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Use of Treated Wastewater: Opportunities, Challenges, and a Reconsideration in the Indian Context

[The question is not only about reuse, but about the best possible use]

In the previous issue, we discussed the perspective that treated wastewater should not be considered merely as an alternative water source only for anthropogenic needs, but also as a potential tool for the rejuvenation of rivers, wetlands, groundwater systems, and ecological systems. However, as the conversation around wastewater reuse progresses, a critical question emerges—should treated wastewater be directly utilized for agriculture, industries, and other consumptive purposes, or should its primary application be reserved for ecological restoration and environmental recovery?

The answer to this question is not straightforward. It involves multiple dimensions, including public health, soil quality, water security, energy requirements, economic feasibility, social acceptance, and long-term ecological sustainability. Continuing this discussion, thisissue explores the benefits, challenges, limitations, and potential risks associated with the reuse of treated wastewater, with a specific focus on the Indian context.

Public Health Responsibility and Institutional Accountability: Safety Before Convenience

The discussion on the reuse of treated wastewater is often focused on water availability, resource conservation, and economic benefits. However, an equally important question is frequently overlooked—who will be responsible if the use of treated wastewater results in adverse impacts on public health?

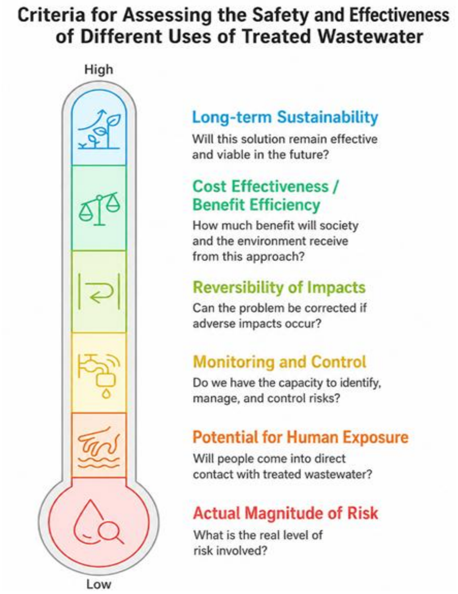
In India, many Sewage Treatment Plants (STPs) are still operating below their designed capacity, and regular quality monitoring and compliance assessment remain challenging in several regions. Under such circumstances, if urban local bodies, state governments, or other public institutions promote the use of untreated, partially treated, or inadequately treated wastewater for agricultural purposes, they are not merely making a water management decision; they are also taking a decision that directly affects the health and well-being of millions of people. Scientific studies have indicated that treated wastewater may still contain potential contaminants such as pathogenic microorganisms, antibiotic-resistant bacteria, pharmaceutical residues, endocrine-disrupting chemicals, heavy metals, microplastics, and other emerging contaminants. The impact of these pollutants is not limited to agricultural fields alone; through the food chain, groundwater pathways, and environmental interactions, they can potentially reach and affect the wider society.

The most immediate risks of treated wastewater reuse are borne by farmers and agricultural workers through direct exposure. Contaminants may subsequently affect livestock, irrigated crops, the food chain, and ultimately consumers. If these contaminants accumulate in soils and leach into groundwater, they could threaten drinking water supplies for millions of people.

In India, where nearly 85% of rural drinking water and about 60% of irrigation depend on groundwater, water quality management extends beyond agriculture and represents a critical public health priority. In a diverse country like India, where treatment technologies, operational capacities, and monitoring systems vary widely, the safe agricultural reuse of treated wastewater requires robust quality standards, clear accountability, and transparent monitoring to protect public health. Therefore, the key question is not whether treated wastewater should be reused, but whether adequate safeguards are in place to responsibly manage the associated health risks before promoting its widespread adoption.

Agricultural Use vs. Ecological Restoration: Balancing Risks and Benefits

While discussing the reuse of treated wastewater, two major perspectives often emerge. The first approach emphasizes its direct use in agriculture and industries to reduce dependence on freshwater resources. The second approach focuses on utilizing treated wastewater for the restoration of declining rivers, wetlands, and other ecological systems. However, this debate is often presented in an overly simplified manner—as if agricultural use is inherently risky and ecological restoration is completely safe. The reality is far more complex.



In agricultural applications, treated wastewater becomes directly linked with the food production system. Crops, livestock, farmers, and consumers may all come into contact with it, increasing the possibility of contaminants entering the food chain. In contrast, when treated wastewater is used for the restoration of rivers, wetlands, and water bodies, the associated risks are primarily related to ecological systems, sediments, and groundwater interactions, while direct human exposure is comparatively indirect.

In addition, natural processes such as sedimentation, dilution, biological uptake, and natural purification can contribute to reducing certain risks during ecological restoration. Therefore, the evaluation of different applications of treated wastewater should not be based solely on the presence of risks, but also on the nature of those risks, the possibility of human exposure, and the long-term public interest.

Key questions that need to be considered include:

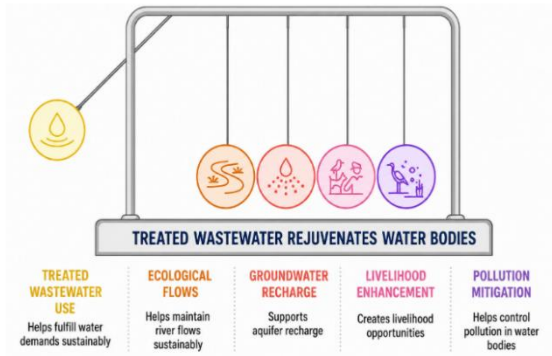
- How extensive are the benefits derived from its use?
- Is the proposed solution sustainable in the long term?

Perhaps the question is not whether treated wastewater should be used for agriculture or ecological restoration; rather, it is about where, for what purpose, at what quality level, and under what monitoring framework it should be utilized.

Therefore, no option should be evaluated simply as "safe" or "unsafe." A comprehensive assessment requires addressing fundamental questions such as:

- What is the actual magnitude of the risk?
- What is the likelihood and extent of human exposure?
- How effectively can the risks be monitored and controlled?
- If a problem occurs, is its impact reversible or irreversible?

Ultimately, the success of treated wastewater management does not lie in choosing a single preferred option, but in establishing a scientific, transparent, and long-term balance between risks and benefits. The question is not where treated wastewater should go; rather, it is about determining which level of risk is more acceptable for society.



Long-Term Impacts on Soil Health: An Invisible but Critical Challenge

A common argument in favour of using treated wastewater for agriculture is that it increases the availability of irrigation water and, due to the presence of nutrients such as nitrogen, phosphorus, and other elements, may partially reduce the dependence on chemical fertilizers. However, an important aspect that receives relatively less attention is its impact on soil health.

Soil is not merely a medium that supports crop growth; it is a complex and living ecosystem where millions of microorganisms, organic matter, nutrient cycles, and water movement processes remain continuously active. The long-term impact of any irrigation source is ultimately reflected in the functioning and stability of this ecosystem.

With continuous irrigation, the accumulation of salts, sodium, chloride, sulphates, trace pollutants, and various residual chemicals in soil may occur. Over time, this can lead to problems such as soil salinization, sodicity, reduced water infiltration capacity, degradation of soil structure, and decline in agricultural productivity. In addition, pharmaceutical residues, microplastics, and other emerging contaminants may influence soil microbial communities and disrupt natural nutrient cycling processes.

Soil is a living ecosystem.

Treated wastewater may help grow crops, but can it also maintain soil health? Alternative sources of water can be found, but healthy soil cannot be easily replaced.

Therefore, the use of treated wastewater must also be evaluated against the critical benchmark of long-term soil health.

In India, where low soil organic carbon, land degradation, and nutrient imbalance are widespread, the agricultural reuse of treated wastewater should be viewed not only as a means to augment water resources but also as a strategy for sustaining long-term soil health. Ultimately, the question is not whether treated wastewater can support crop production today, but whether it can sustain soil productivity and ecological health over the coming decades.

Because while water scarcity can be addressed through alternative sources, restoring degraded and damaged soil is often far more difficult, expensive, and time-consuming.

Monsoon Hydrology and Nature's Self-Purification Capacity: India's Natural Restoration Mechanism

India receives nearly 4,000 BCM of rainfall annually, most of which occurs during a few months of the monsoon season. This vast amount of rainfall flows through rivers, streams, lakes, ponds, and wetlands, facilitating the redistribution of sediments, nutrients, and salts, supporting groundwater recharge, and playing a significant role in the natural dilution of pollutants.

The use of treated wastewater for rejuvenating drains, ponds, lakes, and wetlands strengthens interconnected hydrological systems. During non-monsoon periods, it helps sustain ecological flows, enhances groundwater recharge, and supports biodiversity. During the monsoon season, natural processes such as flushing, dilution, sedimentation, biological transformation, and flow dynamics assist in the redistribution and processing of accumulated materials. Ultimately, the question is not only where treated wastewater should be reused, but also how it should be managed by considering India's monsoon-driven hydrology, natural flushing capacity, and ecological processes. This integrated approach can transform wastewater reuse from merely a water management practice into a foundation for water management that works in harmony with nature.

Energy, Economy, and Public Interest: A Broader Perspective on the Use of Treated Wastewater

The evaluation of treated wastewater reuse should not be based only on water availability, but also on its energy requirements, economic feasibility, climate implications, and the overall benefits it provides to society. If treated wastewater is to be made completely safe for agricultural use, conventional treatment alone may not be sufficient. Advanced treatment systems—such as membrane-based technologies, UV disinfection, ozonation, advanced oxidation processes, activated carbon, and reverse osmosis—may be required to remove pathogens, pharmaceutical residues, microplastics, endocrine-disrupting chemicals, excess nutrients, and salts. While these technologies significantly improve water quality, they also involve higher energy consumption, increased carbon emissions, greater capital investment, and higher operational costs.

This brings forward the question of economic feasibility. In India, agriculture accounts for the largest share of total water consumption, while the economic value of irrigation water remains very low, and in many states, the full cost of water supply is not recovered. Considering farmers' limited income, uncertain agricultural profitability, and the political sensitivity of water pricing, it is difficult to expect the agricultural sector to bear the actual cost of advanced wastewater treatment. Therefore, the issue is not only technical but also economic and policy related.

The success of any water policy should not be measured only by the quantity of water recovered, but by the public benefits created, ecological balance restored, and long-term water security achieved

In contrast, if a significant proportion of treated wastewater is directed towards the rejuvenation of rivers, wetlands, lakes, and other water bodies, the benefits generated are not restricted to any single individual or group. Restored ecosystems enhance groundwater recharge, conserve biodiversity, support environmental flows, help regulate urban temperatures, increase carbon sequestration, and provide essential ecological services such as flood regulation.

In addition, society gains several indirect benefits, including recreational opportunities, aesthetic value, cultural significance, and improved local water security.

Ecological Restoration and Resource Recovery through Treated Wastewater

When used in accordance with scientific standards, treated wastewater can support the rejuvenation of declining ponds and lakes, creation of wetlands, restoration of drains and streams, and maintenance of minimum ecological flows. This approach not only enhances water availability but also contributes to groundwater recharge, biodiversity conservation, and the maintenance of local ecological balance.

In this context, nature-based treatment systems hold special importance. Systems such as constructed wetlands, oxidation ponds, ecological lagoons, and riparian restoration systems can improve water quality with relatively low energy requirements. These systems not only help reduce excess nutrients and pathogens but also provide habitats for birds, fish, aquatic plants, and other organisms. Thus, water treatment and ecological conservation can be achieved simultaneously.

Restoration of water bodies using treated wastewater may increase the risk of eutrophication. However, in the Indian context, nutrient inputs arise not only from treated wastewater but also from agricultural runoff, livestock activities, groundwater, soil erosion, and atmospheric deposition. Therefore, the focus should be on balanced nutrient management rather than complete nutrient removal.

This approach aligns with the principles of resource recovery. Controlled harvesting of aquatic plants and algae from restored water bodies enables the recovery of nitrogen, phosphorus, and organic carbon. The harvested biomass can be converted into compost, biofertilizers, biochar, or bioenergy, transforming excess nutrients from pollutants into valuable resources within a circular economy.

The benefits of treated wastewater extend beyond augmenting water resources. When integrated with ecological restoration, it can support a green economy by promoting wetland management, sustainable fisheries, biomass utilization, ecological tourism, green employment, and carbon credit initiatives. Thus, treated wastewater serves not only as a valuable resource but also as a catalyst for environmental and economic sustainability.

However, ecological restoration should not be considered a completely risk-free solution. Challenges such as eutrophication, algal blooms, sediment contamination, microplastics, pharmaceutical residues, and potential impacts on groundwater systems may also arise. Therefore, the success of any restoration initiative depends on appropriate treatment standards, regular monitoring, assessment of the carrying capacity of water bodies, and the adoption of adaptive management approaches.

Despite these limitations, Indian conditions present a significant opportunity. Considering the country's vast monsoon rainfall, extensive river networks, natural flow systems, and increasing ecological degradation, the use of treated wastewater for the restoration of ponds, lakes, wetlands, drains, and degraded river systems can, in many situations, provide broader social and environmental benefits compared to direct agricultural reuse.

This perspective can help transform treated wastewater from being viewed as a waste product into a strategic resource for future water and ecological security.