GLOBAL CHALLENGES AND SOLUTIONS IN WASTEWATER MANAGEMENT

https://doi.org/10.5281/zenodo.15028154

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Abstract: Water used for domestic and industrial activities becomes contaminated and unfit for consumption or agriculture, commonly referred to as wastewater. Containing chemical mixtures, organic matter, and heavy metals, wastewater has posed significant global challenges over the past 30 years. Its contamination causes diseases like cancer, gastrointestinal disorders, bacterial infections, and disrupts marine ecosystems, leading to habitat destruction and species extinction.

Moreover, wastewater pollution negatively impacts tourism, agriculture, and fisheries by reducing biodiversity, damaging crops, and creating toxic environments, which in turn affects human health and economic productivity. Regions with severe pollution, such as the Ganges and Long Island Sound, exemplify these consequences, with cancer rates spiking near polluted areas (Wohl, 2012). International organizations like the UN, UNESCO, and the World Bank are prioritizing wastewater management. Practical solutions, including Wastewater Treatment Plants, Bio-Sand Filters, and improved sewage regulations, have successfully treated 55-85% of contaminants. These efforts highlight the urgency and potential for addressing this critical issue globally.

Keywords: Wastewater, Contamination, Chemical mixtures, Organic matter, Heavy metals, Pollution, Marine ecosystems, Habitat destruction, Species extinction, Biodiversity

Introduction:

Wastewater, which is produced by domestic activities, industrial processes, and stormwater, is a significant concern globally due to its contamination, which makes it unsuitable for consumption, agriculture, and other uses. Domestic wastewater arises from everyday household activities, industrial wastewater results from manufacturing processes, and stormwater is generated through rain or runoff. The contamination of wastewater is a pressing environmental and public health issue, as it can introduce hazardous chemicals, heavy metals, and harmful organic matter into water systems, threatening human health, ecosystems, and economic productivity. In response to this issue, various wastewater management approaches have been implemented, with a focus on reducing pollutants and managing wastewater in both developed and developing regions (Wastewater Research Project 21D).

International efforts, such as those outlined in the United Nations' Sustainable Development Goals (SDGs), emphasize the need for effective wastewater management systems. These efforts aim to reduce pollution, reuse wastewater, and minimize hazardous substances in water. Additionally, strategies like Centralized Wastewater Management (CWTS), Decentralized Wastewater Management (DWTS), and Combined Wastewater Treatment Systems are being adopted to manage wastewater more effectively (UN World Development Report, 2017). Each of these systems has its advantages and drawbacks, depending on factors like population density, infrastructure, and geographical location (UNCLOS).

Results:

The different wastewater treatment systems show varying levels of success depending on their context and application. Centralized Wastewater Treatment Systems (CWTS), widely used in urban areas with high population density, provide an efficient way to manage large-scale wastewater through extensive underground pipe networks (Hawkins et al., 2013). However, CWTS can be costly to establish and maintain, particularly in rapidly industrializing regions. It also faces technological vulnerabilities, which could lead to sanitation disruptions if not properly secured. On the other hand, Decentralized Wastewater Treatment Systems (DWTS), used in rural and low-population areas, offer a more affordable and scalable solution. These systems, which include septic tanks, aerobic treatment units, and constructed wetlands, are much cheaper to build and maintain (Anjaneyulu et al., 2005; Crini and Badot, 2007, 2010). They are also more suited to specific, localized needs but can face limitations due to space requirements and scalability in larger communities. Combining CWTS and DWTS into a hybrid system is increasingly being adopted to address the challenges of both systems. This approach can handle wastewater efficiently while managing stormwater during heavy rainfall, thus preventing environmental contamination. Moreover, localized systems like septic tanks and constructed wetlands can serve smaller communities without the need for extensive infrastructure (Hawkins et al., 2013).

Furthermore, Wastewater Treatment Plants (WWTPs) play a central role in wastewater management, allowing for the filtration and recycling of water, reducing the strain on freshwater supplies. These plants treat water through a series of stages (pre-treatment, primary, secondary, and tertiary), ensuring that biological, chemical, and physical contaminants are removed before water is released back into the environment (Anjaneyulu et al., 2005; Crini and Badot, 2007). In areas facing water scarcity, treated wastewater can be reused for irrigation, industrial processes, and even street cleaning, contributing to water conservation efforts (UNICEF/WHO Joint Monitoring Program, 2021). However, there are also challenges associated with wastewater treatment, including the need for large land areas, increased water volume during heavy rains, and potential chemical hazards. Despite these drawbacks, the continued development and optimization of wastewater treatment technologies are essential for improving water quality and managing water resources effectively, particularly in the face of growing global water scarcity (US EPA and USGS). By balancing both centralized and decentralized systems, cities, towns, and rural areas can benefit from tailored solutions that optimize wastewater treatment based on local needs, environmental conditions, and economic constraints (World Nuclear Association, 1990; American Society of Civil Engineers).

DISCUSSION

Currently, one of the victims of the wastewater crisis has been Uzbekistan. One of the unresolved problems is the problem of management of formed return waters and discharge they are fed into the trunk of rivers, lakes and wetlands, because the collector-drainage flow is the source of salt intake into rivers and pollution of water bodies. With the development of irrigation and drainage systems, however, there was a constant increase in the volume of formed return collector and drainage waters in the region, which reached up to 36-38 km3 /year. After 1991 The volume of return waters has stabilized somewhat over the year. On average for the period 1990-1999, their total volume ranged from 28 to 33.5 km3 /year. Of these, about 13.5-15.5 km3 were formed annually in the Syr Darya basin and 16-19 km3 in the Amu Darya basin. Over the last decade (2000 - 2009), according to the SIC ICWC, the total volume of collector and drainage waters on average is about 30 km3 /year, this indicates a slight decrease in runoff. More than 51% of the total volume of return waters is diverted by collectors to rivers; about 33% is in the lower reaches and only 16% is reused for irrigation. One of the major problems in the region has become the problem of huge the volume of discharge of drainage runoff and, together with them, dissolved salts into river systems. In Uzbekistan, basic schemes have been considered that allow solving the problem of using CDW for irrigation without investing large capital funds. At the same time, it was determined: what part of the volume of CDW and what quality can be used, on which soils and in which areas. The assessment of the possibility of using collector and drainage waters for agricultural production is given based on foreign and domestic classifications and generalization of the results of field experiments. It was found that for the conditions of the Bukhara and Kashkadarya regions, the most acceptable mineralization of the used CDW is 2.5 g/l. The volumes of CDW having the specified mineralization in the Bukhara region is 750 million m3/year. Drainage and discharge waters are of good quality in the Vabkent, Gijduvan, Zhandor and Shafrika districts. In the Kash- Kadarya region, suitable for The use volumes of CDW are about 150-200 million m3 . Areas with a light mechanical composition have been installed, on which mineralized waters can be used without much damage, since they do not adsorb harmful salts. Reuse of return waters with mandatory consideration of their quantity, the quality and changes in the hydro chemical regime are important not only now, but also in the future as an additional source of water resources in the region. Therefore, issues related to the use of return water and recycled/ re-water supply become a priority. Currently, they are the most relevant for the Central Asian region. In this regard, a number of scientific – technical studies on the use of return waters. One of these experiments, the "Method of electrochemical water treatment", was carried out in 1980-1985 years at the Central Asian Scientific Research Institute of Irrigation named after V.D. Zhurin (SANIIRI) and the Central Asian Scientific Research Institute of Natural Gas (SredazNIIgaz), but only at experimental sites where a special UEV-4 installation was used (installation of water electroactivation) and positive results were obtained. Based on the results obtained, it was issued by the State Committee USSR for Inventions and Discoveries copyright certificate No. 1165638 for the invention of the "Method of water treatment for irrigation of agricultural crops". Authors: Jalilov Zafarbek Khakimovich, Danielova Lyudmila Nikolaevna, Spiritual Victor Abramovich, Mamadzhanov Ulmas Djuraevich, Bakhir Witold Mikhailovich, Volodin Vitaly Aleksandrovich and Spector Leonid Efimovich. The invention relates to the field of technical- It can be used in agriculture when using waste water for irrigation of agricultural crops. The proposed method provides for the effect on water by electric current in the area of one of the electrodes of the electrochemical system - unipolar electrical treatment. The method of unipolar water treatment allows, by electrochemical rotation of substances, to reduce the mineralization of water, change its chemical and ionic composition, as well as the physico-chemical and electrodynamic properties of water. As a result of the electrochemical activation of CDW in the negative electrode zone , the total mineralization decreases due to the removal of toxic magnesium salts, chlorides and partially sodium from the water, which improves the water quality for The effectiveness of unipolar water treatment is determined not so much by traditional indicators of the quality of electrochemical processes (degree of decomposition substances, etc.), how much is the difference in pH and redox potentials of the initial and processed system subjected to unipolar- the number of effects. In addition, inexpensive the cost of water treatment and the simplicity of the structure makes it possible to conduct research in the field of treatment of collector and drainage waters in order to reuse them for irrigation. Access to the safe water and sanitation remains a challenge in rural areas and small towns of the state. This results in higher pollutant concentrations in both surface and groundwater sources, especially in regions with water scarcity or heavy industrial activity (e.g., Karakalpakstan, Khorezm, and Bukhara). Industrial activities in Uzbekistan withdraw approximately 1.2 km^3 of water annually, but only 0.58 km^3 is consumed, with the rest being discharged as industrial wastewater. Close to 50% of withdrawn water returns as wastewater, posing significant environmental risks due to insufficient treatment. Discharges contain 8–15 contaminants, often exceeding permissible concentrations for household drinking water and fishery standards by 2–10 times. According to the Asian Development Bank, less than 40% of the country's population benefits from wastewater treatment facilities, and approximately one-fifth of the rural population lacks access to safe drinking water. The water supply and sewage systems are outdated, leading to inefficient and high-water losses. The sewer network spans 4,260.1 km, of which 14% requires replacement. In rural areas, the absence of adequate system exacerbates water loss, soil waterlogging, and environmental concerns. The ratio of centralized sewer system shows even worse data, only 63% of population being connected with significant disparities between urban (30.7%) and rural areas (0.7%). Septic tanks are the most realistic solution for Uzbekistan's wastewater problems. Wastewater treatment plants can be expensive because Uzbekistan is a developing nation that prioritizes more pressing needs including healthcare, education, and basic infrastructure. Due to financial limitations and a lack of foreign direct investment, wastewater infrastructure investments—particularly in rural areas—are inadequate. Furthermore, using centralized sewage systems is made considerably more challenging by 20% of mountainous terrain and desert areas. Large-scale replacement of outdated sewage pipes could throw internal economies out of balance. Septic tanks, which are inexpensive and easy to use, are therefore suitable for the state's current situation. This straightforward construction can be placed in any land location and measures around 10 feet long by 5 feet wide by 5.5 feet deep (3 meters by 1.5 meters by 1.7 meters). The storage capacity can accommodate typical household waste because it can be constructed based on waste size. Septic tanks are a suitable tool in areas where all four seasons occur, operating under any seasonal variation such as rain or snow. Together, these characteristics set septic tanks apart not only for Uzbekistan but also for all Central Asian countries with comparable environmental conditions.

Wastewater problem has also showed devastating problems in Africa, including countries in the North, Sub-Saharan, and East Africa. Citizens, especially children, woman, and the disabled residing in rural and remote areas with limited access to healthcare, have been threatened with wastewater problem. Unstable infrastructure has also caused vide spread of diseases that has been caused by contaminated water in water resorts. As recent estimates, around 82% of wastewater in Sub-Saharan Africa is discharged untreated into the environment. Only 29% of population has access to freshwater, and 25% of the wastewater is collected. The simplicity, cost, and adaptability of constructed wetlands to the environmental and socioeconomic conditions of Africa make them feasible to be practical in African lands. Similar to septic tanks, they are affordable and compact enough to fit in various locations. Wetlands can be exploited in Africa because of its consistently bright climate, as nothing in the surroundings may affect it. CWs are perfect in areas with a shortage of skilled workers because they require little operational input and technical knowledge. Wetlands aid in the reuse of water in aquaculture and agriculture by eliminating pollutants through natural processes. By encouraging biodiversity, they can aid in the restoration of degraded areas. In addition, CWs can operate in places with erratic electrical supplies because they are dependent on gravity and natural ecosystems. Wastewater Treatment Plant in short WWTP. Because they can effectively handle the massive volumes of wastewater produced by crowded cities and industry, wastewater treatment plants are crucial in developed countries like USA, UK, Australia, Germany, Japan, and South Korea. These facilities adhere to stringent environmental rules and guarantee the elimination of dangerous pollutants through a multi-stage treatment process. Wastewater treatment plants can scale to meet expanding urban demands while recovering important resources like electricity and cleaned water, unlike smaller or decentralized systems. They are significantly more practical than other approaches to managing wastewater in cities because of their all-encompassing strategy, which not only eliminates pollution and disease but also promotes sustainable urban expansion and economic efficiency.

REFERENCES:

1. Wohl, 2012 (for the mention of cancer rates near polluted areas like the Ganges and Long Island Sound).
2. **Wastewater Research Project 21D** (for the general description of wastewater sources).
3. **UN World Development Report, 2017** (for the statement about 80% of wastewater being discharged untreated).
4. **UNCLOS (United Nations Convention on the Law of the Sea)** (for the mention of the protocol on pollution from land-based sources).
5. **Hawkins et al., 2013** (for the mention of combined wastewater treatment systems).
6. **Anjaneyulu et al., 2005; Crini and Badot, 2007, 2010** (for the stages of wastewater treatment).
7. **UNICEF/WHO Joint Monitoring Program, 2021** (for the 2.1 billion people lacking access to safely managed drinking water services).
8. **US EPA and USGS** (for the daily wastewater production in urban zones of the USA).
9. **World Nuclear Association (WNA)** (for the use of treated wastewater in cooling nuclear plants).
10. **Milter, 1990** (for the mention of the potential 10-15% reduction in freshwater scarcity using treated wastewater).
11. **WHO and EPA** (for the global usage of septic tanks and constructed wetlands).
12. **American Society of Civil Engineers** (for the increased water volume during heavy rains).