

Furthermore, the importance of water can also be identified in its role in preserving biodiversity in an ecosystem such as in freshwater ecosystems. Opposed to marine ecosystems that have high salt concentrations, freshwater ecosystems – rivers, lakes, ponds – consist of bodies of water that are low in solute concentration.

However, as water scarcity intensifies, the intricate balance of these ecosystems will be threatened, likely leading to an insufficient supply of freshwater for survival and, hence, the extinction of living organisms in these ecosystems.

This water scarcity can be categorized into two main types in our society based on their underlying causes: physical and economic water scarcity. Physical scarcity is the commonly discussed type and is defined as the water scarcity that emerges due to insufficiencies in meeting our population's demands. It includes the lack of water resources, especially in dry areas, overexploitation, and geological factors, such as limited rainfall (Giordano). Physical scarcity is most experienced in the Middle East, in countries such as Saudi Arabia and Jordan. They struggle to meet their populations' needs, as they lack water resources.

Economic water scarcity, on the other hand, is when a population has adequate water resources but lacks investment in water-collecting infrastructure and efforts to preserve these water resources. It is the absence of proper water management (Petruzzello).

Communities that experience high economic water scarcity usually tend to be the ones with high rates of poverty, as obtaining water supplies takes much time and effort that could rather be spent on other productive activities required for the community, such as education or employment. Moreover, experts' predictions indicate that as the human population continues to grow, we are expected to experience much more scarcity in our water resources than before (Water Scarcity – One of the Greatest Challenges of Our Time). Thus, it is against this background that this essay aims to examine the issue of water scarcity, focusing on the causes, impacts, and technological solutions.

Root Causes of Global Water Scarcity

To understand water scarcity in a deeper context, it is crucial to examine the key contributing factors. Some of these factors, as identified by research, include agriculture, water pollution, and Human manufacturing.

Agriculture plays a big role in the increasing rates of water scarcity, as it requires the most freshwater resources to operate out of all the human activities in the world, withdrawing approximately 70% of the world's freshwater (Water Scarcity – One of the Greatest Challenges of Our Time). It involves the use of

water in various ways, such as through irrigation of crops, watering livestock, or processing food sources. For instance, although irrigation is essential in improving crop yield and supporting the maintenance of sustainable farming practices, it is known to cause overuse of water and inefficient water usage. Attesting to this, a U.S. Geological report shows that irrigation accounts for 42% of the United States' total water withdrawals. Additionally, it was reported that 40% or more of the water that is used for irrigation is wasted at the farm level through evaporation and percolation (The Practice of Irrigation). This means that only 40-50 percent of the water used is being effectively utilized for irrigation, representing a substantial loss of water resources. On the extreme end, Haryana, India, specifically had wasted up to 70% of the water used for irrigation. These clear inefficiencies definitely contribute significantly to the further depletion of water resources, mainly in already stressed areas (70% of Irrigation Water Is Wasted: Mohapatra). When such large amounts of water are lost, the severity of water scarcity amplifies, undermining agricultural productivity in these areas. This, in turn, accelerates the decrease in food resources, correlating to the rise in food insecurity and production costs.

Additionally, water pollution has also been identified as a notable cause of water scarcity. Water pollution refers to the contamination of water bodies (such as rivers, reservoirs, lakes, oceans, etc.) by various undesirable or unwanted substances such as trash, organic or inorganic substances, etc. (Lin et al.). According to research, 15,000 water bodies are affected by nutrient pollution in the US, and approximately 10% of the world's population consumes food irrigated by wastewater. While crop irrigation is the largest source of water waste, livestock farming is the primary factor in agricultural water pollution, as they require the most use of water that is often mismanaged. Large-scale livestock farming typically produces immense amounts of animal waste, which contains high levels of nitrogen and phosphorus, as well as harmful pathogens. If these operation facilities leak, the pollutants will enter nearby waterways and contaminate rivers and groundwater. Moreover, the contamination of groundwater will decrease the amount of available clean water. Polluted groundwaters will soon become unsuitable for human consumption. This is more severe due to the fact that groundwaters are more susceptible to these chemical substances than surface waters, which can generally purify themselves over time.

Another large contributor to water pollution, though not nearly as detrimental as agriculture, is human manufacturing. Human manufacturing systems account for up to around 12% of global water withdrawals through industry-specific demands, placing additional strains on freshwater resources and contributing to industrial waste and runoff. Specifically, textile and garment manufacturing processes require the most water. It is known that manufacturers use around 2866 gallons of water for the production of a single pair of jeans. This is because of the intensive water consumption for every single stage of production, from cotton cultivation to the final

washing processes. For instance, cotton, which is the primary material that makes up denim, needs immense amounts of water irrigation as it is a water-intensive crop. It takes up to 10000 liters of water on average to produce a kilogram of cotton due to the long-term growth and high water transpiration rates. Even after the cultivation of cotton, factories still needed to do their wet processing, dyeing, cooling, and washing. After the factories first undergo processes of making cotton into fabric, they move on to wet processing, where cotton is scoured (prepared for bleaching), bleached, and dyed. According to the PLOS sustainability and transformation, the whole process consumes around 164 liters of water per kilogram of textile material, with a standard deviation of 81.8 (Uddin). This highlights the strain that textile production places on water resources.

Moreover, manufacturing industries such as textile industries will further cause problems relating to water scarcity by setting up factories near urban areas that can provide labor and infrastructure. These establishments lead to rapid city growth due to the increase in people from rural areas who strive for employment, ultimately increasing the demand for water further. This would put more stress on water resources, making it harder for water scarcity to be combated in the future.

Socioeconomic and Environmental Impacts of Water Scarcity

The repercussions of water scarcity can be observed in diverse domains, with human, economic, and social health being the most predominant areas.

Firstly, water scarcity leads to a reduction in the supply of clean drinking water. When clean drinking water is unavailable, and humans have to rely on contaminated water, we are exposed to many different kinds of waterborne diseases, such as cholera, typhoid, and dysentery. These bacterial infections can lead to severely harmful symptoms such as diarrhea, high fever, abdominal pain, and dehydration, ultimately making a deadly impact on our populations. For instance, untreated cholera was reported to have a mortality rate of 50-60% (Tulchinsky et al.), killing half and more of the population that was infected. One large example is the cholera outbreak in Zimbabwe in 2018, which killed 48 people out of the 98 that were confirmed as a case alone during this period.

Furthermore, adequate water resources are also essential in maintaining proper sanitation and hygiene. In areas with high water scarcity, people may not have access to clean water to clean their homes and wash their hands and bodies properly. Thus, as people lack access to basic hygiene practices, water scarcity can exacerbate public health issues further by increasing the risks of infectious diseases such as dysentery, cholera, and hepatitis A. Impure facilities in households and societies may lead to open defecation, contaminating additional water resources and sustaining the diseases for a longer period of time (The Consequences of the Lack of Water). Increasing levels of water scarcity also negatively impact our economy, affecting diverse sectors of society, including agriculture, manufacturing industries, and energy production. As explained above, agriculture requires the most water resources

among human industries. If water scarcity continues, we will not be able to maintain our agricultural production at the same rate and will experience an immense decrease in our food sources and raw materials. In the process, farmers will lose crop yields, increasing production costs and ultimately leading to higher food prices. This cycle will not only affect farmers unfavorably but will also negatively impact consumers and their surrounding communities, particularly in marginalized and low-income communities. The potential reduction of food crops would exacerbate food insecurity and hunger around the world, particularly in vulnerable regions (Dolan et al.).

Additionally, water scarcity can also cause industries that require large amounts of water to experience higher operational costs and lower productivity. These factors can all lead to a long-term economic decline in these regions, as water won't be as abundant as before, which would, in turn, decrease the activity of companies, leading to increased job losses and decreased productivity.

Overall, in a region that depends heavily on these industries, societies will collapse in their economic stability, affecting other communities that are related to the specific region. This collapse in economic stability will also directly affect our social stability, as it will aggravate existing inequalities further. For instance, water scarcity will disproportionately affect marginalized communities that generally have less access to water compared to other wealthy communities. Similarly, marginalized people such as women and children that have to travel a long distance in order to acquire water resources will be negatively impacted, as they will lose much of their time that could otherwise be spent with their families, working, earning education, etc. (Khalsa)

Furthermore, if water scarcity worsens in a specific region, the people who live there will start migrating to other areas, which will lead to overpopulation and much more exacerbation in water demands and scarcity, which will ultimately lead to the depletion of societies.

Solving water scarcity is intrinsically related to environmental justice, as it protects ecosystems and humans while solving the inequalities and problems that arise in marginalized communities. As water scarcity is combated, humans and the environment that surrounds us will be protected and guaranteed with the provision of basic necessities. No matter the race, nationality, income, or situation, all people will have access to a healthy environment, with everybody having equitable access to natural resources, ensuring environmental justice.

Technological Approaches to Address Water Scarcity

Several technological approaches can be adopted to reduce water scarcity. For example, technology can be used to modify the irrigation process in order to avoid water usage and increase water management and efficiency. One such technology is the new innovative water-saving system, named "Smart irrigation" or "Precision irrigation," designed to maximize water efficiency in agriculture (Hossain et al.).

Similarly, an example of advanced irrigation technology is a weather-based irrigation controller (WBIC), which is a real-time weather database and landscape condition monitoring system that can provide information on the optimal amount of irrigation water needed. The smart technology can reduce water usage by 15-40% compared to traditional irrigation systems (FEMP). This can mean a pivotal change from the traditional method of irrigation into a much more advanced and efficient way of water usage. Additionally, another example is the subsurface drip irrigation system, a process that involves the installation of drip lines below the soil surface. This can lead to the minimization of water loss through evaporation, reduction of manual labor, improved crop health, and disease prevention through strong and effective rooting systems.

Furthermore, water recycling and reusing techniques are also another approach to addressing water scarcity (Water Recycling and Reuse). Adopting these techniques can lead to significant reductions in water consumption at the household level, contributing to a more sustainable use of water resources overall. Attesting to this, MDPI states that recycling gray water at household levels can save up to 57% of freshwater resources. Moreover, the process of water recycling is fairly simple: collecting wastewater from homes (sinks, showers, and washing machines), businesses, etc (Shady). After the collection, water undergoes some treatments to make it clean and usable, removing dirty particles between the H2O particles. The treatments vary in complexity depending on the use of recycled water: basic filtration, membrane filtration, or chemical treatments. These techniques can be used in agriculture, industrial processes, etc., enhancing efficiency in water usage in the future.

Additionally, it is important to note that improving water efficiency alone isn't sufficient enough to address the broader issue of water scarcity. As mentioned earlier, water scarcity isn't only due to the overexploitation of water but also the mismanagement and inefficiencies when using it ~ the inefficiencies that are plausible to cause water pollution. To prevent water pollution, we can use pollution control technologies. These technologies include WWTPs (wastewater treatment plants), filtration systems, and bioremediation (Nti et al.). WWTPs are facilities that treat sewage and industrial wastewater by physical, chemical, or biological methods based on the specific types of contaminants present. The pivotal technology keeps natural water bodies from being filled with toxins and contaminants, separating solids and neutralizing harmful chemical substances to save animals and wildlife. Filtration systems are systems that remove pollutants and kill particles (bacteria) so that no unwanted chemicals are in the freshwater resources. Water that has passed through a filtration system is free of contaminants and impurities and is, therefore, more suitable for personal consumption.

Last but not least, bioremediation is a technique that uses microorganisms or plants to degrade pollutants from water. Although being limited to organic contaminants, it has great potential for cleaning up polluted waters. These

technologies have impacts beyond environmental protection. By helping keep water resources clean, they positively contribute to public health, economic stability, and long-term sustainability, ensuring that both human populations and ecosystems can thrive.

Lastly, smart water management systems in the future can revolutionize how we conserve and manage water resources. Smart water management systems use sensors and IoT devices to gather real-time information about water flow, pressure, quality, and consumption (Olatunde et al.). This information is used in human water management, identifying our usage patterns and warning us about how water is used the most inefficiently. These systems will provide valuable insights into understanding how water demand will change in the future and how we will cope with the changes in the future.

Thus, as we further embrace these technologies, fostering more efficient and sustainable environments for a better understanding of water management, we will be able to make smarter decisions in our water usage, ultimately securing the future of our human population and ecosystems. It will be the foundation for a water-secure generation in years to come.

Conclusion: A Path Toward Water Security

Water scarcity has emerged as a notable concern globally, given its multifaceted nature and negative impact on our society. In combating the problem, we need a collective effort that can likely start with the use of the technological solutions provided (smart irrigation, water recycling, pollution control technologies, and smart water management systems). Each of these innovations directly targets the main causes of water scarcity, from inefficient water usage to water source pollution.

In conclusion, the change toward sustainable water usage must begin with individual responsibility and collective action. Despite the potential cost and implementation challenges that may arise, it is essential for the individuals and the government to work together to address this problem as soon as possible. The vision for water security is within our reach.

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