Environmental elimination and recycling strategy towards wasted water

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***Abstract*- Because of human activities, the release of effluents seriously affected the environment. Because of pollution, water is affected. Many pollution-related causes have caused a decline in the quality of the water. Water treatment technologies have a considerable influence on wastewater recycling. The effluents are treated through physical and chemical methodologies and with the help of which the wastewater can be recycled. These contaminants hurt both human health and the environment. Filtration, sedimentation, precipitation, etc., are some of the methods used to remove contaminants. These methodologies are used to regulate water pollution. Different methodologies are discussed here with the help of which the pollutants are removed from the wastewater. The latest research development on the treatment of wastewater and its future aspects are also discussed in this review paper.**

***Index Terms*—water pollution, wastewater, recycling method, environment, sustainability**

I. Introduction

Water is the most crucial substance for all living things on Earth.[1] There is about 71% water on the surface of the earth of which only 2.5% is freshwater.[2] It is important for all forms of life that are vital to assist life and the environment. Some freshwater resources include lakes, ponds, rivers, groundwater, etc. In this, only 1% is accessible for human, industrial, and other requirements and the rest water is unusable that is in the form of glaciers.[3] Because of continuous population expansion and industrialization, these water resources are becoming short day by day. Climate change is the other reason for the depletion of freshwater resources. So, the issue of lack of fresh water can be an important environmental issue. It has a significant negative influence on human life, environmental quality, and economic development throughout the world.[4] According to the United Nations FAO study(2007), around 1.1 billion of the world's population consumes contaminated water, and this figure might rise to two-thirds of the global population in the future. It is important to protect water from getting polluted, recycle it, or look for backup resources to overcome this issue.[5]

The possible method that recycles water from the wastewater of industry is wastewater remediation.[6] Industrial wastewater is discharged that contains dissolved substances due to all the pursuits taking place in industries.[7] The pollution is spreading because of industrial wastewater.[8] Wastewater treatment is used for the protection of the environment. The contaminants that are present in industrial wastewater are heavy metals, dyes, pesticides, and other compounds.[9] A serious threat to the environment is caused when these substances enter the surroundings. Toxic chemicals are present in the effluents from the textile, dye, or other chemical industries that caused serious health issues to humans. Pollution is increasing day by day in developing countries.[10, 11]

A considerable number of harmful compounds, such as polycyclic aromatic hydrocarbons, have been identified in freshwater in poor nations.[12] If an alarming level of pollutants is present, then there is a need for effective and remedial treatment for wastewater recycling. The methods for recycling wastewater were initially developed to combat the harmful effects that polluted water had on the environment.

Water remediation is the process of recycling wastewater and converting it into non-toxic products. Toxic wastes are released and have an impact on the water due to the overuse of fertilizers, pesticides, and spills from industries.[13] In this review paper, we will discuss the causes of wastewater and different strategies used to treat polluted water.

II. CAUSES OF WATER POLLUTION

Environmental pollution is a major concern regarding global human health and biodiversity. The release of industrial effluents into the environment as a result of human activity has an impact on water quality.[14, 15] Industrial waste, household waste, sewage, oil pollution from agriculture, and natural disasters are the main causes of water pollution.

The two types of waste that are most likely to end up in freshwater resources are industrial and household wastes. For the contamination of the ecosystem, the decomposition of pollutants is the important reason. Direct releases of toxic chemicals from industries pollute the water and harm earthly life. Toxic industrial pollutants emit an unpleasant odor as well. The use of wastewater affects the human body parts that cause diseases related to the kidney, lungs, liver, and bladder. Global chemical industries are growing as a result of rising demand, which has an impact on both the environment and human health.[16]

Food producers and consumers could suffer grave health consequences if nutrient-rich wastewater is used in the food production process.[17] Due to the effects that the hydrocarbons in oil have on the aquatic environment, oil

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pollution is also considered to be a toxic pollutant. The oil on the water's surface, which also affects life underwater, prevents sunlight from entering the water. The oxygen content in the water is decreased because of increasing microbial growth that is due to the presence of biodegradable substances that produces toxic chemicals in the water. This natural type of pollution causes diseases such as cholera, typhoid, etc.[18]

III. SIGNIFICANT CONTAMINANTS IN THE WASTEWATER

Water pollutants are substances that alter the chemical and physical characteristics of water as well as its quality.[19] Industrial pollutants released into freshwater resources have an impact on the freshwater's availability.[20] Heavy metals, dyes, oil, plastics, and other important water pollutants are specifically mentioned.

A. Heavy metals

The metals having a density greater than 4 grams per centimeter cube are called heavy metals.[21] From industries, a large amount of heavy toxic metals are released such as Cu, Cr, As, Pb, etc.[22] So they enter into the environment and water resources through natural ways. These metals are entered into the plants through their roots, which are then passed onto animals when they eat these plants.[23, 24] Consumption of that water causes serious health hazards. Ingestion of these heavy metal ions affects the cellular organelles in humans; for example, Cu may cause Wilson disease and Cr may cause DNA damage in human cells. [25, 26]

B. Dyes

In addition to being toxic, dyes are those substances that change the color of the water. Sewage from industries that have an impact on the environment released a significant amount of dyes.[27, 28] The dyes that reduce photosynthesis and affect water life obstruct the entrance of sunlight into water resources. In humans, the consumption of dyes causes renal, respiratory, and neurological disorders.[29, 30]

C. Plastics and oil

Oil pollution in water, which is produced by wastewater from the petroleum industries, is significantly impacted by oil spills.[31] The dyes that hinder photosynthesis and have an impact on aquatic life prevent sunlight from entering water resources. Less dissolved oxygen results in a change in the oxygen content of water. Aquatic birds died as a result of the oil adhering to their plumes, which negatively impacts their respiratory systems. It causes serious health hazards in humans because the food chain is affected now.[32, 33] For the water environment, plastic is also toxic and spreads because of the scarcity of waste management. Due to the color and odor of plastics, aquatic organisms are attracted. The toxic chemicals affect the stomach of aquatic organisms by reducing their capacity to ingest food when they consume those plastics resulting in abnormal growth.[34]

IV. POLLUTION CONTROL/RECYCLING STRATEGIES FOR WATER POLLUTION

Different recycling strategies are utilized for water pollution in which toxic pollutants are removed from the water and made useable. These recycling strategies for water pollution are selected because of the strategy's cost, compatibility with the environment, and strategy's flexibility. The methods used for recycling typical wastewater are physical and chemical:

A. Physical methods

The methods that use the physical processes for the environmental elimination and recycling strategies over typical wastewater without any involvement of biological and chemical changes are termed physical methods. The most common physical methods include filtration, sedimentation, and degasification. The physical methods of pollution control, their advantages and disadvantages are shown in Table 1.

1) Filtration

The process in which pollutants are removed based on their size is called filtration. After the removal of these pollutants from the polluted water, the water becomes useable for several purposes. Depending on the types of effluent, this strategy uses different filters. The two primary types of filtration strategies used for this method are membrane filtration and particle filtration.[35, 36] Particle filtration is used for removing solid particles whose size is greater than 1 micron. Two main types of filters are used in the filtration process: Bag and cartridge filters.

Bag filters are a type of filter that trap solid particles while allowing water to pass through with the solid waste still present. Wastewater with solids is placed into the bags. Comparing bag filters to cartridge filters, which are another type of filter, bag filters are used to remove wastewater at a very low level and produce a negligible amount of waste.

On the other hand, the cartridge filters are where the effluents are gathered. During this process, waste particles are caught while the water flows through the end part of the filter vessel into which the wastewater is poured. Some of the challenges when employing this type of filter include air reversal and filtration material selection. Through the process of filtration, matter, solid particles, and microorganisms like bacteria and viruses are eliminated.[37]

2) Sedimentation

Sedimentation is the process by which particles are separated from a liquid by gravity. This process is an important strategy for recycling water that is polluted. During the process of recycling polluted water, a decrease in water velocity takes place even in quiescent conditions because of which the particle in suspension remains stable. After that, with the help of gravitational force, particles settle.[38, 39]

For the sedimentation process, the size of particles plays a significant role. The residual time for settling the particle is termed settling velocity. Before coagulation, the concentration of solids is reduced during the sedimentation process for reducing the coagulants in number.

3) Degasification

The removal of dissolved gases from a liquid is a process known as degasification. This method is based on Henry's law, which states that the partial pressure of a gas in a liquid is proportional to the amount of dissolved gas in the liquid. For removing CO2 from the contaminated liquid, the method is thought to be both expensive and effective. The pH of the water is increased by removing gas. This process generally happens at a specific temperature. The temperature of contaminated liquid, the tank's capacity, and power &

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frequency are the factors which are involved on which this strategy is dependent.

TABLE I.
PHYSICAL METHODS OF POLLUTION CONTROL, THEIR ADVANTAGES, AND DISADVANTAGES

Serial No.	Physical Methods	Advantages	Disadvantages
01	Filtration	In some cases, autoclaving can be done	1. Prolonged procedure 2. The possibility of filter clogging
02	Sedimentation	No need for energy	1. The process of selection 2. Is imprecise
03	Degasification	Reduces the number of chemicals required for the next step.	Short capacity for removing pollutants

B. Chemical methods

To minimize the release of dangerous substances, chemical treatments are used. Ion exchange, chemical precipitation, ozonation, flocculation, and coagulation are some chemical methods. Table 2 shows the chemical pollution control methods, as well as their advantages and disadvantages.

1) Flocculation and coagulation

In industrial wastewater treatment, coagulation and flocculation are critical for solid-liquid separation. The addition of specific compounds known as coagulants to the coagulation process neutralizes their charge and destabilizes the colloidal suspensions. In flocculation, the more unstable particles are combined with the larger particles.[40, 41] The mechanism of the coagulation process is depicted in Figure 1.

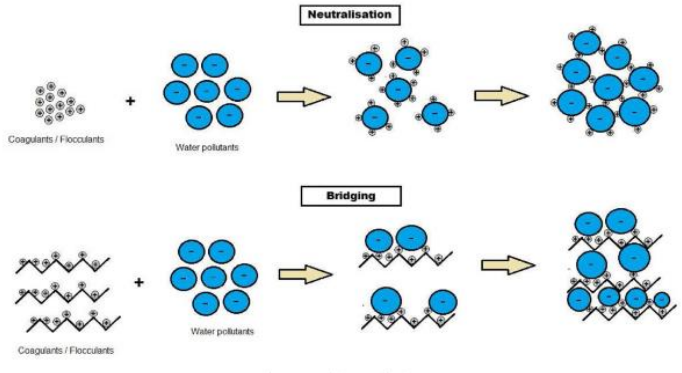

Fig. 1. Coagulation mechanism

In some circumstances, flocculants are used to speed up coalescence and improve the efficiency of settlement. Due to structural variations like functional groups, charge, and weight, different coagulants and flocculants have unique properties. The effectiveness of the procedure is significantly influenced by the coagulants used. Coagulation and flocculation are usually done at the same time in most circumstances.[42] Long-chain anionic or nonionic polymers are flocculants because most of the particles that are dispersed are negatively charged. Metal salts present in the solution rapidly hydrolyze to form cations after the addition of a coagulant. They are taken up by the wastewater's negatively charged colloidal particles at the isoelectric range. This causes a drop in surface charge while also generating micro-flocs. Small micro-flocs are then transformed by the addition of flocculants into larger, denser flocs that are easier to remove using physical procedures like filtration or sedimentation. The two main mechanisms in play during this process are charge equalization and bridging.[43, 44]

2) Ozonation

Industrial liquid recycling technology has shown a lot of interest in the ozonation process because of its strong oxidation and disinfection capabilities.[45] The use of ozone in the oxidation of wastewater includes the following:

- Smell, flavor, and the materials that produce colors are removed
- Inorganic compounds are converted to higher oxidation states
- Organic contaminants are oxidized
- The process of disinfection is performed.

Because of the unstable nature of ozone gas, it interacts with the materials of polluted water either directly through molecular ozone or indirectly due to the creation of hydroxyl radicals[46]

a) Direct reaction

In water that contains dissolved organic contaminants, molecular ozone undergoes a rapid reaction. In this procedure, there are three basic sorts of response mechanisms.

- Cyclic addition
- Mechanism of nucleophilicity
- Mechanism of electrophilicity

The link is cleaved when molecular ozone reacts quickly with an unsaturated bond in an organic molecule.

b) Indirect reaction

The indirect process involves hydroxyl radicals. Because the hydroxyl radical seems to have an electron that is unpaired and interacts with compounds, most likely contaminants, for getting electrons. There are 3 phases.

- The creation of a superoxide anion as a result of ozone decomposition is the start of a process.
- Ozonide anion is generated when superoxide anion reacts with ozone in a chain reaction. Hydroxyl radical ions are constantly produced.
- Organic and inorganic components in contaminants combine with OH radicals for creating secondary radicals. The purpose of the ozonation process determines how much ozone is produced for each type of polluted water. It is primarily used to purify waste wastewater, reduce sludge, and detoxify. Additionally, it is employed to decolorize, get rid of micropollutants, and reduce CO_2 demand (COD). [47]

3) Chemical precipitation

The process of chemical precipitation is the most significant strategy that is used for taking off the heavy metals from the wastewater. The ionic metals are converted into insoluble particles because of the chemical forming between dissolving

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metal elements and precipitating agents. For removing metals that are cations in nature, a chemical compound is often used. It is also used to remove live anions and molecules.[48] Because of the physical processes i.e. coagulation, filtration, and sedimentation, the process of precipitation is carried out.[49] Three important types of chemical precipitation for recycling wastewater are carbonate precipitation, sulphide precipitation, and hydroxide precipitation.

a) Carbonate precipitation

For controlling water pollution, heavy metals in the form of precipitates and carbonates can be used. For this, $CaCO_3$ and $NaCO_3$ are used in this process. Heavy metals react with $CaCO_3$ to form metal carbonates (Eq. 1), which are then formed by a subsequent reaction of the metal hydroxide-carbonates with H_2O, which results in the release of CO_2 (Eq. 2). [50]

$$Mn^{+} + nCaCO_3 \leftrightarrow nMCO_3 + nCa^{2+}. \quad (1)$$

$$nMCO_3 + H_2O \leftrightarrow CO_2 + (MOH)nCO_3. \quad (2)$$

b) Sulphide precipitation

In the sulphide precipitation process, there is less interference with chelates and a lower concentration of effluents as shown in equation 3.[51]

$$Mn^{+} + S^{2-} \leftrightarrow MnS \quad (3)$$

c) Hydroxide precipitation

Ca $(OH)_2$ is cost-effective for wastewater treatment due to the alkali requirement and precipitant cost. When appropriate hydroxides are added it forms the precipitate of heavy metal-hydroxides that are insoluble as shown in Eq. 4. The process of precipitation happens at an optimum pH.[25]

$$Mn^{+} + Ca(OH)_2 \leftrightarrow M(OH)n + Ca^{2+} \quad (4)$$

4) Ion-exchange

The ion exchange process is the process of substituting ions or ions in wastewater treatment. Contaminants and changed buildings have the same electrical charge that could be either harmful or beneficial. Resin resins are compounds that are utilized to identify impurities.[52, 53] The chemical properties of frames have a significant impact on the separation of iron ions from contaminants. The active groups that are covalently bonded to the resin frames generate a polymer matrix that is coupled to the building spaces and allows for the transportation of ions. The two types of ion exchange processes are cation interchange and anion exchange. An anion or cation exchange procedure involves exchanging the negatively or positively charged ions in contaminated water with the corresponding ions. The cationic ion exchanger, which uses resins that are both strongly acidic and weakly basic, is a much more advantageous type of ion exchanger. Acid and alkaline resins, respectively, are composed of carboxylic and carboxyl functional groups.[54]

TABLE II. THE ADVANTAGES AND DISADVANTAGES OF CHEMICAL POLLUTION CONTROL METHODS

Serial No.	Chemical Methods	Advantages	Disadvantages
01	Flocculation and Coagulation	1. Used to remove fine particles 2. Gets rid of metals, color, and turbidity.	1. Several process steps 2. Hazardous if misused 3. High sludge production 4. High operational costs
02	Ozonation	1. There is no need for chemicals. 2. Removal of a wide variety of microbes, organic and inorganic compounds 3. There is no need to change the pH or temperature. 4. Increased germicidal activity	1. Ozone's low solubility necessitates the use of specialized mixing techniques. More expensive than other methods 3. Toxicity and fire hazards may occur during ozone generation.
03	Chemical Precipitation	1. Simple process control 2. Low operating expenses 3. It is effective across a wide temperature range. 4. Adjustable pH	1. Large-scale sludge production 2. Difficulties with sludge disposal
04	Ion Exchange	1. The resin can be regenerated. 2. It is possible to achieve zero hardness. 3. Process of rapid separation 4. Requirement for a small amount of space	1. Most effluents require pretreatment. 2. Ionic conflict 3. Matrix fouling

V. CURRENT SITUATION & FUTURE PERSPECTIVES

Roughly a third of the water supply on Earth today is hazardous to both people and the environment. Its restoration of energy, nutrients, and water is a crucial aspect of the conflict. It causes three times as much environmental damage as conventional medicinal plants. More action is required as the population grows. With assistance from the public sector and the private sector, cities ought to be able to take the initiative in resource transition. To protect the marine environment, Aqaba, the Gulf of Aqaba's largest city, developed a "zero-emitting" policy for industrial wastewater disposal. Wastewater is being gathered and processed in 90 percent of cases. Second, Bangkok is the world's biggest city for the collection, treatment, and conversion of sludge into fertilizer. The best energy-producing resources are constantly being researched. As a result, the amount of land pollution caused by improperly maintained septic tanks and untreated combined sewers is steadily declining. Since the city is experiencing environmental problems as a result of population and industrial growth, Beijing, the capital of China, is actively investing in "mega" infrastructure to reduce pollution in wastewater flow growth. Due to limited water resources, Chennai, the capital of Tamilnadu, is the first significant Indian city to achieve 100% sewage collection. This achievement was made possible by strong connections and effective governance. Wastewater reuse

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in Chennai fulfills 15 percent of the total of the state's groundwater resources.

Significant clinical safety and security requirements have been attempted to be met by experts by enhancing rules. Standard water purification facilities should always be improved due to the constantly rising level of water quality. Constraints are frequently imposed by a lack of space, though. New solutions have been developed for this problem by the integrated film method, the ballasted reaction processor, and the membrane bioreactor process. In biological aerated filters, the immersed medium acts as both a filter to separate solids from contaminated water and as a contact point for biological treatment. Aeration is used for washing back. Only about 15% of the land area needed by a conventional mud system is needed by a biological aerated filter. Elevated filtration involves a complicated process to keep plants operating steadily and reliably, which frequently calls for cutting-edge technologies like complex stabilization and process control. Automation of the treatment process is made possible by analytical tools, complex programmed controls, human-machine interfaces, and other process control systems. This can greatly improve system performance and lower the amount of administrative work required. Some of the current and potential areas of interest are as follows:

- Creative wastewater collection framework techniques that give resource board decision-makers ongoing condition evaluation data.
- Imaginative inventions or cutting-edge methods are being created to get rid of harmful pollutants with minimal expense and energy use.
- Conservative approaches to treating plants after natural disasters.
- Develop energy-efficient methods, plans, systems, and equipment.

VI. Conclusion:

In this review paper, several wastewater treatments are discussed. Different methodologies are discussed in this review paper with the help of which the pollutants are removed from the wastewater. The recent research development on the treatment of wastewater and its future aspects are also discussed in this review paper.

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