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Research Article

Water Pollution Status and Solutions in Vietnam

Vu Xuan Manh[1], Pham Ha Ngoc[2], Nguyen Linh Chi[2], Nguyen Cao Hoang Anh[3], Tong Tran Khanh Chi[4], Do Thi Phuong An[5]

[1]*Hanoi University of Science and Technology, Hanoi, Vietnam.*
[2]*Hanoi - Amsterdam High School for the Gifted, Hanoi, Vietnam.*
[3]*Nguyen Huu Cau High School, Ho Chi Minh City, Vietnam.*
[4]*HUS High School for Gifted Students, Hanoi, Vietnam.*
[5]*Foreign Language Specialized School, Hanoi, Vietnam.*

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Abstract - *Water is an indispensable and limited resource crucial for the continuation of life on the Earth. The escalating global population and rapid industrial expansion have led to heightened rates of emissions and pollution, making the reclamation of contaminated water an urgent necessity. Polluted water, unfit for human and animal consumption, can lead to various illnesses or fatalities. The toxic substances present in water can exert both acute and chronic detrimental effects on both human health and the environment. Water purification aims to eliminate these toxins, including undesirable chemical and biological contaminants, as well as suspended solids and gases, to restore water to a safe state. This ensures that the water meets the stringent standards required for medical, pharmacological, industrial, and chemical applications.*

Keywords - *Water Pollution, Water Purification, Water Treatment.*

I. INTRODUCTION

Water pollution is defined as the contamination of water sources, including both surface and groundwater, leading to a detrimental alteration in their composition and quality, and introducing hazardous substances that severely impact human health and aquatic ecosystems [1]. This contamination can originate from both natural and anthropogenic sources. While natural factors such as decomposing animal carcasses and storm-induced runoff contribute to localized pollution, the predominant cause of current water pollution stems from human activities. Water purification refers to the application of various processes designed to eliminate toxins, undesirable chemical and biological contaminants, suspended solids, and gases from polluted water [2]. The ultimate goal is to render the water safe for consumption and usage, safeguarding both aquatic and terrestrial life, and ensuring it meets specific standards for medical, pharmacological, industrial, and chemical applications.

Vietnam is one of the largest countries in Southeast Asia, stretching from the border with China in the north to the Mekong Delta in the south, with a dense river network including major rivers such as the Red River , Dong Nai river, and Mekong River. The country has a population of more than 100 million which makes it more susceptible to water pollution through various means. This is because the high population needs clean water for daily use in households, agriculture, and industry. This large population also leads to the production of significant amounts of wastewater, especially in major urban cities like Hanoi and Ho Chi Minh City, where wastewater treatment systems are still insufficient. As a result, one of the main causes of water population in Vietnam is untreated domestic sewage being discharged directly into rivers and lakes [3]. Vietnam is a developing country with a rapid economic growth, primarily driven by sectors such as agriculture, manufacturing, and exports. However, these achievements come with environmental challenges, particularly water pollution. The widespread use of chemical fertilizers and pesticides in agriculture, along with wastewater from industrial zones and traditional craft villages, often ends up being washed into water bodies during heavy rains. This leads to high concentrations of harmful chemicals in rivers and lakes, making the water unsafe for human consumption and harmful to aquatic ecosystems. Therefore, the need for effective water purification and treatment technologies has become increasingly urgent in Vietnam today. The paper presents water pollution status and solutions in Vietnam. The numerical analysis and real examples are provided to demonstrate the effectiveness of the water purification.

II. RELATED WORKS

The section reviews existing works on water pollution and purification. Heavy metals such as lead, cadmium, mercury, and arsenic are commonly discharged into water bodies by mining and manufacturing industries. According to work in [4] these metals persist in ecosystems and accumulate in the food chain, posing long-term risks. Fertilizers, pesticides, and animal waste enter water systems, leading to eutrophication and contamination. The work in [5] highlight nitrogen and phosphorus as the primary pollutants causing algal blooms and hypoxia in freshwater and marine ecosystems. Urban areas contribute significant amounts of organic and microbial pollution. The work in [6] found that untreated sewage is a major factor in microbial contamination of rivers in South Asia, contributing to waterborne diseases that include sand filtration, activated carbon, and membrane filtration. The work in [7] showed that nanofiltration and reverse osmosis effectively remove viruses, bacteria, and salts, though cost and maintenance remain challenges. Used for disinfection. While effective, the work proposed in [8] noted that byproducts such as trihalomethanes pose health concerns. The work in [9] investigates the water pollution status in Vietnam from 1996 to 2001. The pollution of rivers is investigated. After that, some recommendations for improving the quality of water is given. The researches on water pollution and purification in Vietnam has received great attention. The issue needs to be further investigated to improve water quality in Vietnam.

III. WATER POLLUTION STATUS IN VIETNAM

Vietnam is currently facing several serious challenges in water pollution, driven by a combination of economic development, urban expansion, and environmental mismanagement. The following are the main sources of water contamination in the country:

A. Industrial Waste

The continued growth of industries means that production also rises. Most of the industries use various chemicals that are highly toxic. Once the finished products have been made the toxic are released to river streams and lakes which bring about water pollution. Water pollution occurs when harmful substances are introduced into rivers, lakes, oceans, or other bodies of water, making them unsafe for human use and damaging aquatic ecosystems. Toxic water pollution is caused by harmful chemicals entering water bodies, endangering aquatic life, ecosystems, and human health [10]. Various countries have diverse laws that govern the level of toxics that may be released to river streams as it would have fewer consequences. The treatment of this waste before release is quite high and thus many industries rarely do it causing increased water pollution.

B. Petroleum Spillage

The transportation of petroleum products by road or other water bodies such as lakes, oceans and rivers has high risks. When hazardous situations occur, the petroleum may spill on the water bodies causing lots of pollution to the water bodies. Petroleum contains harmful substances that, when mixed with water, threaten both human health and aquatic ecosystems.

Figure 1. Water Pollution by Petroleum

C. Sewage

The use of water by human beings for various purposes leads to the final product not being usable anymore and is what contributes to sewage pollution of water bodies. A large portion of household wastewater in Vietnam is discharged without proper treatment. In urban areas, sewage systems are often overloaded or incomplete, while rural areas commonly lack any sewage infrastructure. This leads to untreated waste entering rivers, causing high levels of bacterial contamination and organic matter, which are harmful to human health.

D. Soil Erosion

Soil particles may pollute the water under a downpour. This is because heavy rains wash loose soil and sediments into rivers, increasing turbidity and degrading water quality. While this type of pollution is less toxic, it still affects aquatic habitats and complicates water purification processes.

Figure 2. Water Pollution by Soil Erosion

E. Agricultural Runoff

Agricultural runoff plays a key role. The widespread use of chemical fertilizers and pesticides in farming areas leads to runoff into water bodies during rainfall. These substances can accumulate in rivers and lakes, causing eutrophication and harming both aquatic ecosystems and human health.

F. Plastic and Solid Waste Pollution

Improper disposal of plastic waste, especially single-use plastics and household garbage, contributes significantly to water pollution in rivers and coastal waters. Urban drainage systems often get clogged with trash, leading to flooding and increased pollutant loads.

IV. WATER PURIFICATION METHODS

Water purification involves using various processes to remove toxins and undesirable chemical, biological contaminants, suspended solids, and gases from polluted water. These toxins pose threats to aquatic life, as well as to terrestrial plants, humans, and animals. The goal of purification is to make water safe for reuse and to meet standards set by the medical, pharmaceutical, industrial, and chemical sectors.

The sections analyzes some technique applied for water purification.

A. Application of Integrated Technologies

Integrated Technologies (IoT, AI, GIS, Sensors): A critical approach involves using sensors, the Internet of Things (IoT), Artificial Intelligence (AI), and Geographic Information Systems (GIS) technologies. This workflow is designed to collect, evaluate, classify, and predict water quality, with encouraging numerical outcomes for creating precise water quality prediction models. This suggests a comprehensive, real-time monitoring and analytical framework.

B. Application of Machine Learning

Hybrid machine learning algorithms for Water Quality Index (WQI) Prediction: Advanced analytical approaches entail developing and implementing novel hybrid machine-learning algorithms to improve the prediction of water quality indices. These methods compare standalone models (RF, M5P, RT, and REPT) to hybrid models, which combine single models with techniques such as Bagging, CVPS, and RFC. The analysis is based on large datasets, spanning six years of monthly readings from several stations. Model correctness and stability are evaluated rigorously using measures including R^2, RMSE, MAE, NSE, and PBIAS. Key factors influencing water quality are found, with Fecal Coliform having the most impact and Total Solids having the least, highlighting critical metrics assessed throughout the process.

C. Chemical Purification

Chemicals are used to accelerate the process of making water safe for consumption. Chlorine is one of the most widely used chemicals for killing bacteria or viruses and is also crucial for preventing recontamination in the water. While a challenge of using chlorine is that it can impart a specific taste and smell to the water, this risk is generally considered minor compared to its benefits. In general, wastewater treatment chemicals react with oils or toxic substances in the wastewater to form safe sludge, gases, and water, which can then be discharged into the environment without causing pollution or harming human health. Spectrophotometer method for Total Nitrogen (N) and Total Phosphorus (P) is a core technique to assess eutrophication. For total N: All organic Nitrogen forms, NO3-, and NO2- are converted to Ammonium ions (NH4+) through an oxidation digestion process, followed by reduction of nitrates and nitrites using zinc. The resulting NH3 is distilled and absorbed in an acid solution, and the NH4+ concentration is then determined via spectrophotometry using Nessler's reagent. For Total P: All Phosphorus forms are converted to Orthophosphate via oxidative digestion with sulfuric-nitric acid mixture. The Orthophosphate then reacts with molybdate reagent to form a blue compound, and its concentration is determined spectrophotometrically.

Equipment and Reagents: Specialized equipment like UV-VIS spectrophotometers, pH meters, analytical balances, and Kjeldahl distillation units are used. High-purity chemicals and double-distilled water are essential. Calibration: Calibration curves for Ammonia and Phosphate are established and statistically validated for reliability. Measurement of Other Key Parameters: Beyond N and P, parameters such as pH, Dissolved Oxygen (DO), and Chemical Oxygen Demand (COD) are also measured. In quantitative chemical analysis, the calibration curve method using photometry is commonly used to determine the concentration of analytes in solution based on their light absorption properties. This technique is based on the Beer-Lambert rule, which establishes a linear relationship between absorbance and concentration for many chemicals. To do this, a series of standard solutions with precisely specified concentrations are prepared by diluting a stock solution of the target chemical.

These standards are then examined using a spectrophotometer, which transmits light of a certain wavelength through each sample and measures absorbance. The absorbance data is plotted against concentration to form a calibration curve, which is typically fitted with linear regression. To calculate concentration from unknown samples, the observed absorbance is interpolated into this curve. This approach is especially recognized for its simplicity, quick analysis, and minimal operational expenses. However, possible interference from matrix components or coexisting chromophores might impact absorbance measurements, therefore it is critical to utilize matrix-matched standards or blank corrections when studying complex samples to guarantee accurate quantification.

V. A CASE STUDY OF WATER PURIFICATION IN HANOI CITY, VIETNAM

Hanoi city is the capital of Vietnam. To solve the water pollution issue, the city has provided several significant solutions. Current and future strategies for water purification and river revival in Hanoi are multifaceted:

- **Comprehensive Planning**: The Hanoi City Council has approved a master plan for the capital with a vision extending to 2050, which includes a specific objective to thoroughly address pollution and "bring the To Lich River back to life". This plan envisages the construction of dams, such as the Xuân Quan dam on the Hồng River and the Long Tửu dam on the Đuống River, to raise water levels and enhance water intake into the irrigation system, thereby revitalizing the rivers.
- **Yen Xa Wastewater Treatment Plant Project**: This ambitious project, initiated in October 2016 with an investment exceeding 16,000 billion VND, is central to Hanoi's water purification efforts. It comprises a wastewater treatment plant with a capacity of 270,000 m^3/day-night and an extensive network of wastewater collection pipelines along the To Lich, Lu rivers, serving an area of approximately 4,874 hectares [5].

Figure 3. Wastewater Treatment Plant commencing Trial Operation in Yen Xa District, Hanoi City, Vietnam

From December 1st, 2024, with the Yên Xá Wastewater Treatment Plant commencing trial operation, approximately 200 tons of sludge are expected to be generated per day. Significant progress has been made in the renovation work, with Phase One completing the dredging of nearly 50,000 m^3 of sludge and waste from a 7 km stretch of the river by early July 2025. Phase Two, covering a 5 km section, is underway and expected to be completed by August 2025. Simultaneously, efforts are focused on connecting 63 additional wastewater discharge outlets to redirect their flow to the Yên Xá plant. As of early July, 19 outlets have been completed, with the remainder projected for completion in July 2025.

- **Expert Recommendations**: Experts emphasize the complexity of reviving the Tô Lịch River, highlighting the critical need for effective collection of wastewater along both riverbanks to prevent direct discharge into the river.

VI. CONCLUSION

In conclusion, the pollution of water is a global issue where the explained methods should be utilized to recover the polluted water. The water pollution status in Vietnam is presented, then some solutions are given to solve the issue. This is because life is dependent on water and there are numerous people who are not able to acquire sufficient clean water in the world. Moreover, the paper presents a solution of water purification in Hanoi, Vietnam. The water treatment process may be applied and developed in large area to improve the quality of water.

Conflicts of Interest

The authors declare that there is no conflict of interest concerning the publishing of this paper.

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