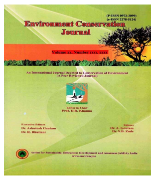
Environment Conservation Journal 25 (1):267-273, 2024

Journal homepage:https://www.environcj.in/

Environment Conservation Journal

ISSN 0972-3099 (Print) 2278-5124 (Online)



Methods for eliminating micropollutant from wastewater: A review

Mangesh B.Thakre ✉
D. R. B. Sindhu Mahavidyalaya, Nagpur, Maharashtra, India
Sushil B. Kapoor
Dr. Khatri Mahavidyalaya Tukum, Chandrapur, Maharashtra, India
Nilesh Gandhare
Nabira Mahavidyalaya, Katol, Nagpur, Maharashtra, India

ARTICLE INFO

Received : 12 September 2023
Revised : 15 October 2023
Accepted : 05 November 2023

Available online: 12 January 2024

Key Words:
Advanced oxidation technology
Biological methods
Micro pollutant
Powdered activated carbon
Wastewater

ABSTRACT

The amount of suspended solid and medicinal micropollutants, such as fungicides, personal care products, contraceptive medications, antibiotics and aromatic hydrocarbons are increasing daily and has reached an alarming level. The micropollutant present in wastewater must be treated before its release because it forms adverse effect on mortal health. Because some harmful micropollutants are incredibly difficult to remove from WWTPs because of their nonbiodegradability, poor adsorption capability, complex nature and traditional wastewater treatments are precious or insufficient for decontamination. For the micropollutant declination some of the conventional physicochemical has been used. The use of powdered activated carbon (PAC) for water purification has been proven to be effective without harming the environment. Advanced oxidation technologies (AOTs), typically applied after natural processes have recently emerged as effective tertiary treatments for the withdrawal of micropollutants at high concentrations. Various methods have been developed and studied for the removal of these micropollutants from wastewater. This review aims to provide a comprehensive overview of the different methods employed, including physical, chemical, and biological processes, highlighting their effectiveness and limitations in micropollutant removal. As well as improving treatment efficiency, they can also remove any accumulation of dangerous byproducts produced during treatment.

Introduction

All living creatures need water to survive, and water availability is associated with major causes of mortality, such as domestic use and agriculture. Some contaminants of emerging concern (CECs) from different sources end up in aquatic resources, including ground water, surface water and drinking water, at concentrations ranging from a few nanograms/liter to a few milligrams/liter (Barbosa *et al.,* 2016; Bhutiani *et al.,* 2022; Ahamad *et al.,* 2023). Domestic, agricultural, sanitarium and industrial wastewater; livestock; and aquaculture are among the anthropogenic sources of MPs (Barbosa *et al.,* 2015; Bhutiani *et al.,* 2021). Urban wastewater treatment plants (UWWTPs) release treated backwaters as a significant source of MPs, and conventional physicochemical and biological treatment methods are not designed to eliminate organic composites completely from trace concentrations (Barbosa *et al.,* 2015; Bhutiani and Ahamad, 2018; Sousa *et al.,* 2018). The severe biological effects of these micropollutants have led to years of research on these pollutants (Aschermann *et al.,* 2018; Batel *et al.,* 2020; Gautam *et al.,* 2020). The amount of organic micropollutants, such as fungicides, personal care products, contraceptive medications, antibiotics and aromatic hydrocarbons, is increasing daily and has reached an alarming level (Mailler *et al.,* 2016; Meza *et al.,* 2020). Some harmful micropollutants are incredibly difficult to remove from WWTPs because of their nonbiodegradability, poor adsorption capability, complex nature and traditional wastewater

Corresponding author E-mail: *nilkanth81@gmail.com*
Doi:https://doi.org/10.36953/ECJ.26652643

treatments, which are valuable or insufficient for decontamination (Benstoem *et al.,* 2017; Chau *et al.,* 2018). The majority of the review studies focused on physicochemical techniques for micropollutant elimination. The biological treatment of micropollutants, which is increasingly important due to its various advantages, such as low cost, simple design and high removal effectiveness, when compared to conventional treatment methods, is still the subject of relatively few reviews. Therefore, the purpose of this research is to review the knowledge gaps that exist today about the various biological treatment procedures that are employed to remove micropollutants from wastewater. Similarly, new biological remedy structures, such as immobilized bioreactors, moving bed biofilm bioreactor systems and two-section partitioning biorreactors, have not been reviewed in advance. AOTs can be applied to distinctly toxic water effluent as a preremedy to decrease toxins and increase the biodegradability of the water. The installation of additional AOT devices after secondary biological treatment has attracted great interest in the water industry, as similar processes have been attributed to the removal of multiple MPs from UWWTP streams. PAC recycling with coagulant ($FeCl_3$) has been used in the past for wastewater treatment, but there is no literature on the interaction of coagulant (FeCl3) with flocculants for water hardness. To the best of our understanding, the PAC recirculation process, biological treatment process and advanced oxidation technology have been used for the removal of micropollutants. Thus, this research also fills these research gaps by providing a suitable, flexible, simple and usable method for wastewater treatment.

Sources of organic micro pollutants

Medical facility effluents, industrial wastewater, medical facility backwater, runoff from concentrated animal feeding operations, agricultural runoff, etc., are the main sources of micropollutants in the environment. Micropollutant pollution of the environment is largely the result of pharmaceutical, large-scale pesticide and other chemical industry waste water production. One of the main sources of micropollutants is runoff from farmland and best-parenting areas, notably in the case of fungicides used to boost productivity as well as antibiotics and hormonal steroids used for best conservation (Song *et al.,* 2007). Industrial waste streams, septic tanks, sewage treatment facilities and leakage from landfills are the other sources of micropollutants (Matthiessen *et al.,* 2006). In addition to pharmaceuticals (NSAIDs, anticonvulsants, lipid regulators, antibiotics, stimulants, and blockers), personal care products (UV filters, fragrances, insect repellents, and disinfectants), and steroid hormones (estrogens), domestic wastewater is a major source of many micropollutants (Luo *et al.,* 2014). Both ecology and human health are adversely affected by micropollutants, although micropollutants cannot be arranged in the same order based on their package. Pruden *et al.* (2006) discussed the impacts of micropollutant exposure, which includes both short- and long-term toxic and endocrine-dismembering effects.

Effect of micropollutants

At certain boluses, a number of substances interfere with the endocrine system, producing malignant excrescence and other birth defects in energized infants. There have been reports of other health problems related to an implied hazard from micropollutants, such as anomalies in children and babies, bone cancer, diabetes/metabolic syndrome, and reproductive failure. Certain germs that are frequently exposed to the same toxins also become resistant to antibiotics, increasing the difficulty of treatment. Long-term displays may also result in ecosystem bioaccumulation (Choi *et al.,* 2016). Therefore, the presence of micropollutants in the environment has been established to have a detrimental effect on the health of all living things. Therefore, micropollutants in landscape pollutants negatively affect the health of all living organisms. The negative health effects of these micropollutants necessitate the use of technologies that help facilitate their release into the environment, including physicochemical processes, such as advanced oxidation techniques, membrane-based processes, adsorption and biological processes, using various bioreactors.

Removal of organic micropollutants from wastewater

By incorporating advanced and creative treatment technologies into WWTP design, micropollutants can be converted into composites that are less harmful or even nonharmful. Activated carbon powder (PAC), membrane separators (MSSTs), and advanced oxidation technologies (AOTs) are all innovative water treatment processes (Sudhakaran *et al.,* 2013). In the literature, several bacterial and fungal species are described as generating micropollutants (Murínová *et al.,* 2014; Barbosa *et al.,* 2016; Bhutiani *et al.,* 2016; Ahmed *et al.,* 2017). A decrease in micropollutants by microbes is accompanied by catabolic activity, during which micropollutants become substrates for growth (Tran *et al.,* 2013). Micropollutants can be efficiently degraded using oxidizing chemical agents, such as chlorine, hydrogen peroxide, and ozone, along with a mixture of transition metals and advanced oxidation processes (AOPs) based on metal oxide-based catalysts.

Powdered activated carbon (PAC)

As a powder or granule produced with a surface prolixity of less than 1 mm, activated carbons are capable of diffusing into or onto their surfaces easily. PAC is made from pretreated or crushed carbon particles, which are also added directly to process units such as gravity filters, cleanses, high-speed mixers and dewatering ports. Two types of PACs, Norit SAE-Super (Norit) and Donau Carbon Carbopal AP (Donau), were used for all the experiments; these materials were made from different starting materials and produced by different manufacturers. The resulting products differed in terms of particle size distribution, specific pore volume, and skeletal density. The PAC particle size plays an important role in the removal of micropollutants from wastewater either by precipitation or sedimentation. Therefore, measuring the particle size distribution is critical. This is why Norit is larger than Donaus. Dose effects were estimated with varying dose concentrations of PAC in wastewater ranging from 10 to 40 mg/l. In wastewater treatment (WWT), two different kinds of PACs (Norit and Donau) were tested, and the results were compared on the basis of performance. After a certain range, the PAC can begin to donate to solid components of the wastewater, which then begin to participate in adsorption in the active zones together with the suspended solids. As a result, negative analogous outcomes were determined based on the above research (Boehler *et al.,* 2012 and Guillossou *et al.,* 2020). Particles may coalesce or coalesce as the PAC dose increases, leaving fewer active sites for adsorption (Noreen *et al.,* 2020). In terms of particle size, diameter, formation material and bone density, Donaul has slightly different characteristics from Norit. It is obvious that the Donu withdrawal efficiency was relatively lower than that of Norit for all the samples. A smaller number of coarser and finer particles produced a smaller adsorption amount. Additionally, the lower specific pore volume (cm^3/gm) promoted the more efficient performance of Norit on its surface than on the other surfaces because small draped micropollutants (MPs) are wrapped in the pores of the Norit surface and cannot be released. Laboratory experiments, performed mainly with PAC, provided a comprehensive understanding of the adsorption mechanisms, which were also expressed in previous studies (Karelid *et al.,* 2017a). This lower quantity of adsorbed material on Donau Island was due to differences in the production material, size, internal structure, etc.

Physicochemical treatment processes

Several physicochemical processes have been estimated for the removal of micropollutants through water and wastewater. The potency of physicochemical techniques relies on functional conditions, material composites and the type of wastewater (Bhutiani *et al.,* 2017). Membrane filters are commonly used to remove microorganisms and salt from wastewater and surface water; however, their use for the removal of micropollutants has recently been demonstrated in the literature. Commonly used membrane techniques incorporate high-pressure and low-pressure grade systems. Microfiltration (MF) and ultrafiltration are low-pressure grade systems used at pressures ranging from 5 bar to 10 bar, while reverse osmosis (RO), high-pressure RO and nanofiltration (NF) are low-pressure grade systems that operate at pressures ranging from 50 bars to 150 bars. Among these systems, a high-pressure grade system is more appropriate for removing organic micropollutants (MPs) (Coday *et al.,* 2014). Adsorption onto membranes, charge repulsion mechanisms and size exclusion generally occur during micropollutant retention through membranes. The molecular weight cutoff, specific physicochemical study, membrane fouling, process type and micropollutant working conditions all have significant impacts on the efficiency of the retention mechanism. Membrane fouling as a result of the deposition of particles and colloidal particles in the affluent is the primary drawback of the filtration process (Villegas *et al.,* 2016). The first expense of membrane-grounded innovation is likewise high. Although membrane-based technologies can destroy the filtrate in evaporation ponds, direct release of the filtrate into the environment poses a risk to ecosystems (Umar *et al.,* 2015). The most common method for removing micropollutants from wastewater is sorption, which mimics the physicochemical properties of sorbents (e.g., polarity, surface properties) and micropollutants (e.g., pKa, polarity, molecular weight). Adsorption and absorption involved in the sorption process of micropollutants. One of the major drawbacks of the adsorption process is the production of harmful sludge containing microputants; if this material is not disposed of properly, it can accidentally enter the environment (Justo *et al.,* 2015). In the 1980s, AOPs for the treatment of drinkable water that use multiple oxidizing species similar to sulfate or hydroxyl radicals were proposed for the first time. Additionally, it is currently being extensively utilized to treat a variety of types of wastewater, including sewage, industrial wastewater, and medical wastewater. Strong oxidants can degrade a variety of organic pollutants (Deng *et al.,* 2015). AOP can be used before or after a natural treatment process because it can degrade any carbon-containing micropollutants. AOP is similar to electro-Fenton processes; Fenton and photoFenton processes; electrochemical oxidation processes; wet peroxide/air oxidation in the presence of a catalyst; ozonation (catalytic); heterogeneous photocatalysis; and amalgamation of AOPs because standard oxidative processes ($KMnO_4$, H_2O_2, ClO_2, Cl_2, etc.) are inefficient (Ribeiro *et al.,* 2015). High operational costs, high energy consumption and the production of poisonous byproducts are the primary drawbacks of catalytic processes. Additionally, a variety of radical-scavenging compounds found in wastewater can harm these processes. Biological treatment systems have been prioritized as a means of overcoming the drawbacks of physical-chemical methods for the removal of micropollutants. They have been shown to be the most environmentally friendly, low cost and long-lasting, making them ideal for meeting environmental standards in developing nations.

Biological treatment process

Micropollutants are degraded by numerous species of bacteria and fungi, as reported in the literature. Micropollutant degradation by microbes is linked to the catabolic activity of microbes, and during this process, micropollutants are ingested as growth substrates (Tran *et al.,* 2013). Pollutant degradation is indirectly impacted by microbial growth on micropollutants and is dependent on many operational variables, such as light requirements, pH, extreme temperature, doubling time and agitation. Pollutant characteristics, including water solubility, surface characteristics, and charge, are crucial elements that affect treatment effectiveness. It has been widely reported that bacteria-based microorganisms can digest a variety of microputants. Pseudomonas sp. bacteria, for instance, are known to oxidize a variety of micropollutants. DCF was metabolically oxidized by *Pseudomonas putida* during active manganese oxidation. Few fungi produce extracellular enzymes that are very productive at degrading a variety of endocrine-disrupting chemicals (EDCs) despite their low substrate specificity. When phenolic chemicals are present, the lactase enzyme oxidizes them (Wong *et al.,* 2009). It was claimed that the enzyme acetate kinase can breakdown micropollutants such as bisphenol, galaxolide, nonylphenol, naproxen, and diclofenac when anaerobic conditions are present (Gonzalez-Gil *et al.,* 2017). To determine the role and method of action of a methanogenic enzyme described in this overall study's anaerobic breakdown of such micropollutants, additional research is necessary.

Advance oxidation technology –

According to the research of Garcia-Fernandez *et al.* (2018) and Garcia-Fernandez *et al.* (2015), the composition of the water matrix has a substantial impact on the inactivation of bacteria during water disinfection processes. Moreover, scavengers in the water matrix may hinder the removal of dissolved organic matter (DOM), which constitutes the majority of the organic matter in biologically treated urban wastewater. The location, time of year, operational conditions (pH, temperature, flow, etc.), and wastewater sources (industrial, home, agricultural, etc.) all affect the DOM composition. Fully characterizing the structural and functional complexity of DOM has become challenging. Because it can be evaluated broadly and lacks structural information, dissolved organic carbon (DOC) is typically utilized as a proxy variable for its quantification (Michael Kordatou *et al.,* 2015). The biological characteristics and environmental impact of DOM may change as a result of its transformation and byproduct creation during WWTP procedures, but our understanding of this process is currently limited. The most recent research on this topic described DOM in terms of its MW distribution, optical characteristics, and hydrophobicity (Wang *et al.,* 2018). DOM chemistry and reactivity have been characterized using many analytical methods, including spectroscopic chromatography, physicochemical analyses, thermal degradation methods and other fractionation procedures. The components of wastewater include a variety of organics (e.g., carbohydrates, proteins, fulvic acid, humic substances, etc.), which react with HO%, either by competing with organic MPs for oxidation or interacting with them or by forming the respective radicals with lower oxidation potential (Michael *et al.,* 2012).

Conclusion

As a result of various industrial and domestic activities and agricultural activities, micropollutants are emerging pollutants that pose a significant threat to the environment and public health. These two pollutants cause groundwater pollution and surface water pollution, respectively. Thus, water is dangerous and poisonous for human consumption. Traditional physicochemical treatment methods are not effective at treating micropollutants in wastewater; they are expensive, require large inputs, or produce large amounts of toxic sludge. Thus, advanced oxidation technology, electric activated carbon (EAC) and biological treatment systems have recently been the focus of this field.

Conflict of interest

The authors declare that they have no conflicts of interest.

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