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Commentary

Empowering indigenous resilience with treatment wetlands

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Many Indigenous communities in Canada have little or no access to water treatment facilities. Treatment wetlands could offer a nature-based solution with localized and decentralized wastewater treatment. However, it is crucial that Indigenous ecological knowledge and cultural practices are integrated into the design, implementation, and management of treatment wetlands.

INTRODUCTION

The United Nations has included "Clean Water and Sanitation" in the Sustainable Development Goals (SDGs [goal .6]). However, global progress toward achieving the specific targets of SDG 6 by 2030 is mixed.[1] It is a substantial achievement that an additional 637 million people have gained access to safely managed drinking water between 2015 and 2022. But in contrast, little, if any, progress has been made in the proportion of wastewater that is treated before being discharged into the environment. This polluted water causes ecosystem degradation and loss of biodiversity. It is evident with surpassing clarity that improved governance of water resources is needed.

High on the list of actions recommended by the UN to reach SDG 6 is to improve the participation of Indigenous communities. Indigenous peoples constitute 5% of the global human population but steward up to 20% of terrestrial landscapes with ~80% of the planet's biodiversity.[2] Their traditional knowledge of local ecosystems accumulated over generations includes a deep understanding of water cycles.[3] Indigenous peoples recognize water as a sacred and life-sustaining resource and thrive for a holistic approach to water management and stewardship that is rooted in cultural practices, spiritual beliefs, and a deep respect for nature. However, access to adequate wastewater treatment and water purification services remains a challenge for many Indigenous communities. A case in point is seen in First Nations communities in Canada. In a survey with data up to 2015, 212 out of 442 wastewater facilities in First Nations communities were considered to be at moderate or high risk of underperforming or failing.[4] Little had changed by 2021 according to the most recent governmental report,[5] with insufficient or broken water infrastructure still being a substantial problem. Barriers to advanced treatment are high infrastructure costs, especially when a community is located in a remote and sparsely populated area, which requires expensive piping systems, and lack of skilled personnel.[5]

Wetlands could provide a promising solution to mitigate water treatment risks, as they have a natural capacity to filter and purify water[6] and Indigenous communities largely rely on natural processes for water treatment. Specifically, treatment wetlands (TWs), also known as constructed wetlands (CWs), mimic the processes occurring in natural wetlands. As wastewater flows through the wetland system, physical, chemical, and biological processes, such as sedimentation, filtration, nutrient uptake, and microbial degradation, contribute to the removal of pollutants and the improvement of water quality. Hence, wetlands are environmentally friendly, highly self-sustaining, and cost-effective water treatment systems,[6] forming examples of a nature-based solution (NBS) for various water treatment applications.[6] So far, there are only a few TWs used in Indigenous communities.[7] In this commentary, we highlight the potential of TWs as an effective alternative for wastewater treatment in Indigenous territories (Figure 1).

Natural benefits of TWs

As with activated sludge-based treatment plants, TWs are for the protection of aqueous ecosystems, including drinking water sources, from pollution rather than providing drinking water directly. The efficacy of TWs is influenced by various parameters, including water flow path, plant species, substratum, temperature, hydraulic residence time, and pollutant loading rates. Different types of TWs vary in their removal efficiencies, providing choices to users according to their possibilities and treatment aims. For example, a set of floating TWs could treat 60 million m^3 of wastewater annually at a cost of US \$0.00026 per m^3, attenuating 48%–83% of standard wastewater parameters.[8] Enhanced performance is achieved by intensified TWs, such as with artificial aeration and bio-electrical systems. Other improvement measures include the selection of cold-resistant plants, gravel bank filtration, and the use of gel flocculants. TWs can also effectively remove contaminants such as heavy metals, emerging pollutants, pesticides, and microplastics.[9] However, high aqueous pollutant concentrations can limit plant growth or extend treatment times.

TWs also provide opportunities for the recovery of valuable resources such as nutrients, energy, and harvested biomass

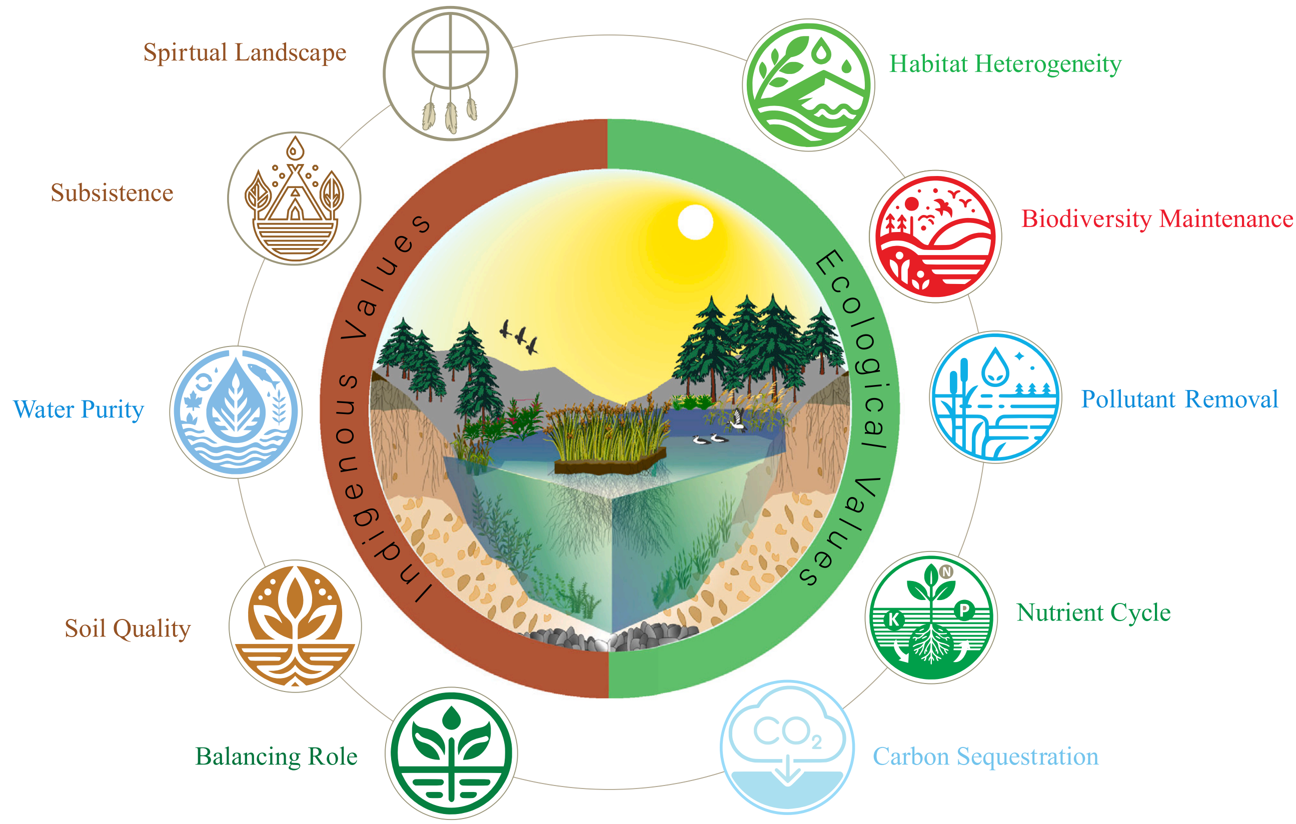

Figure 1. An illustration of indigenous and ecological values of treatment wetlands

for revenue generation. The systems may allow for the agricultural use of nutrient-rich wastewater, reducing the need for fertilizers.[9] TWs contribute to the conservation of biodiversity by providing habitats for diverse plants and animal species for which they offer nesting sites, food sources, and shelter, supporting local biodiversity.[10] By creating, restoring, and maintaining diverse habitats within TWs, Indigenous communities can restore ecosystem functions, enhance their resilience, and support the recovery and conservation of culturally significant species.[10]

Economic and societal benefits of TWs

TWs could offer compelling economics compared to conventional wastewater treatment plants. The lower life cycle costs of TWs, including capital investment and minimal operational requirements, are due to their use of natural processes and zero or only small energy requirements. A comparative analysis of operational efficiency for wastewater treatment and disposal strategies in three villages showed that a semi-centralized TW required 83% less energy than a central technical system and 72% less energy than discharge to a large-scale sewage treatment plant 20 km away.[11] Furthermore, TWs can be designed to include features or species of cultural significance to Indigenous communities. Many naturally occurring wetland plants have traditional uses, ranging from food and medicine to tools and shelter.[12] Prioritizing these native plants in TW design can help counteract the habitat loss threatening many species, preserving both Indigenous practices and ecological health.

A local TW provides a customized water management solution that can be specifically designed to address the requirements of a particular community while minimizing infrastructure costs and complexity.[13] Importantly, decentralized systems offer distinct advantages for communities in remote regions where centralized infrastructure is either impractical or cost prohibitive. These decentralized systems can be built and operated as several units, which enhances functional resilience as opposed to single centralized facilities that carry the risk of a complete shutdown.[13] Furthermore, decentralized TWs provide Indigenous communities with greater control and autonomy over their water resources. Incorporating local systems allows communities to collaboratively engage in wastewater treatment processes. This participatory approach to water management aligns with the values of self-determination that are treasured by many Indigenous communities.

Promoting multiple-stakeholder engagement in TWs

There can be many different stakeholders and rightsholders (i.e., stakeholders with constitutional rights) involved in the planning and implementation of TWs in Indigenous communities, especially when non-domestic wastewater is involved.

Meaningful community engagement is crucial from the early stages of planning to the long-term management of the TWs. Some Indigenous communities possess valuable wetland knowledge and follow traditional practices associated with wetland ecosystems. These practices may include sustainable cultivation methods that promote biodiversity and soil health. For example, Indigenous knowledge guided the selection of three priority sites for para grass weed management in northern Australia.[14] Indigenous communities in the Amazon rainforest, Canada, and the Pacific Islands have initiated watershed restoration projects that focus on improving water quality, restoring riparian habitats, and promoting sustainable resource management. These initiatives also support eco-tourism ventures, which generate additional income for Indigenous communities. The programs involve collaboration with local tribes, traditional knowledge holders, and other community members to restore habitats, reintroduce native species, and implement sustainable land management practices. The programs emphasize the involvement of Indigenous communities in decision-making processes to promote rights-based conservation models by providing input on design elements, management strategies, and monitoring protocols. Such collaborative approaches could ensure that the TW aligns with the community's needs and rights, aspirations, and cultural values.

To enable and empower Indigenous communities to participate in TW management, it is important to set up initiatives aimed at enhancing their capacity and skills for sustainable development and natural resource management. The initiatives could be included in existing programs that involve Indigenous communities, such as Indigenous language revitalization, Indigenous-led cultural education initiatives, digital inclusion and connectivity, and land-based and experiential learning programs. Education programs should adopt a culturally sensitive approach that respects and incorporates Indigenous knowledge systems, traditions, and values. Technical training could be provided to Indigenous communities in the design, construction, operation, and maintenance of TWs. The Indigenous Peoples' Biocultural Climate Change Assessment Initiative (IPCCA) is one such example that aims to strengthen the capacity of Indigenous peoples to understand and respond to climate change by documenting and sharing traditional knowledge and practices.[15] Building local capacity could empower the community to take an active role in the decision-making processes and management activities.[16]

TW management also requires professional knowledge and policy support. Strengthening cooperation between Indigenous communities and stakeholders such as government agencies, non-governmental organizations, and academic institutions is crucial. Partnerships can provide access to resources, expertise, and funding opportunities and facilitate knowledge exchange and learning between different stakeholders and rightsholders. For example, the Elwha River restoration in the United States was accomplished through a partnership between the scientific community and the Lower Elwha Tribe; combining scientific expertise with Indigenous knowledge led to ecosystem-level changes and contributed to the betterment of the ecosystem.[17] Another example is the successful ecological restoration of severely degraded acidic soil at East Trinity wetland in Queensland, Australia. Indigenous rangers addressed the issue of acidity and played a vital role in reviving the wetland, demonstrating the importance of combining traditional knowledge and scientific expertise in ecosystem restoration.[18]

It is essential to note that the specific details of TW implementation may vary depending on the local context, cultural lenses, and community priorities. A one-size-fits-all approach is less likely to be universally applicable to all Indigenous communities. Regular monitoring, evaluation, and feedback loops are essential for assessing the effectiveness of the TW and making informed decisions for ongoing management. For example, a floating TW added to the local wastewater stabilization pond of a small community in Brazeau, Alberta, Canada, initially provided only limited improvement in water quality.[6] Enhancements such as area expansion and aeration significantly improved performance in subsequent years, achieving notable reductions in pollutants and meeting national guidelines for water quality.

Limitations to the expanded use of TWs

The implementation of TWs faces several challenges. Technically, TWs require design and long-term maintenance expertise, which, although not substantial, is often lacking in less-developed areas. TWs provide mostly secondary treatment with an efficacy constrained by land availability and subject to seasonal variations, with reduced performance in colder climates.[6] Users need to be aware that TWs may not meet the higher effluent standards of tertiary treatment. Financially, the initial investment for construction and land acquisition can be considerable. Ecologically, TWs pose risks such as mosquito breeding if not properly maintained. Finally, the lack of supportive policies and complex regulatory frameworks may delay the adoption of TWs. These constraints highlight the complexity of implementing TWs as a widespread wastewater treatment option.

Conclusions

TWs are an appealing treatment choice for Indigenous communities due to their various natural benefits and compatibility with Indigenous values and priorities. Empowering local communities' participation in TW management and fostering effective collaboration with stakeholders such as governments and research institutes are important ways to promote more efficient TW management. This contributes to enhancing the resilience of local communities and water ecosystems.

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AUTHOR CONTRIBUTIONS

M.A. conceptualized the article and wrote the first draft. C.B., J.H., J.A.M., M.U., and M.G.E.

contributed to the development of the article through extensive discussions and feedback on the manuscript.

DECLARATION OF INTERESTS

The authors disclose that J.H. is the CEO of Clear-Flow Group, which engages in environmental projects. Identifying as Métis, this author advocates for rights-based conservation models and nature-based solutions, which resonate with this manuscript's focus on sustainable reclamation. These affiliations do not impact the scientific integrity of our commentary.

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