STUDYING THE IMPACT OF WATER SCARCITY ON INFRASTRUCTURE AND ENVIRONMENT AND ITS BEHAVIOUR

Shradha P Patil[1], Amit R Gawale[2]

[1]*Assistant Professor, Department of Civil Engineering, KBPCOES Maharashtra, India*
[2] *Assistant Professor, Department of Civil Engineering, KBPCOES Maharashtra, India*

---***---

Abstract - *Water resource management has become a critical global concern due to increasing water scarcity and its influence on infrastructure development and sustainability. This paper reviews the major challenges associated with water resource management, including historical trends in water use, issues arising from water stress, rainwater harvesting practices, water quality degradation, and the impacts of climate change on water resources. The review emphasizes the importance of modernizing water management strategies, particularly in regions experiencing rapid population growth and climate-related risks, to ensure a reliable and sustainable water supply. In addition, the paper discusses practical solutions such as adopting innovative water management technologies, improving water-use efficiency, promoting water reuse, and utilizing alternative water resources. These measures can contribute to environmental protection, public health improvement, and the effective resolution of conflicts among competing water users.*

Key Words: Water resource management, water scarcity, water reuse, water-use efficiency, life cycle assessment.

1. INTRODUCTION

Water is an essential natural resource that supports human health, agriculture, industry, and environmental sustainability. Despite its importance, many regions worldwide are experiencing increasing pressure on available water resources due to rapid urbanization, industrial expansion, population growth, and climate change. These factors have intensified the demand for both surface water and groundwater while contributing to declining water quality and environmental degradation.

Reliable access to clean and safe water remains a significant challenge in many parts of the world. Water is indispensable for drinking, sanitation, agriculture, industrial production, and ecosystem maintenance. However, millions of people continue to face shortages of safe drinking water or have limited access to adequate water supplies. Water scarcity occurs when the demand for freshwater exceeds the quantity or quality of available resources, limiting its sustainable use.

Current global estimates indicate that:

- More than two billion people live in water-stressed regions, and this figure is expected to rise in the coming decades.
- Over one billion individuals still lack reliable access to safe drinking water.
- Approximately 3.4 million deaths each year are linked to diseases caused by contaminated water and inadequate sanitation.
- Millions of women and children spend several hours each day collecting water, often traveling distances of five to six kilometres.
- A substantial proportion of hospital admissions in developing countries are associated with waterborne diseases resulting from poor water quality and sanitation.

1.1 Ecological impact of construction

The continuous growth of the global population has led to an increasing demand for essential resources such as water, food, housing, and energy. Consequently, the construction sector must address its environmental impacts while meeting the infrastructure needs of expanding communities. Since construction activities rely heavily on natural resources, they significantly influence water availability and environmental sustainability.

Water is extensively used throughout construction projects, including site preparation, concrete mixing, dust suppression, equipment cleaning, and the manufacturing of construction materials. With water scarcity becoming a growing global concern, the construction industry must adopt sustainable practices that reduce water consumption and improve resource efficiency. Evaluating and minimizing the water footprint of construction projects can help create resilient infrastructure while reducing pressure on limited freshwater resources.

1.2 Life cycle analysis

Life Cycle Analysis (LCA) is an effective method for assessing the total environmental impact associated with a building throughout its entire lifespan. It enables the evaluation of water consumption, energy use, material extraction, construction processes, building operation, maintenance, and eventual demolition.

In recent years, whole-building LCA has become an essential decision-making tool for architects, engineers, manufacturers, and policymakers seeking sustainable construction solutions. The methodology provides a comprehensive assessment of environmental performance and supports green building certification programs by identifying opportunities to reduce resource consumption and environmental impacts.

The primary objective of sustainable building design is to decrease the use of water, energy, and construction materials while minimizing greenhouse gas emissions and environmental degradation. Governments and industry professionals are increasingly adopting LCA to evaluate climate-related impacts and improve the overall sustainability of infrastructure projects. Using life cycle assessment as a performance-based approach allows informed selection of construction materials and techniques that contribute to long-term environmental sustainability.

1.2 The water use in building material production

Estimating water consumption within the construction industry is challenging because water requirements differ according to the type of material, manufacturing process, and construction technique employed. A complete assessment should consider water use throughout every stage of the construction process.

Water consumption in construction can be categorized into three major components:

1. Direct Water Use

Direct water use refers to the quantity of water consumed at construction sites for activities such as concrete preparation, equipment cleaning, dust control, irrigation, and domestic purposes for workers.

2. Indirect Water Use

Indirect water use includes the water consumed during the extraction of raw materials, manufacturing, transportation, and assembly of construction materials before they reach the project site.

3. Building Life Cycle Water Use

This represents the total amount of water expected to be consumed during the building's operational life, including potable water supply, maintenance activities, equipment operation, and wastewater collection and treatment.

Among commonly used construction materials, steel, cement, and glass require considerable amounts of water during manufacturing. Their production processes may also contribute to water pollution if appropriate treatment systems are not implemented. Furthermore, additional indirect water consumption is associated with electricity generation, industrial cooling, and transportation throughout the production chain.

Brick manufacturing is recognized as one of the most water-intensive construction processes. According to a study published in the Journal of Cleaner Production, the total water footprint of a single brick was estimated at 2.02 litres, comprising 84.8% blue water and 15.2% green water. Blue water represents the volume of surface and groundwater used during production, whereas green water refers to rainwater utilized within the manufacturing process. The study also reported a grey water footprint of approximately 1.3 litres per brick, indicating the freshwater required to dilute pollutants generated during production. Researchers concluded that implementing sustainable water management practices, including water recycling and regeneration systems, could significantly reduce overall water consumption and improve production efficiency by more than 56%.

1.4 The implications of water scarcity for the built environment

Growing water scarcity presents significant challenges for the construction industry and the long-term sustainability of urban infrastructure. As freshwater resources become increasingly limited, future building projects must incorporate efficient water management strategies to ensure resilience against changing environmental conditions.

One important approach is the adoption of water-sensitive urban design, particularly in densely populated regions. These strategies integrate the natural water cycle into urban planning through measures such as storm water harvesting, groundwater recharge, wastewater recycling, and permeable paving systems that enhance groundwater infiltration while reducing surface runoff.

Water shortages also have important economic implications for construction projects. Rising water costs and supply uncertainties can increase construction and operational expenses. Consequently, adopting water-efficient technologies, sustainable construction methods, and responsible resource management can lower long-term costs while improving environmental performance. Such practices provide benefits for developers, communities, and ecosystems by supporting sustainable infrastructure development and conserving valuable water resources.

2. LITERATURE REVIEW

2.1) Sullivan, C. A., et al. (2015). The Water-Energy Nexus: The Impact of Water Scarcity on Power Generation in the United States. Environmental Science & Technology, 49(5), 3002-3011.

Sullivan et al. (2015) examined the close relationship between water availability and energy production, emphasizing how water scarcity influences power generation systems in the United States. Their research demonstrates that power plants requiring large quantities of water for cooling, particularly thermal and nuclear facilities, are highly vulnerable to limited water supplies. Reduced water availability can lower electricity generation capacity, increase operational expenses, and threaten the reliability of energy systems in water-stressed regions.

The study highlights the strong interdependence between water and energy resources and emphasizes the importance of integrated resource management. It also recommends adopting advanced cooling technologies, improving water-use efficiency, and promoting alternative energy sources to reduce dependence on freshwater resources. These findings provide valuable guidance for improving the resilience of energy infrastructure under increasing water scarcity.

2.2) Vörösmarty, C. J., et al. (2010). Global Threats to Human Water Security and River Biodiversity. Nature, 467(7315), 555-561.

Vörösmarty et al. (2010) investigated the worldwide challenges affecting freshwater security and river ecosystems. Their study identifies water scarcity, pollution, climate change, and excessive exploitation of water resources as major factors threatening both human populations and aquatic biodiversity. The authors demonstrate that declining freshwater availability has significant implications for infrastructure systems that depend on reliable water resources, including drinking water supply, irrigation, flood management, and sanitation. The research emphasizes that effective water management should balance the requirements of human development with the protection of ecological systems. By integrating environmental conservation into water resource planning, infrastructure can become more sustainable and resilient. The study also highlights the importance of safeguarding river ecosystems, which play a critical role in maintaining long-term water security and supporting economic development.

2.3) Seckler, D., Amarasinghe, U., Molden, D., De Silva, R., & Barker, R. (1998). World water demand and supply, 1990 to 2025: Scenarios and issues. Water Management, 19, 50. https://doi.org/10.3910/2009.019

Seckler et al. (1998) presented a comprehensive assessment of global water demand and supply projections for the period between 1990 and 2025. Their work analyzes future scenarios of freshwater availability and identifies the growing gap between water demand and accessible resources. The study demonstrates that increasing population, economic development, and agricultural expansion are expected to intensify pressure on available water supplies. The authors discuss how these trends may affect water-dependent infrastructure, including municipal water supply systems, irrigation networks, sanitation facilities, and energy production. Their findings underline the necessity of adopting sustainable water management strategies, improving water-use efficiency, and implementing long-term planning to address future water shortages. The projected scenarios presented in the study provide valuable insights for policymakers and engineers responsible for designing resilient infrastructure in regions vulnerable to water stress.

3. CONCLUSIONS

Freshwater availability is steadily declining across many parts of the world, making water scarcity one of the most significant global challenges of the twenty-first century. Despite technological and economic progress, billions of people still lack reliable access to safe drinking water, and this situation is expected to worsen because of climate change, rapid urbanization, population growth, poor water governance, and increasing occurrences of extreme weather events.

The world's population has expanded considerably over the past several decades and is projected to reach approximately **9.7 billion by 2050**. Population growth, longer life expectancy, urban migration, and changing demographic patterns are placing unprecedented pressure on freshwater resources. As demand for domestic, agricultural, industrial, and environmental water continues to rise, many regions are shifting from conditions of adequate supply to severe water stress. Without effective planning and equitable allocation, competition for limited water resources is likely to intensify. This review indicates that sustainable water management plays a crucial role in reducing the impacts of water scarcity. Regions where water resources are managed efficiently have demonstrated that limited supplies can be distributed fairly among users. Community-managed irrigation systems in Nepal provide a successful example of equitable water allocation under constrained conditions. In contrast, many irrigation networks across Asia continue to experience operational inefficiencies, where upstream users receive disproportionate amounts of water while downstream communities face persistent shortages. Similar inequalities are evident in areas such as the Kathmandu Valley, where access to water remains uneven despite the availability of local resources.

Addressing future water challenges requires a comprehensive and integrated approach that extends beyond short-term solutions. Effective water governance depends on the active participation of governments, local communities, researchers, industries, and policymakers. Since water is closely linked with sectors such as agriculture, energy, public health, and environmental conservation, coordinated planning across these sectors is essential for sustainable resource management.

Furthermore, strengthening institutional capacity and investing in water infrastructure, advanced technologies, and skilled professionals are critical for improving water security. Future water managers should possess interdisciplinary knowledge that combines hydrological science with social, economic, and policy perspectives to develop effective and inclusive management strategies.

Ultimately, ensuring universal access to safe and sufficient water requires sustained investment, responsible governance, and a strong commitment to protecting vulnerable populations. By adopting innovative water management practices, improving water-use efficiency, encouraging water reuse, and implementing integrated resource planning, societies can enhance resilience against future water scarcity while supporting sustainable development and environmental protection.

REFERENCES

1) Seckler, D., Amarasinghe, U., Molden, D., De Silva, R., & Barker, R. (1998). World water demand and supply, 1990 to 2025: Scenarios and issues. Water Management, 19, 50. doi:10.3910/2009.019
2) David Molden (2020) Scarcity of water or scarcity of management? International Journal of Water Resources Development, 36:2-3, 258-268, DOI: 10.1080/07900627.2019.1676204
3) Sullivan, C. A., et al. (2015). The Water-Energy Nexus: The Impact of Water Scarcity on Power Generation in the United States. Environmental Science & Technology, 49(5), 3002-3011.
4) UN (2020). The United Nations World Water Development Report 2020: Water and Climate Change. United Nations Educational, Scientific and Cultural Organization (UNESCO).
5) Grey, D., & Sadoff, C. W. (2007). Sink or Swim? Water Security for Growth and Development. Water Policy, 9(6), 545-571
6) Vörösmarty, C. J., et al. (2010). Global Threats to Human Water Security and River Biodiversity. Nature, 467(7315), 555-561.
7) Asano, T., & Levine, A. D. (1996). Wastewater Reclamation and Reuse: Past, Present, and Future. Water Science and Technology, 33(10), 1-14.
8) A. Adham, M. Riksen, M. Ouessar, R. Abed, C. Ritsema, Development of methodology for existing rainwater harvesting assessment in (semi-)arid regions, in Water and Land Security in Drylands. ed. by E. Jon (Springer International Publishing, Cham, 2017), pp.171–184. https://doi.org/10.1007/978-3-319-54021-4_16
9) Arman NZ et al (2021) A review on emerging pollutants in the water environment: existences, health effects and treatment processes. Water 13(22):3258
10) Mateo-Sagasta J, Marjani Zadeh S, Turral H (2017) Water pollution from agriculture: A global review. Executive summary. Food and Agriculture Organization of the United Nations
11) Jasechko S, Perrone D (2021) Global groundwater wells at risk of running dry. Science 372(6540):418–421. https://doi.org/10.1126/science.abc2755
12) Rodell M, Famiglietti JS, Wiese DN, Reager JT, Beaudoing HK, Landerer FW, Lo M-H (2018) Emerging trends in global freshwater availability. Nature 557(7707):651–659. https://doi.org/10.1038/s41586-018-0123-1
13) Mishra RK (2023) Fresh water availability and its global challenge. Br J Multidiscip Adv Stud 4(3):1–78. https://doi.org/10.37745/bjmas.2022.0208
14) Bossa A, Diekkrüger B, Agbossou E (2014) Scenario-based impacts of land use and climate change on land and water degradation from the Meso to regional scale. Water 6(10):3152–3181. https://doi.org/10.3390/w6103152
15) Sharpley A, Jarvie HP, Buda A, May L, Spears B, Kleinman P (2013) Phosphorus legacy: Overcoming the effects of past management practices to mitigate future water quality impairment. J Environ Qual 42(5):1308–1326. https://doi.org/10.2134/jeq2013.03.0098
16) Mara D (2013) Domestic wastewater treatment in developing countries. Routledge. https://doi.org/10.4324/9781849771023
17) Angeles ME, González JE, Ramírez N (2018) Impacts of climate change on building energy demands in the intra-Americas region. Theor Appl Climatol 133:59–72
18) Schwan S, Yu X (2018) Social protection as a strategy to address climate-induced migration. Int J Climate Change Strateg Manag 10:43–64
19) UNFCCC (2011) Fact sheet: climate change science–the status of climate change science today In: CHANGE, U. N. F. C. O. C. (ed.).
20) Al-Ghobari HM (2014) Effect of center pivot system lateral configuration on water application uniformity in an arid area. Agric Sci Technol 16:577–589
21) Alshattnawi S, Jordan, I (2017) Smart water distribution management system architecture based on internet of things and cloud computing. In: Proceedings of the 2017 international conference on new trends in computing sciences. https://doi.org/10.1109/ICTCS.2017.31
22) Wybrands, M., Frohmann, F., Andree, M., Marx Gómez, J.: WISdoM: An Information System for Water Management. Springer International Publishing, Cham (2021)

23) Goal 6 | Department of Economic and Social Affairs. https://sdgs.un.org/goals/goal6. Accessed 22 Sept 2021

24) Grigg, N.S.: Assessment and renewal of water distribution systems. J. Am. Water Works Ass. 97(2), 58–68 (2005)

25) Jenny, H., Alonso, E.G., Wang, Y., Minguez, R.: Using Artificial Intelligence for Smart Water Management Systems. ADB Briefs (2020)