



INDIAN INSTITUTE OF TECHNOLOGY ROORKEE



**8th International R&D Conference
on
Global Trends in Water Resources, Power & RE Sectors**

Feb 08- 09, 2024

**LIFE CYCLE ASSESSMENT OF CONSTRUCTED WETLAND FOR
WASTEWATER TREATMENT**

Presented by:

Shweta D Jaiswar (M.Tech 2nd year)
Hydro and Renewable Energy Department
Indian Institute of Technology Roorkee

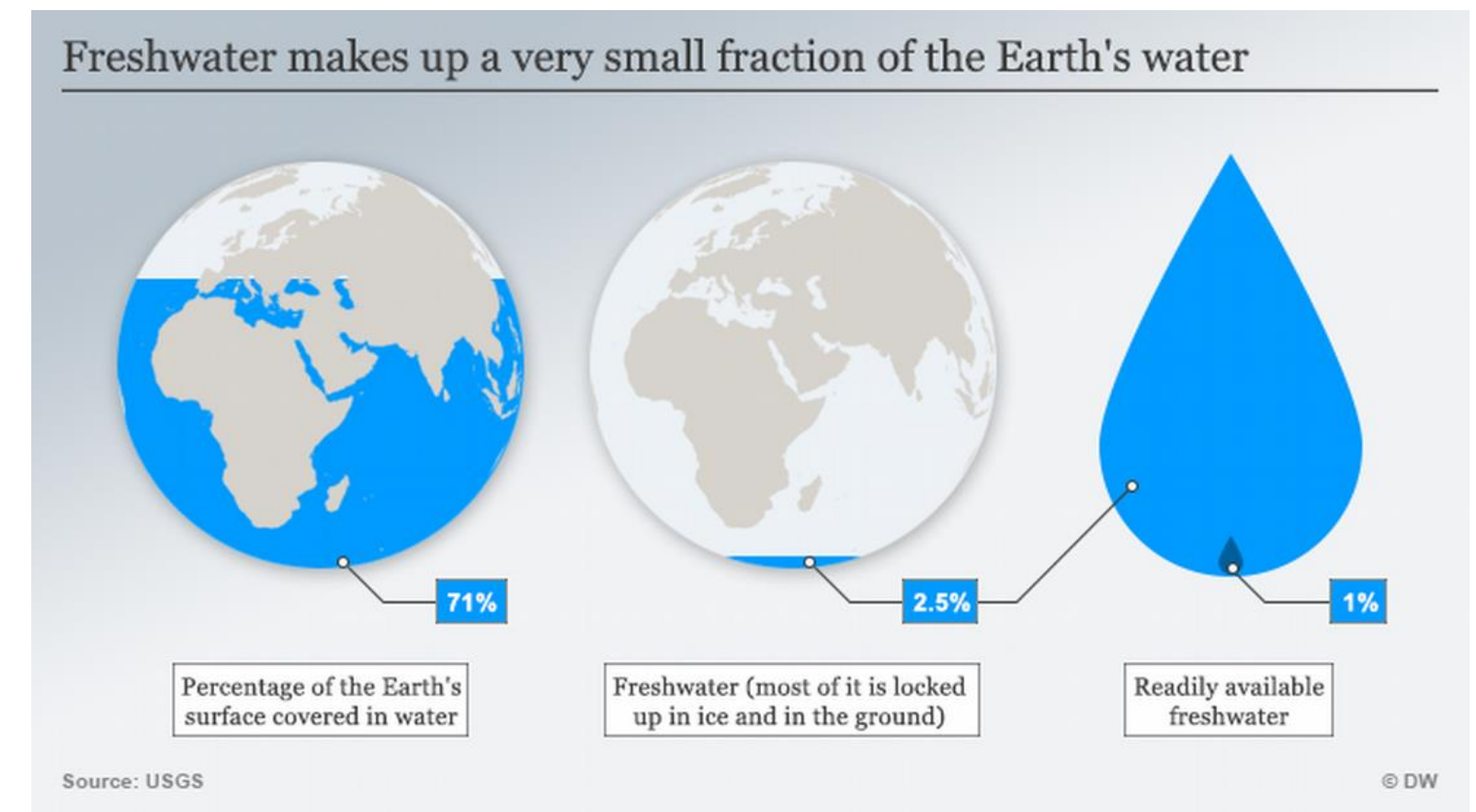




Outline of presentation

- Introduction
- Constructed Wetland
- Life Cycle Assessment
- Literature review
- Methodology
- Result
- Conclusion
- References

- Rapid industrialization, urbanization, and population growth intensify resource usage, especially water, a limited global resource.
- Climate change exacerbates water scarcity and contamination.
- Effective water management systems, particularly in developing nations, become crucial. Urban areas face sanitation challenges, emphasizing the need for sustainable wastewater treatment. In India, inadequate sewage treatment contributes to water pollution.
- Wastewater Treatment Plants (WWTPs) consume substantial energy, prompting a shift toward sustainability.
- Constructed Wetlands (CWs) emerge as an eco-friendly wastewater treatment method, gaining recognition for low energy consumption.



Source: <https://www.dw.com/en/are-we-running-out-of-fresh-water/a-40241057>

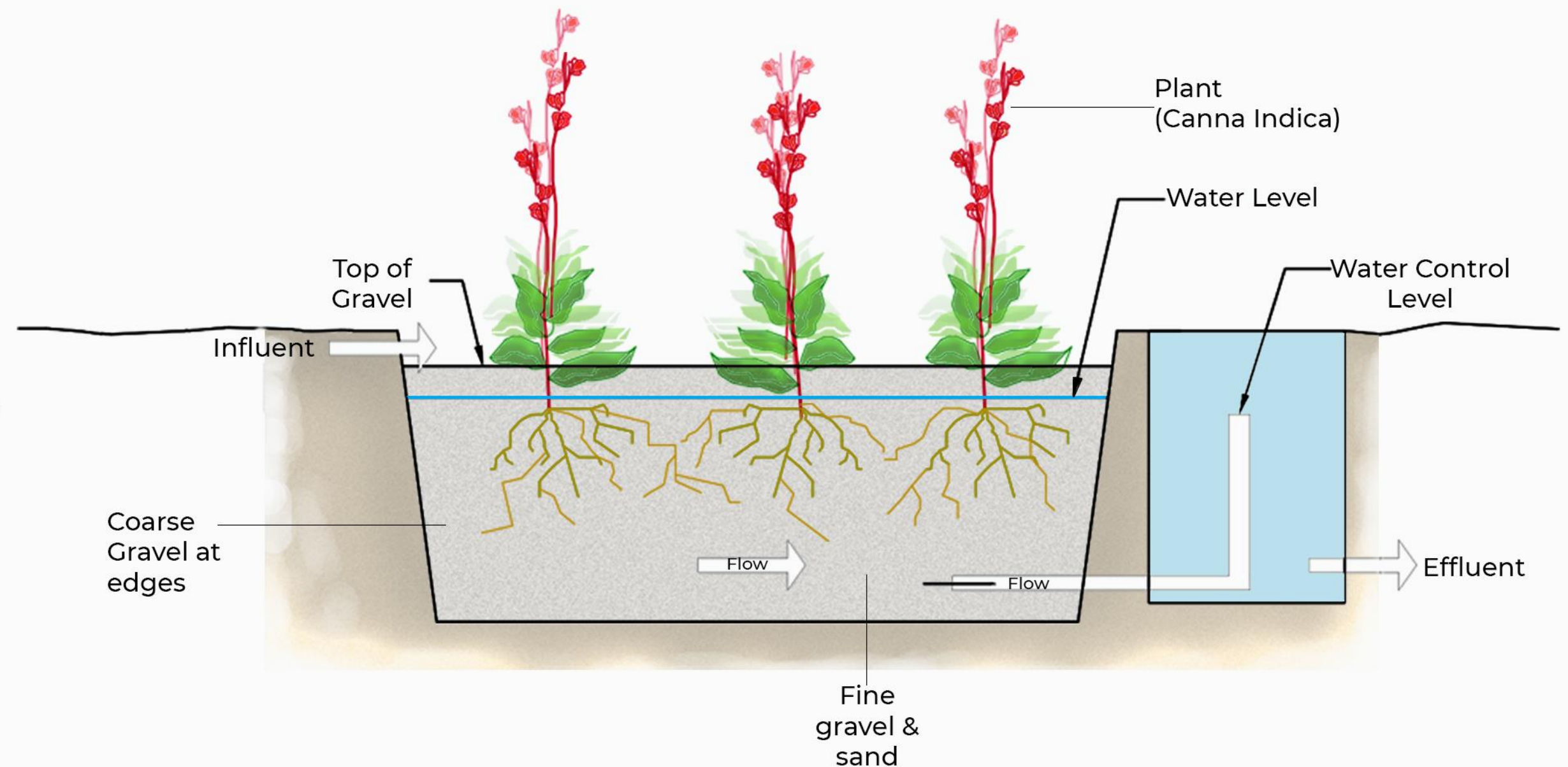
Constructed Wetland



It represents an engineered, cost-effective biological wastewater treatment system utilizing natural processes, including macrophytes, gravel, and microbial interactions, emphasizing eco-friendly treatment with minimal operation and cost.

Components:

- Excavated basin
- Wetland plants
- Gravel and sand
- Water inlet pump and outlet structures to ensure uniform flow distribution
- Adjustable water level control device at the outlet.
- Impermeable lining to avoid infiltration of wastewater into the ground



Types of CWs



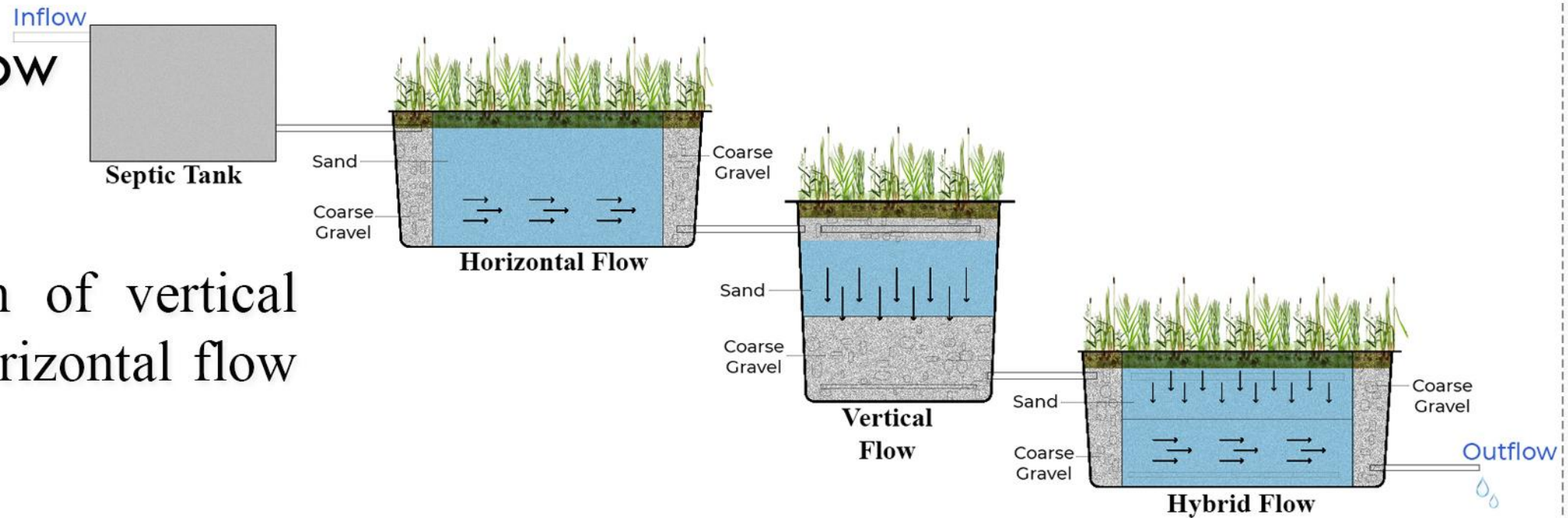
Surface flow
the water flows
above ground

**Constructed
Wetland**

Sub-surface flow
the water level is
below the top of the
gravel media

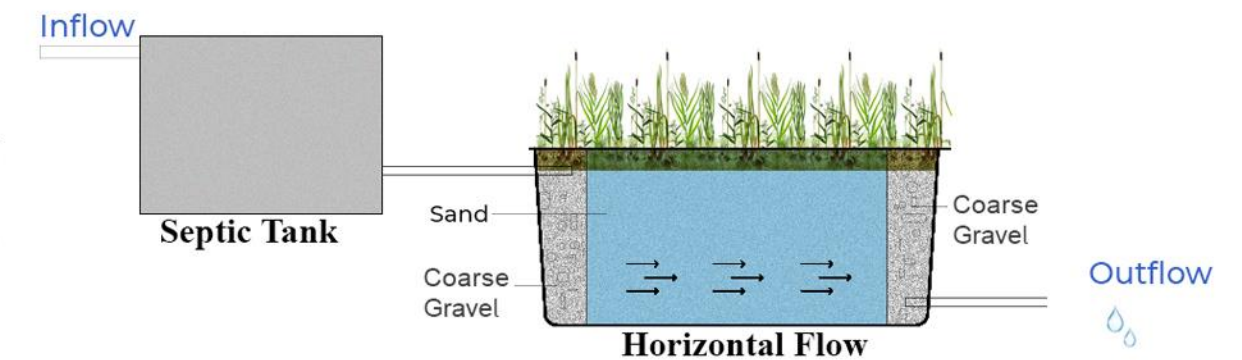
Hybrid flow

Combination of vertical
flow and horizontal flow
CWs



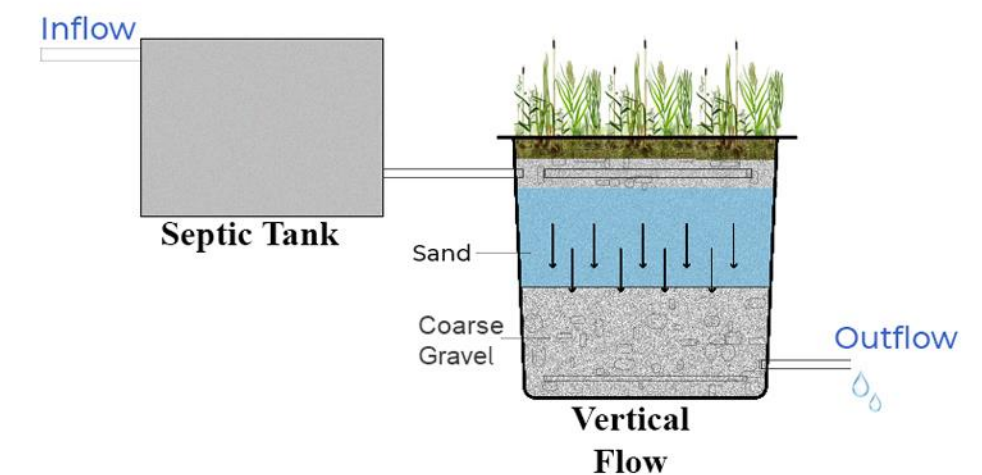
Horizontal flow

Influent flow is often dominated by
horizontal flow through gravity into
the system

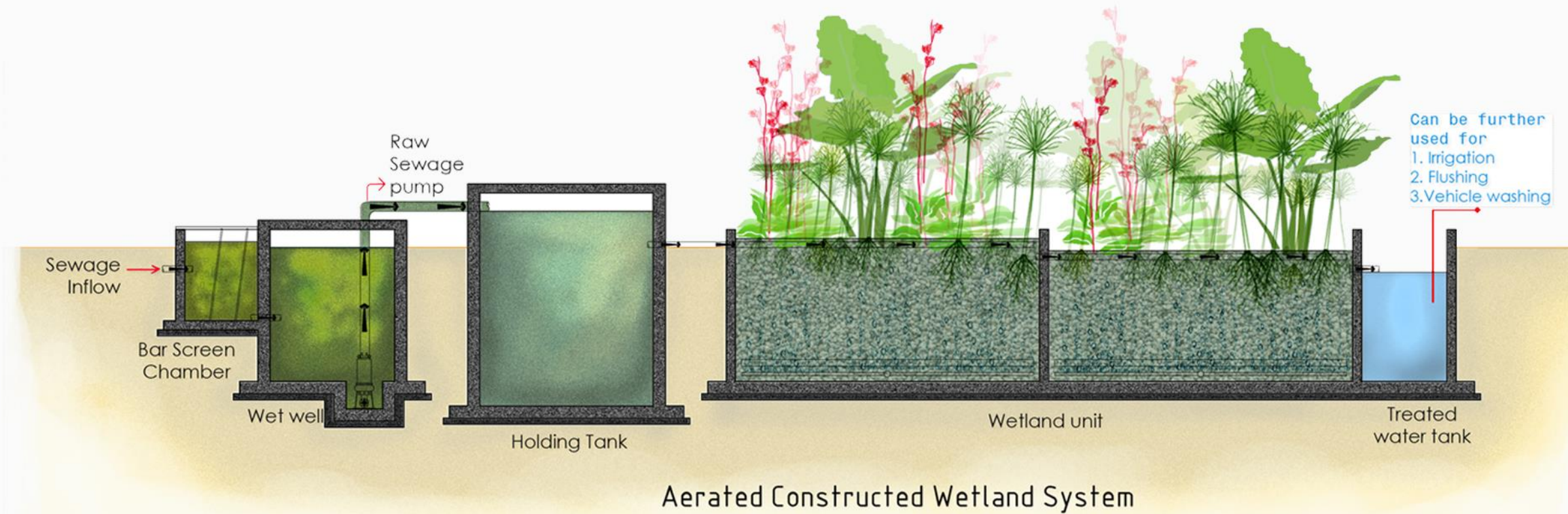


Vertical flow

The influent is splashed vertically
downward periodically into the
system using a pumping system.



Elements of CWs



Bar Screen Chamber: Removes large solid particles

Wet well: It maintains continuous flow to the holding tank via pumping system.

Holding Tank: Retention time is 24 to 36 hours, with microbes added to chambers.

Wetland: Systems typically have two cells, with gravity-driven influent flow.

Treated water Tank: Disinfection

Special plant species include:



Umbrella Palm



Thalia (Hardy Canna)



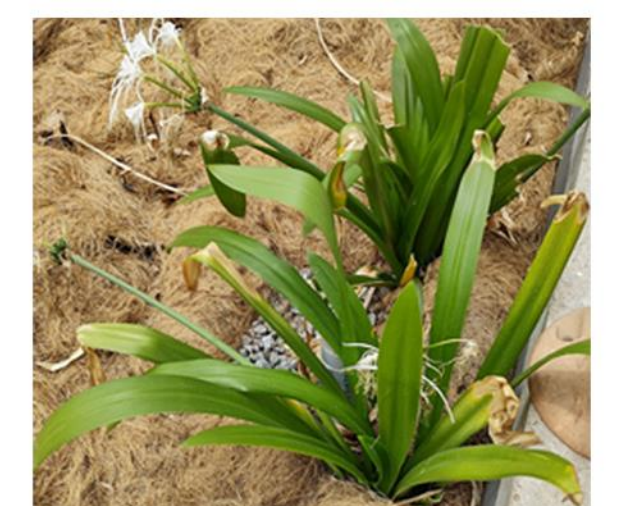
Giant Taro Plant



Canna Indica

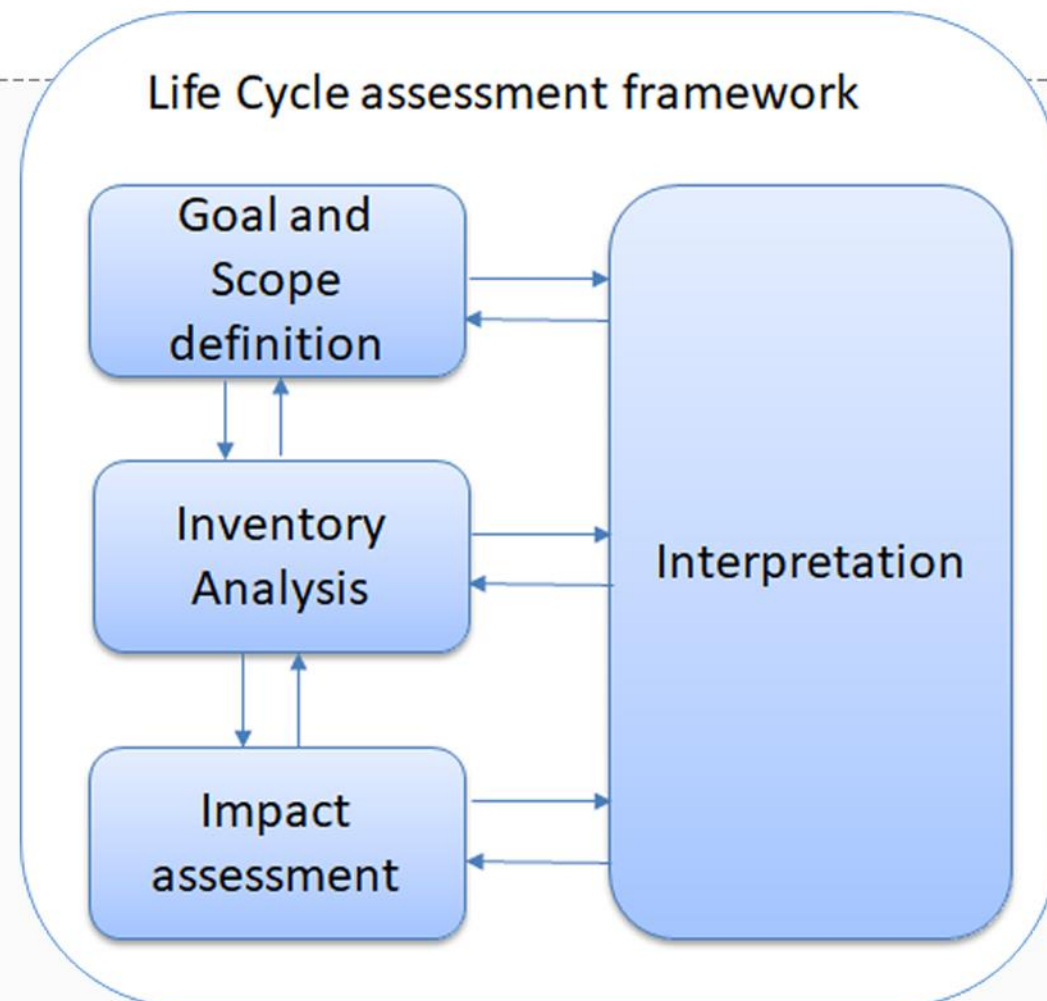


Cyperus Papyrus



Spider Lily

Life cycle assessment (LCA) systematically evaluates the environmental impact of a product or process throughout its entire life cycle, identifying potential harm and emissions.



Constructed wetland & LCA

CWs can have some potential environmental impact during the construction and operation phase, which can be assessed with the Life Cycle Assessment (LCA).



Paper	Aim	Discussions/Results
[1]	<p>To determine the environmental impact and economic viability of constructed wetland with horizontal flow constructed wetland</p> <ol style="list-style-type: none"> 1. Filled with recycled concrete aggregate (RCA) 2. Typical gravel-based 	<ul style="list-style-type: none"> • Utilizing recycled concrete aggregate as the substrate can lower the costs of the system. • Concerning wastewater polish performance, RCA-based CW is better than gravel-based CW. • Substantial impact on the life-cycle environmental is also less in RCB.
[2]	<p>To calculate the life-cycle GHG emissions and primary energy resource consumption of a constructed wetland using a horizontal subsurface flow technique (HSSF).</p>	<ul style="list-style-type: none"> • Results shows better in case of HSSF than those of conventional method.
[3]	<p>The assessment of Constructed Wetland to Microbial Fuel Cell (CW-MFC) discusses treatment effectiveness, performance variation with respect to macrophyte, emerging pollutant removal, and microbial community structure.</p>	<ul style="list-style-type: none"> • The most significant elements directly determining CW's effects on the environment are its construction phase and substrate material selection.
[4]	<p>To identify which (vertical or horizontal) to have low environmental impact over its life cycle.</p>	<ul style="list-style-type: none"> • Vertical Flow CWs fulfil water quality criteria with far less environmental effect and need a lot less acreage than Horizontal Flow CWs.

Methodology



Goal and Scope

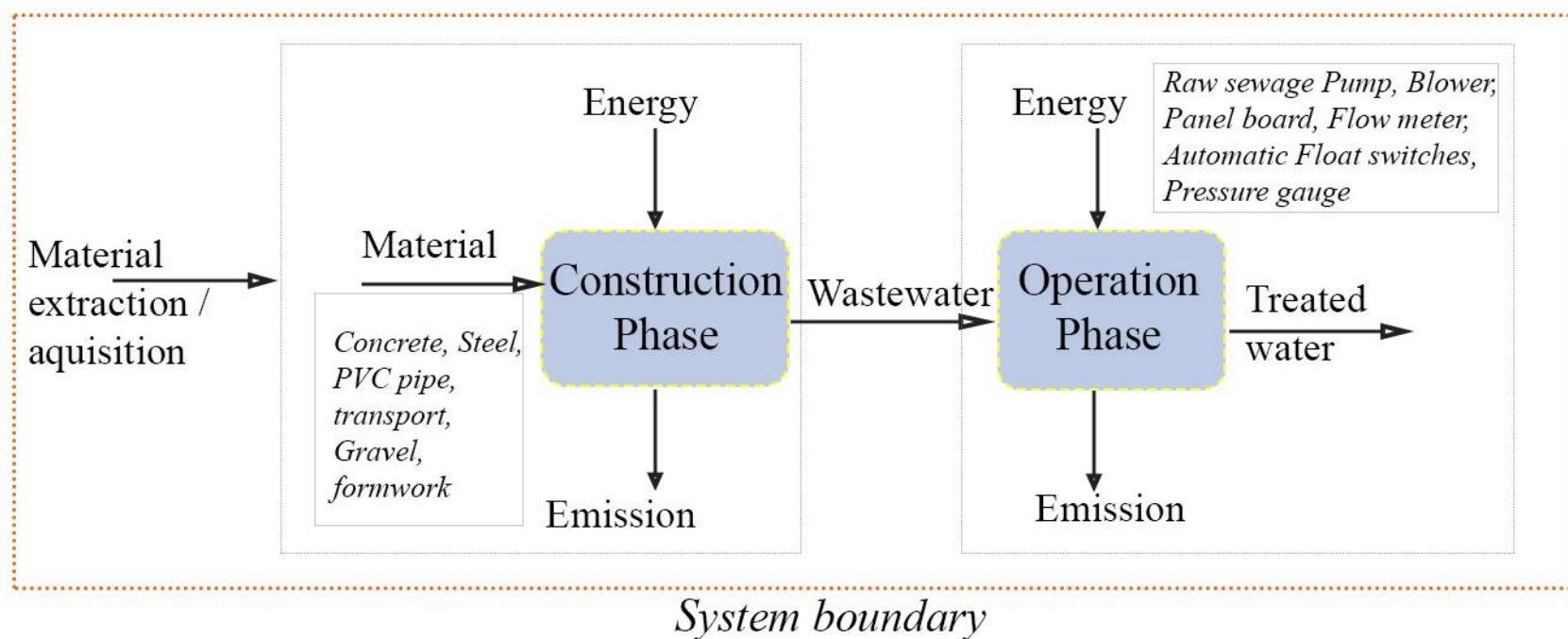
This study compares the environmental performance of two CW systems, a 1.2 MLD Effluent Treatment Plant (ETP) and a 150 KLD Sewage Treatment Plant (STP), focusing on the construction and operation phases.

Functional unit

1 m³ of influent wastewater.

Software

GaBi software version ReCiPe 2016 Midpoint method



1 Deccan Cement Hyderabad

1.2 MLD capacity



2 Nikhila Hyderabad

150 KLD capacity



Description of Case Study

Two VFCW systems, a 1.2 MLD ETP at a cement factory and a 150 KLD STP in Hyderabad, are considered in this study, designed with a 25-year lifespan.

Both systems use aeration for enhanced treatment performance.

Electromechanical equipment includes,

1. Air Blower
2. Raw sewage transfer Pump
3. Pressure Guage
4. Level sensor
5. Flow meter
6. Control Panel

Impact Category			
1. Climate Change	(kg CO ₂ eq.)	6. Freshwater eutrophication	(kg P eq.)
2. Fossil Depletion	(kg oil eq.)	7. Terrestrial ecotoxicity	(kg 1,4 DB eq)
3. Freshwater ecotoxicity	(kg 1,4-DB eq)	8. Land use	(Annual crop eq. yr.)
4. Human toxicity, cancer	(kg 1.4DB eq.)	9. Stratospheric ozone depletion	(kg CFC-11 eq.)
5. Photochemical ozone formation, Ecosystem	(kg NO _x eq.)	10. Marine Eutrophication	(kg P-eq) or (kg N-eq)

Summary of Life cycle inventory for both systems

Phase	Input	1.2 MLD	150 KLD	Use description
Construction	Ready-mix concrete	742.02 Cu. m.	141.07 m ³	For durable infrastructure
	Steel	53568.68 kg	10867.73 kg	Reinforcement steel
	Bitumen emulsion	3957.10 Sq. m.	744.58 m ²	Waterproofing
	Gravel	2656.50 Cu. m.	330 m ³	CW substrate
	Formwork (wood)	2814.4 Sq. m.	889.49 m ²	To support and shape concrete structures till they gain their strength
	Electricity	263.99 kWh	32.99kWh	Used during construction
	PVC Pipes	1200 m	200 m	Pipeline in CW
Operation	Electricity	260 kWh per day	70 kWh per day	To run different electro-mechanical equipment



Summary of the inlet and outlet pollutants concentration of both systems

Pollutants	1.2 MLD		150 KLD	
	Inlet	Outlet	Inlet	Outlet
pH	7.54	7.52	7.66	7.4
TSS	16	<10	73	<10
TDS	1960	1950	1157	1108
COD	140	28	192	76
BOD	27.3	5.3	57.7	14
Oil & grease	7.6	<5	9.6	<5

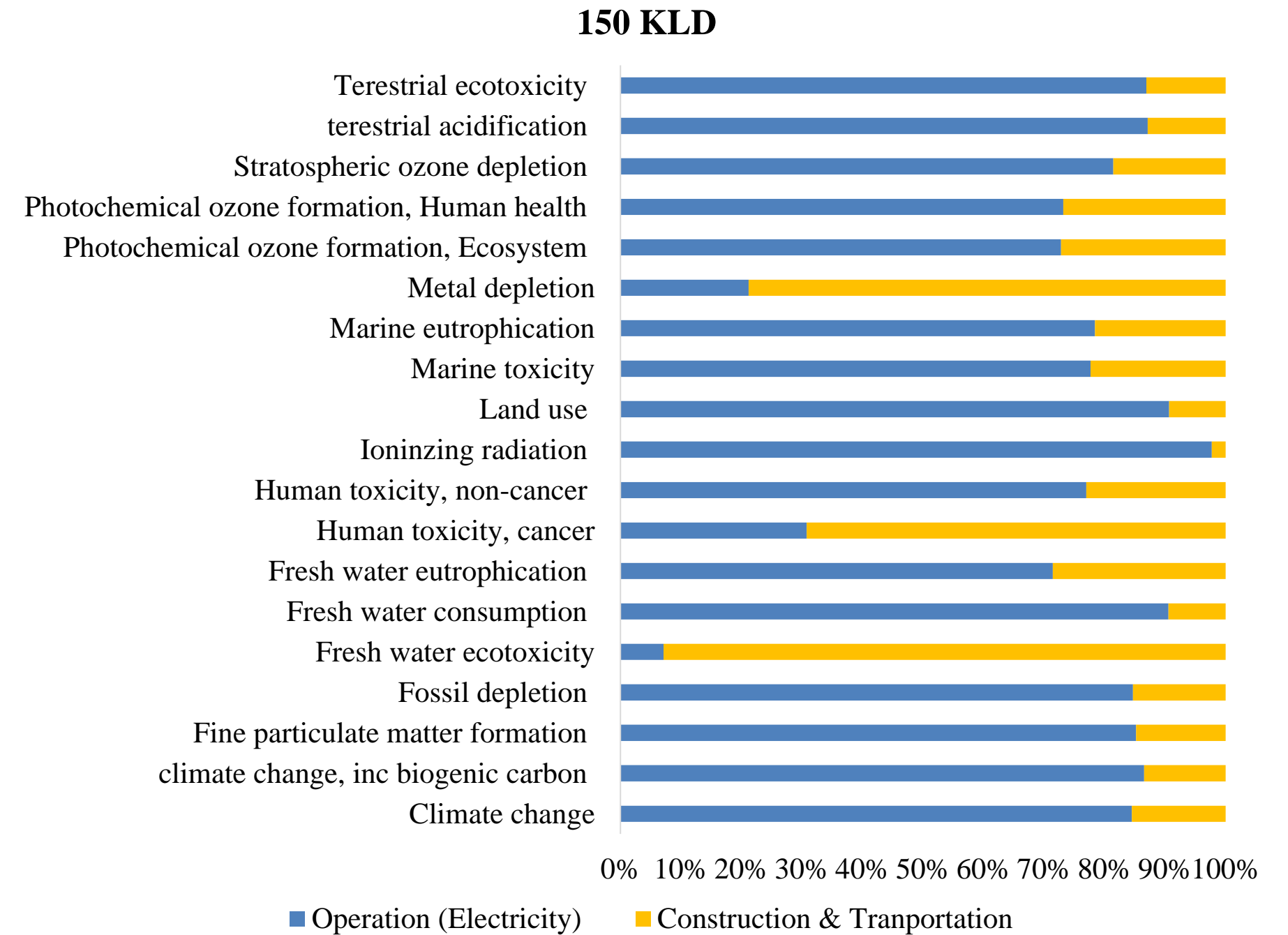
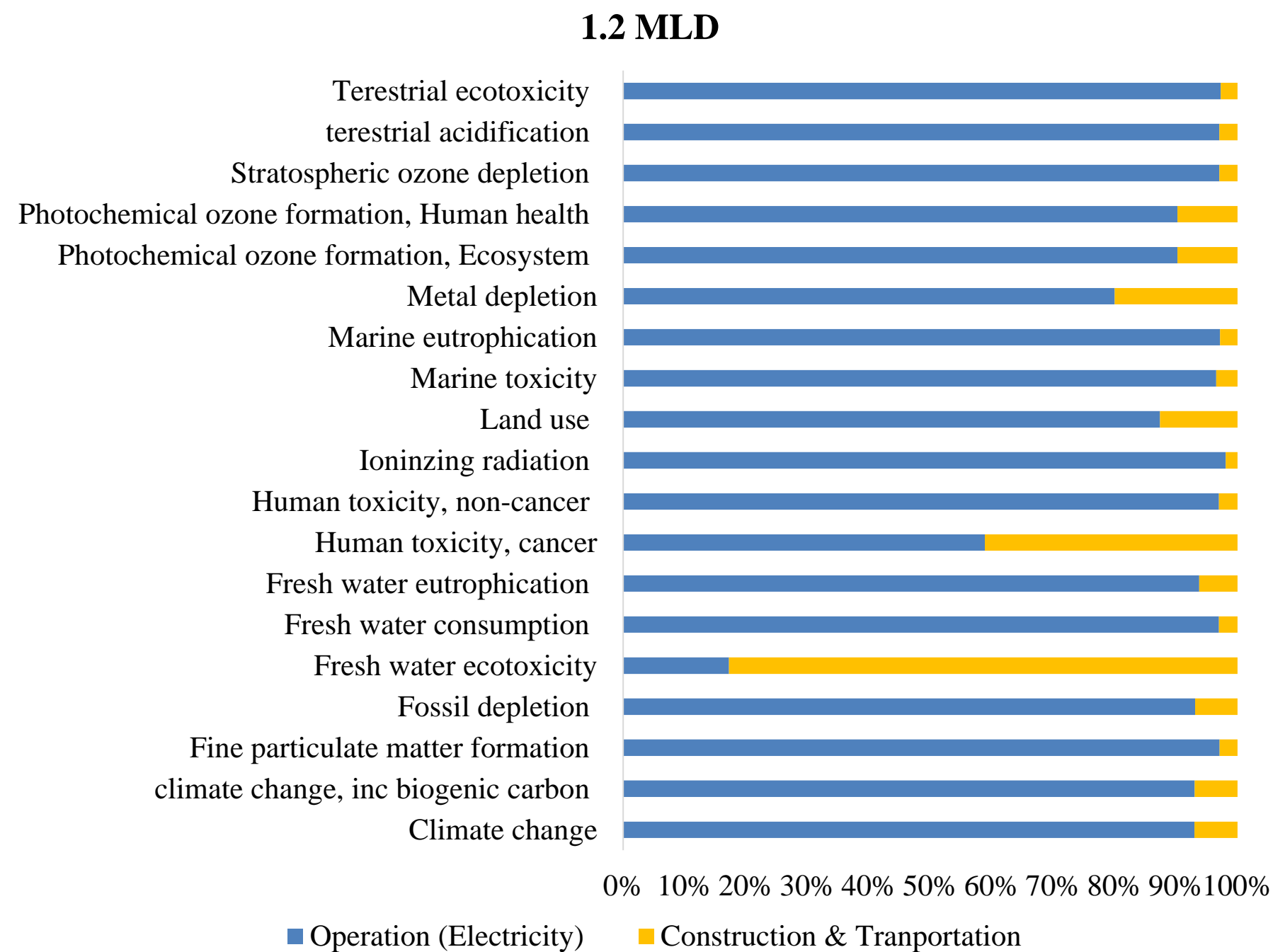


- LCA results, reveal total emissions of 0.523 kg CO₂ eq./m³ for ETP and 0.372 kg CO₂ eq./m³ for STP in the Climate Change category.
- The high total potential impacts for both phases in the ETP system.
- Electricity consumption is the primary contributor to impact in both systems.
- STP system has a high total potential impact on the construction phase.
- Despite higher emissions in its operation and construction phases, the ETP system demonstrates effective pollutant removal in a few parameters, generally outperforming the STP system in reducing various water quality parameters.



Result and discussion

- The high total potential impacts for both phases in the ETP system.
- Electricity consumption is the primary contributor to impact in both systems.

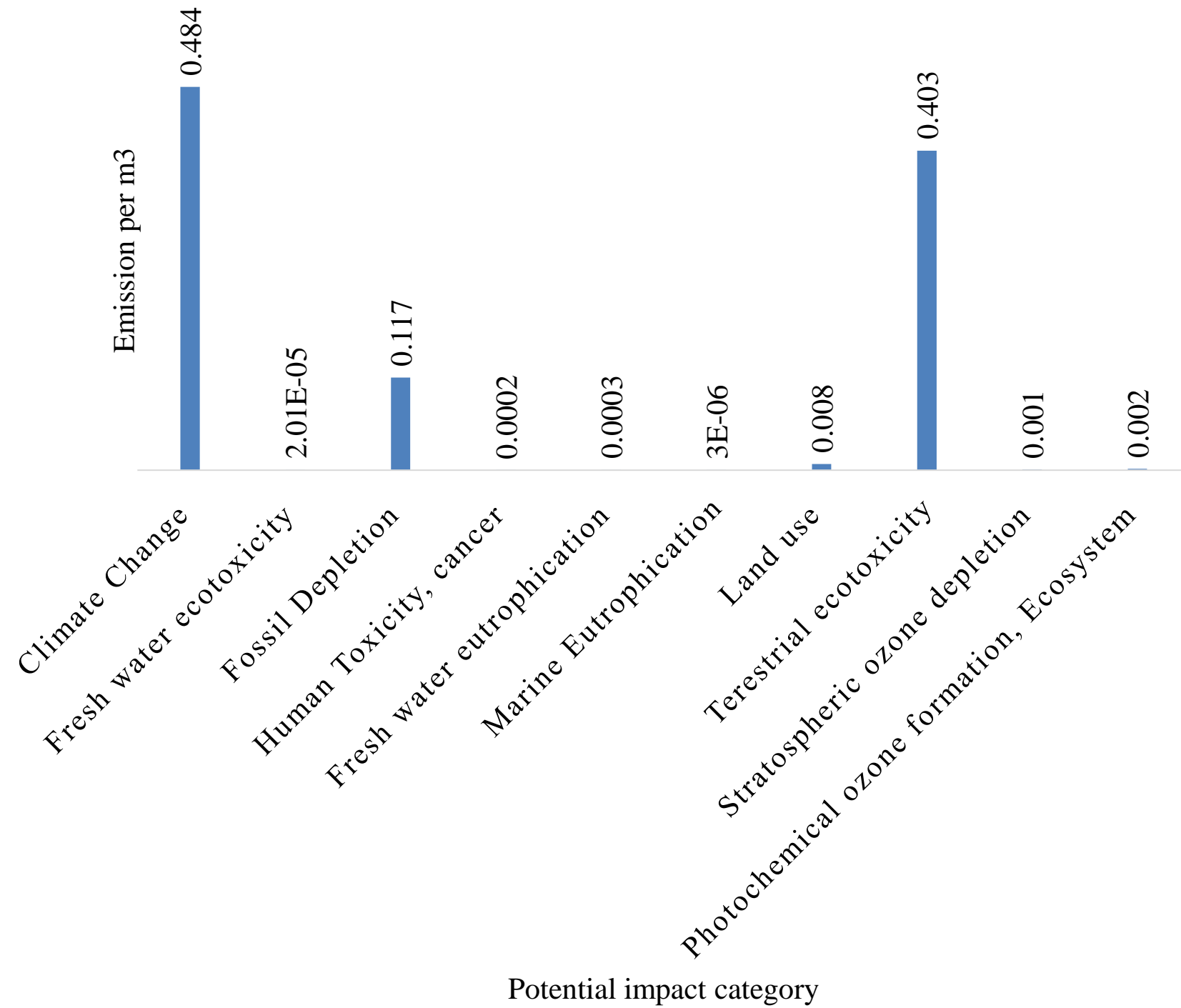


LCA Result of potential impact for different categories from both systems

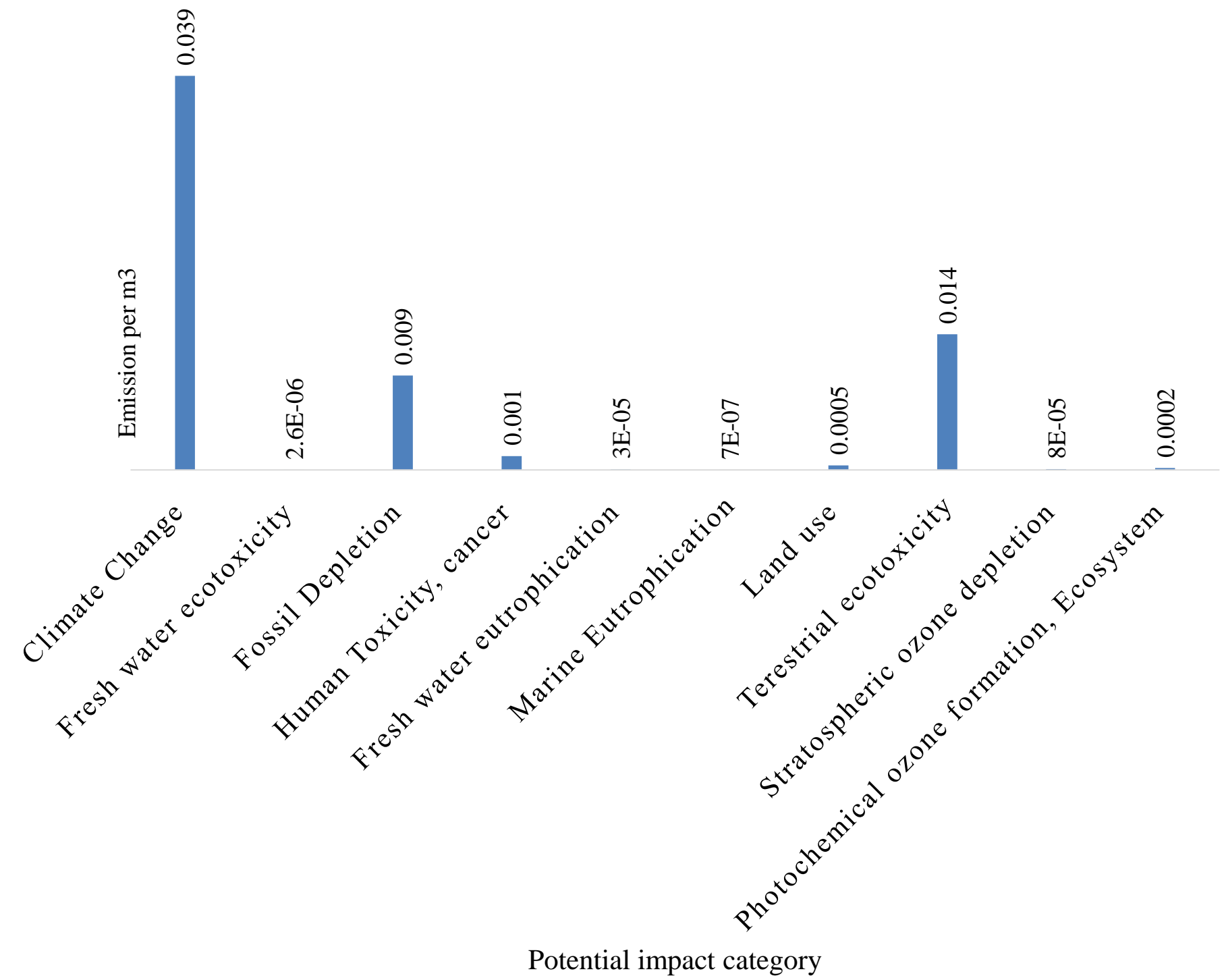


Potential impact for 1.2MLD ETP system

OPERATION PHASE

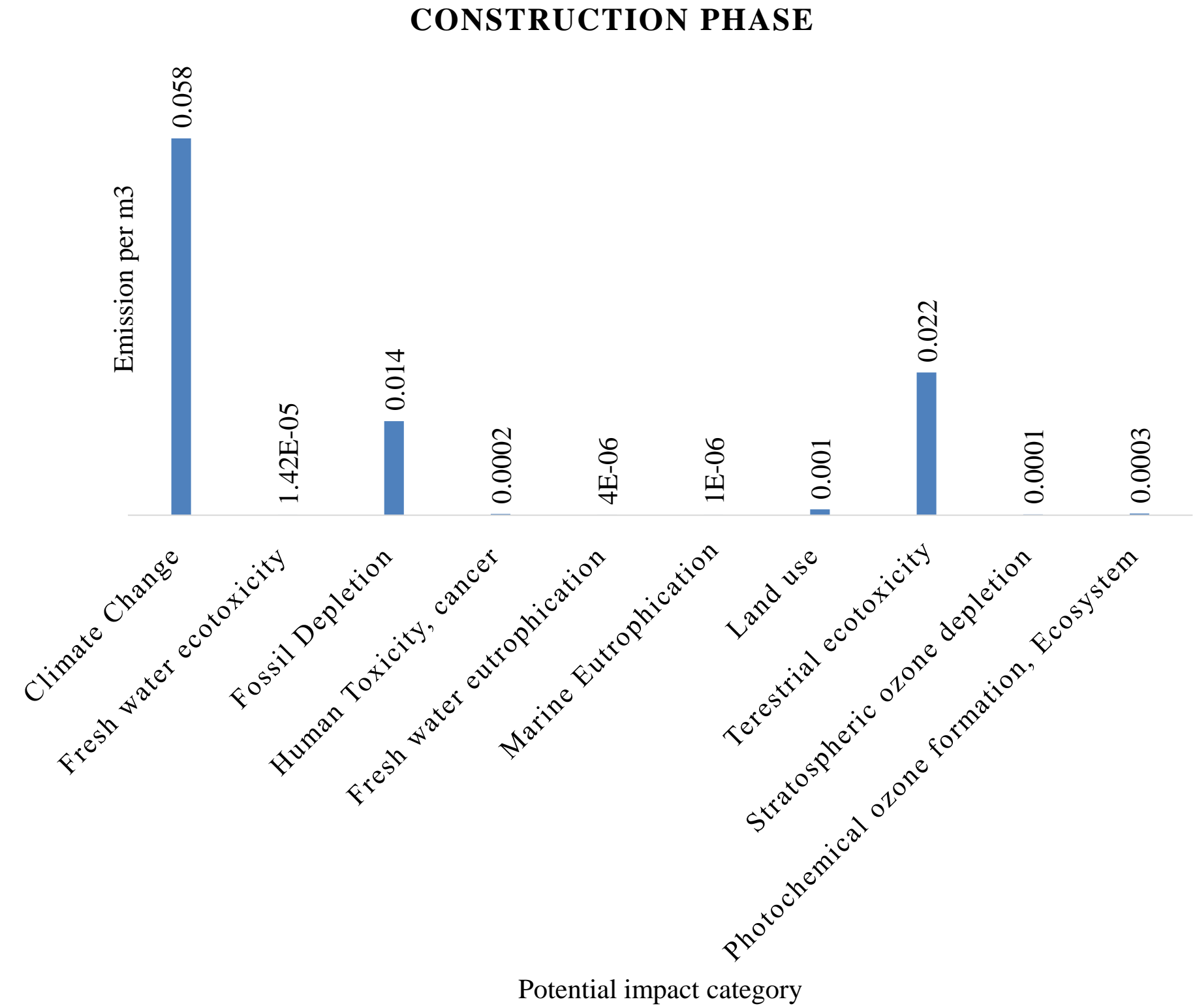
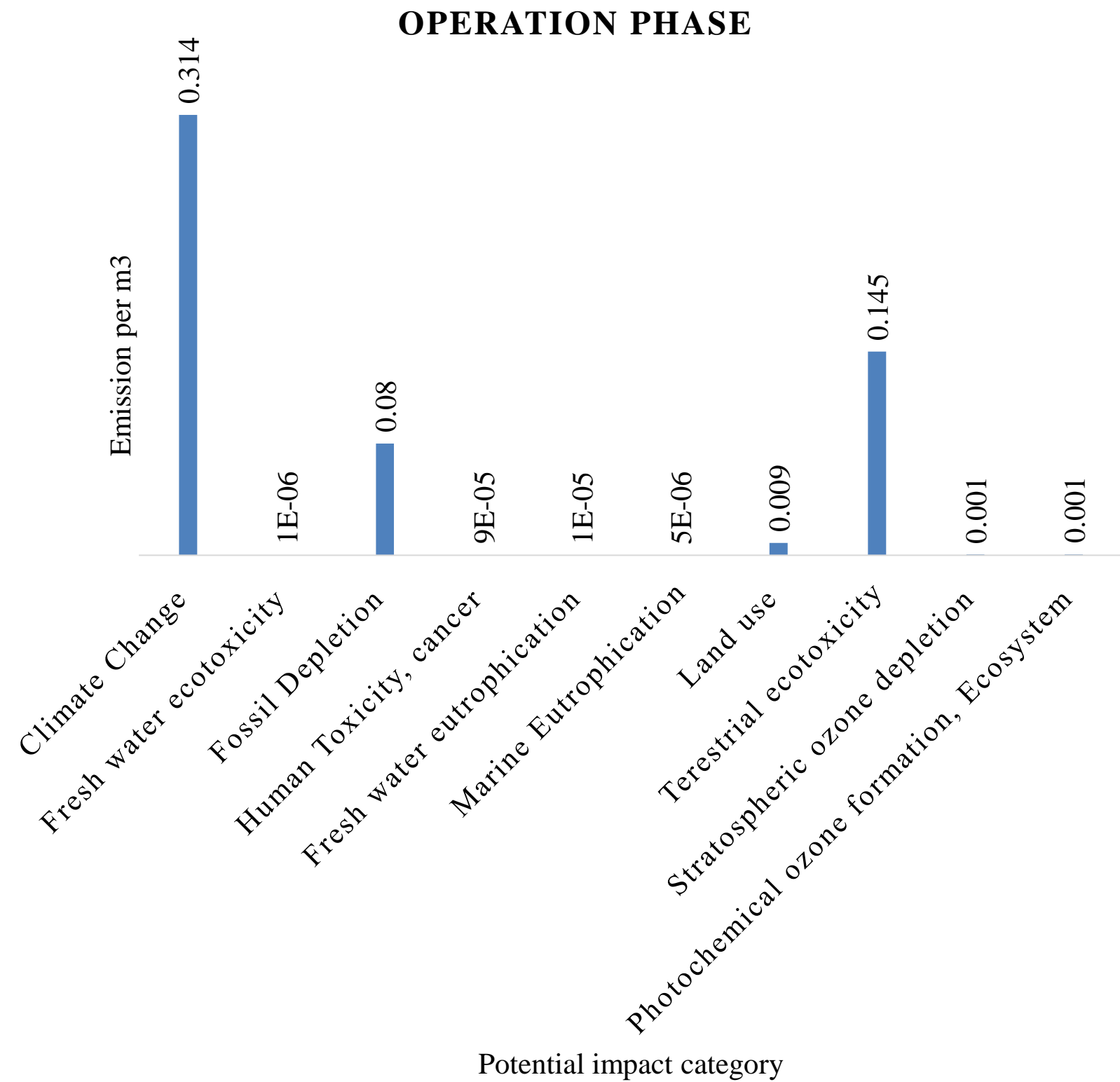


CONSTRUCTION PHASE

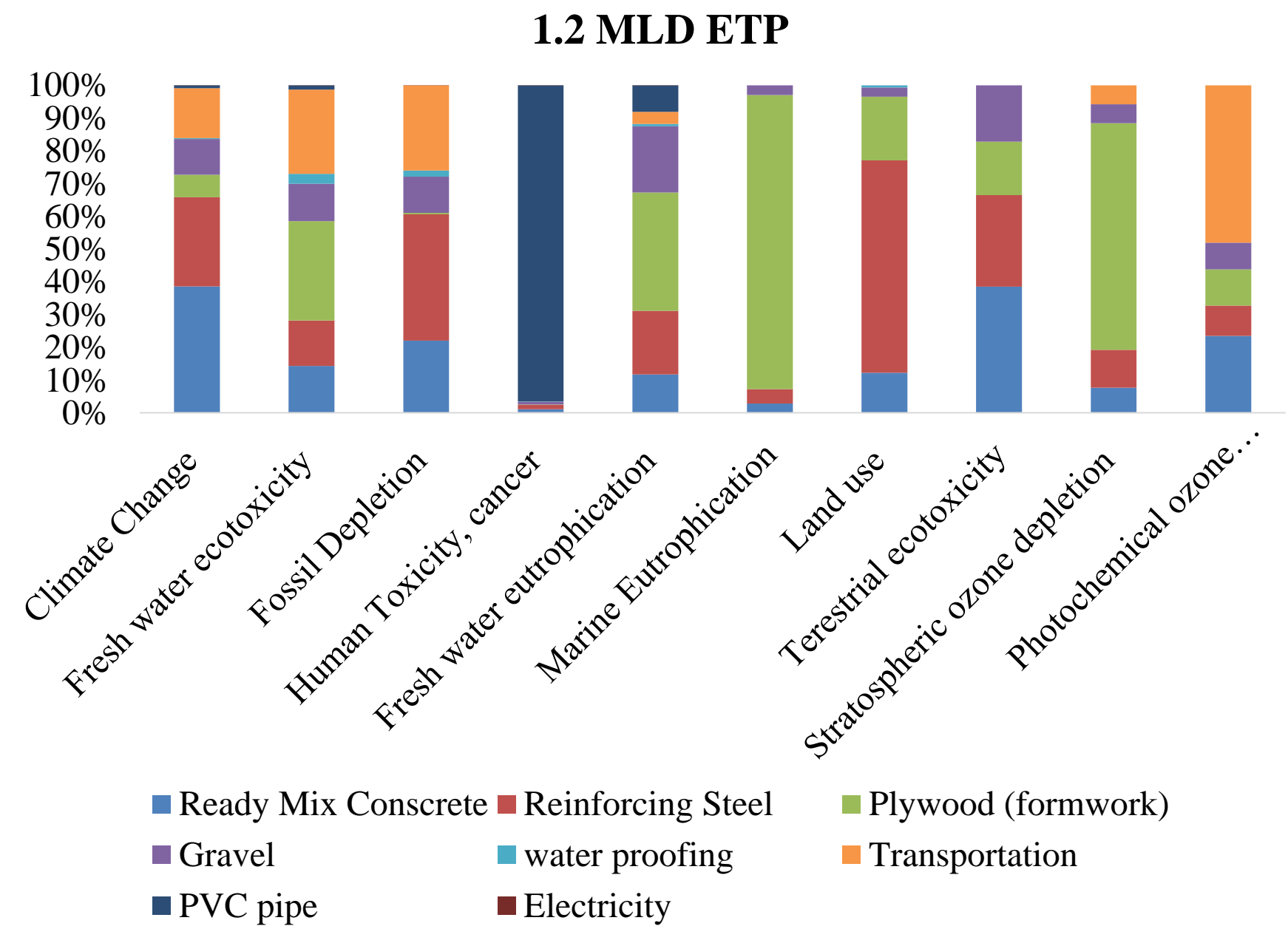
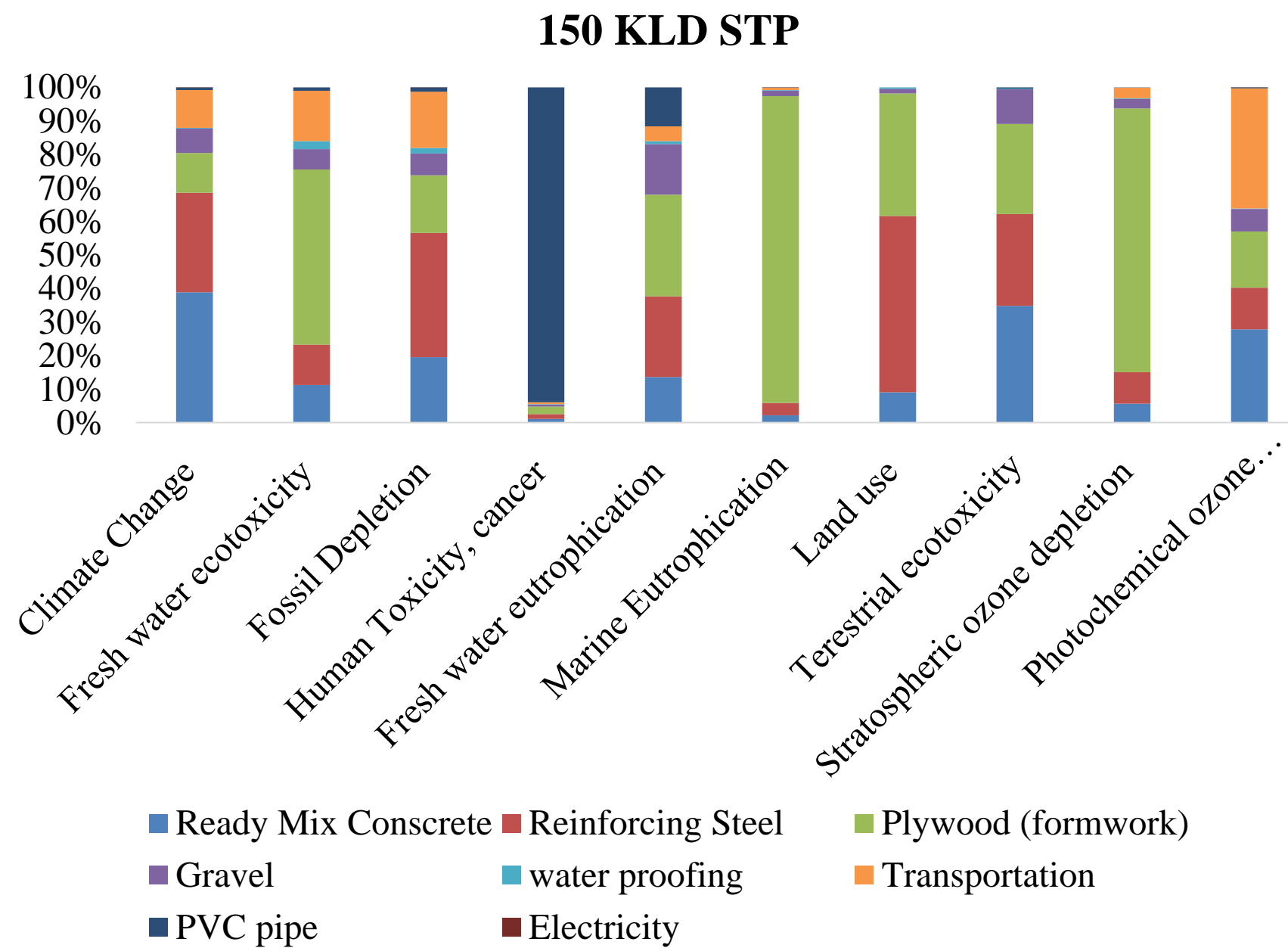




Potential impact for 150 KLD ETP system



Relative potential life-cycle impact of the Construction phase for both systems





- This study compares two CWs, STP and ETP, for wastewater treatment, evaluating their environmental impact during the operation and construction phases.
- Despite higher emissions in the ETP, both systems excel individually in pollutant removal.
- Conclusively, CWs are beneficial for industrial wastewater treatment in India.
- The smaller STP, however, exhibits higher emissions during the construction phase, suggesting the need for impact-reduction strategies through sustainable practices.

Acknowledgment



- Prof. Pratham Arora, IIT Roorkee
- Hydro and Renewable Energy Department, IIT Roorkee
- 8th International R&D Conference on Global Trends in Water Resources, Power & RE Sectors, CBIP New Delhi
- BlueDrop Enviro Pvt. Ltd, Hyderabad



- [1] “Why Wastewater Treatment is Important | Carlow Tanks.” <https://www.carlowtanks.ie/why-waste-water-treatment-is-so-important/> (accessed Apr. 23, 2023).
- [2] “What is life cycle assessment (LCA)? | Golisano Institute for Sustainability | RIT.” <https://www.rit.edu/sustainabilityinstitute/blog/what-life-cycle-assessment-lca> (accessed Apr. 12, 2023).
- [3] E. Risch, C. Boutin, P. Roux, S. Gillot, and A. Héduit, “LCA in wastewater treatment-Applicability and limitations for constructed wetland systems: using vertical Reed Bed Filters Greenhouse design & construction View project in-situ on-site systems assement View project LCA in wastewater treatment-Applicability and limitations for constructed wetland systems: using vertical Reed Bed Filters.” [Online]. Available: <https://www.researchgate.net/publication/316190088>
- [4] U. States Department of Energy, “DEFINING FUNCTIONAL UNITS FOR LCA AND TEA produced by the DOE Advanced Manufacturing Office (AMO) Defining Functional Units for LCA and TEA A tutorial produced by the DOE Advanced Manufacturing Office”.
- [5] J. D. Resende, M. A. Nolasco, and S. A. Pacca, “Life cycle assessment and costing of wastewater treatment systems coupled to constructed wetlands,” *Resour Conserv Recycl*, vol. 148, pp. 170–177, Sep. 2019, doi: 10.1016/j.resconrec.2019.04.034.
- [6] Z. Cao *et al.*, “Comprehensive benefits assessment of using recycled concrete aggregates as the substrate in constructed wetland polishing effluent from wastewater treatment plant,” *J Clean Prod*, vol. 288, Mar. 2021, doi: 10.1016/j.jclepro.2020.125551.
- [7] Y. Casas Ledón, A. Rivas, D. López, and G. Vidal, “Life-cycle greenhouse gas emissions assessment and extended exergy accounting of a horizontal-flow constructed wetland for municipal wastewater treatment: A case study in Chile,” *Ecol Indic*, vol. 74, pp. 130–139, Mar. 2017, doi: 10.1016/j.ecolind.2016.11.014.
- [8] S. Katakai, S. Chatterjee, M. G. Vairale, S. Sharma, S. K. Dwivedi, and D. K. Gupta, “Constructed wetland, an eco-technology for wastewater treatment: A review on various aspects of microbial fuel cell integration, low temperature strategies and life cycle impact of the technology,” *Renewable and Sustainable Energy Reviews*, vol. 148. Elsevier Ltd, Sep. 01, 2021. doi: 10.1016/j.rser.2021.111261.
- [10] S. Katakai, S. Chatterjee, M. G. Vairale, S. K. Dwivedi, and D. K. Gupta, “Constructed wetland, an eco-technology for wastewater treatment: A review on types of wastewater treated and components of the technology (macrophyte, biofilm and substrate),” *J Environ Manage*, vol. 283, Apr. 2021, doi: 10.1016/j.jenvman.2021.111986.



- [11] F. H. Lakho *et al.*, “Life cycle assessment of two decentralized water treatment systems combining a constructed wetland and a membrane based drinking water production system,” *Resour Conserv Recycl*, vol. 178, Mar. 2022, doi: 10.1016/j.resconrec.2021.106104.
- [14] M. Garfí, L. Flores, and I. Ferrer, “Life Cycle Assessment of wastewater treatment systems for small communities: Activated sludge, constructed wetlands and high rate algal ponds,” *J Clean Prod*, vol. 161, pp. 211–219, Sep. 2017, doi: 10.1016/j.jclepro.2017.05.116.
- [19] C. A. Lutterbeck, L. T. Kist, D. R. Lopez, F. V. Zerwes, and E. L. Machado, “Life cycle assessment of integrated wastewater treatment systems with constructed wetlands in rural areas,” *J Clean Prod*, vol. 148, pp. 527–536, Apr. 2017, doi: 10.1016/j.jclepro.2017.02.024.



Thank You