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Review article

Removal of antibiotics from wastewater using advanced technologies: A review

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ABSTRACT

Antibiotics are an effective tool for treating a variety of infectious diseases, their widespread usage has caused resistant bacteria to arise and proliferate. Different phytochemicals are found in plants have varying biological functions. Antibiotics have been found in aquatic environments on a regular basis at concentrations of up to ppm level. Antibiotics are a new class of environmental micropollutants, so it's important to remove them from water by creating highly effective, low-cost adsorbents. Antibiotics can be removed from aqueous environments using a variety of techniques, the most common being biological treatment, membrane treatment, advanced oxidation, photodegradation and adsorption. In comparison to other techniques, adsorption technology has garnered significant interest in the water treatment industry for the removal of conventional pollutants due to its simplicity, feasibility, economy, and efficacy. However, there are still very few adsorbents have been used for the treatment of antibiotics, and more research is still needed to fully understand the underlying adsorption mechanism.

1. Introduction

Sir Alexander Fleming's (1881–1955) 1928 discovery of penicillin signalled the beginning of the antibiotic revolution (Adedeji, 2016). Antibiotics are physiologically active substances that influence the metabolism of bacteria, fungus, and protozoa in order to prevent or stop the growth of microorganisms and, for the most part, prevent disease in humans and animals (Langbehn et al., 2021). The period between 1940 and 1970, known as the "Golden Age" of antibiotic research, saw the intensive development of work on antibiotics, including their commercial application. The usage of new class of medications resulted in the saving of numerous lives (Krasucka et al., 2021). The demand for antibiotics has dramatically expanded as a result of the rising food demand brought on by a growing population. As antibiotics spread widely, issues related to their over usage started to emerge (Krasucka et al., 2021).

In 2023, 128 billion specified daily doses of antibiotics would be consumed globally, which is an increase of more than 200% from 2015. In the meantime, an increasing number of unused antibiotics are dumped into the environment, seriously polluting it (Zhang et al., 2023). Antibiotics manufactured all around the world eventually end up in the environment from sewage waste and usage. Significant concentrations of antibiotics have been detected in the influents of wastewater treatment plants (64 ng/mL for Cephalexin, 80 ng/mL for Beta-lactams), hospital effluent (124.5 ng/ml for Ciprofloxacin), and culture wastewater (540 ng/mL for Tetracyclines, 275 ng/mL for Macrolides). Hospitals, drug manufacturing facilities, and sewage treatment facilities all generate large amounts of sewage that must be thoroughly cleansed before being discharged into a natural water body (Peng et al., 2016; Afzal et al., 2018). About 30% to 90% of parent antibiotics are expelled via faeces due to the poor ability of animal and human guts to absorb antibiotics (Jia et al., 2022).

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Antibiotics can be eliminated from water and waste water using a variety of techniques, such as oxidation processes, bio-electrochemical systems, heterogeneous photocatalysis, microbiological techniques, and adsorption techniques and nanotechnology (Zhang et al., 2023; Katiyar et al., 2022; Rawat et al., 2022). Research was frequently conducted on the physicochemical elimination or breakdown of a particular class of antibiotics by biochar (Adwani et al., 2023). It was discovered that various forms of biochar made from different feedstocks have distinct effects on antibiotic remediation. Biochar has gained a lot of interest because of its inexpensive cost and potent adsorption characteristics for organic pollutants from aqueous solutions including antibiotics (Katiyar et al., 2022).

A critical assessment of the current technologies approach to remove or treat the trace of antibiotics and unmetabolized antibiotics found in wastewater is lacking, despite the abundance of review articles on different technologies for the removal of pharmaceutical waste and advanced biological processes. This review looks at and talks about a few ways to remove antibiotics from wastewater treatment.

2. History and source of Antibiotics

Antibiotics are said to be effective when kill a targeted infection while causing the host as little harm as possible. Antibiotics are particularly helpful as therapeutic agents in the management of infectious diseases affecting humans, and they are increasingly widely employed in aquaculture and the livestock business (Ben et al., 2019). One of the most commonly used antibiotics for both human and animal feed additives are tetracyclines (TCs) (Chen et al., 2018). From 2015 - 2017 approximately 44% of tetracycline used in veterinary worldwide (Jia et al., 2022). Due to high mobility and poor absorption of antibiotic (Sulfonamides), it has high risk of transportation in water bodies and remain persisted in soil and water for very long time (Jia et al., 2022).

3. Impact of Antibiotics on ecosystem

Antibiotics are medications that are either produced artificially or naturally and are commonly used to treat and prevent diseases brought on by pathogenic bacteria. While the bulk of antibiotics are manufactured chemical compounds, the first antibiotic was a natural substance. Many illnesses in people worldwide are brought on by bacteria: The diseases like leprosy, TB, syphilis, gonorrhoea, plague, and fever have cured by using antibiotics**.** Antibiotic resistance in bacteria is ultimately caused by the ongoing increase in antibiotic use. Bacterial resistance, or ARGs, are regions of the bacterial DNA or gene that encode the capacity to survive in the presence of antibiotics. Antibiotic resistance in bacteria can be attributed to a number of mechanisms, including antibiotic degradation or modification, alteration of the cellular target, antibiotic efflux, or pumping the antibiotic out of the cell, and drug uptake inhibition (Fig. 2). In the presence of antibiotics, ARB survives and multiplies more readily than susceptible strains, enriching resistant strains while the antibiotic is being administered (Kumar et al., 2018).

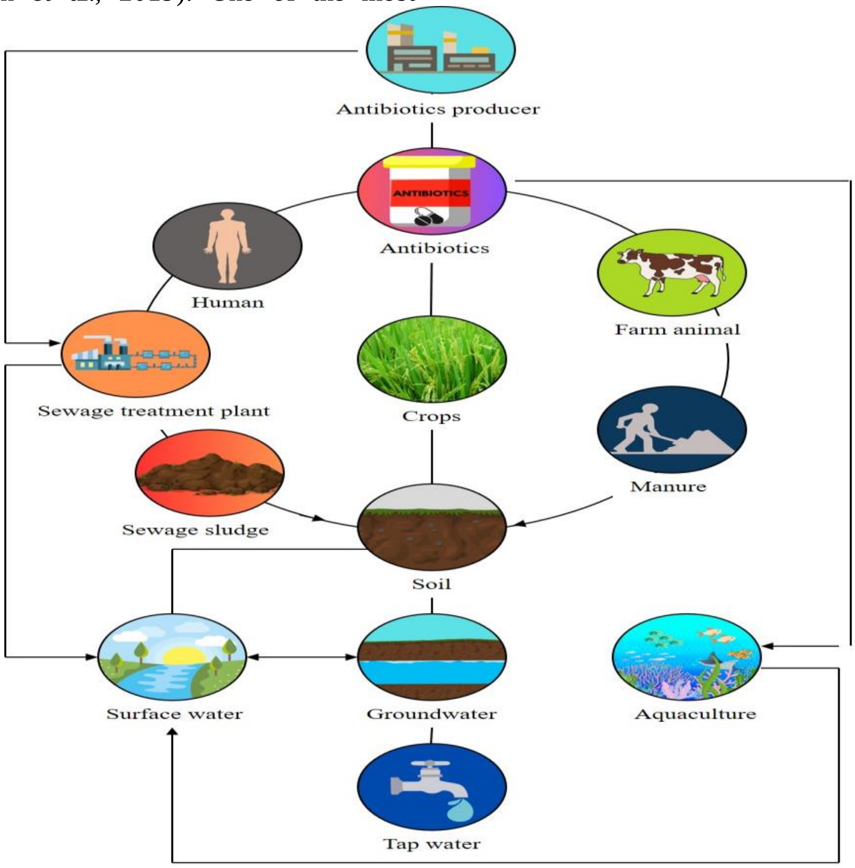

Fig.1. Antibiotic source as a pollutant

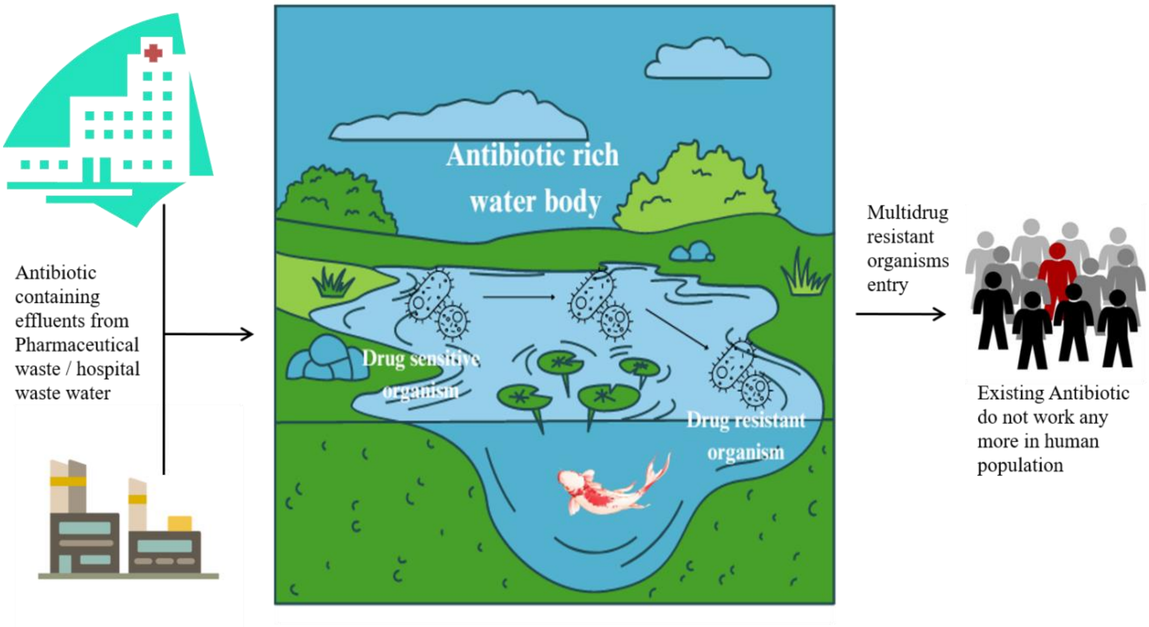

Fig. 2 Antibiotic resistance genes (ARG) affecting ecosystem

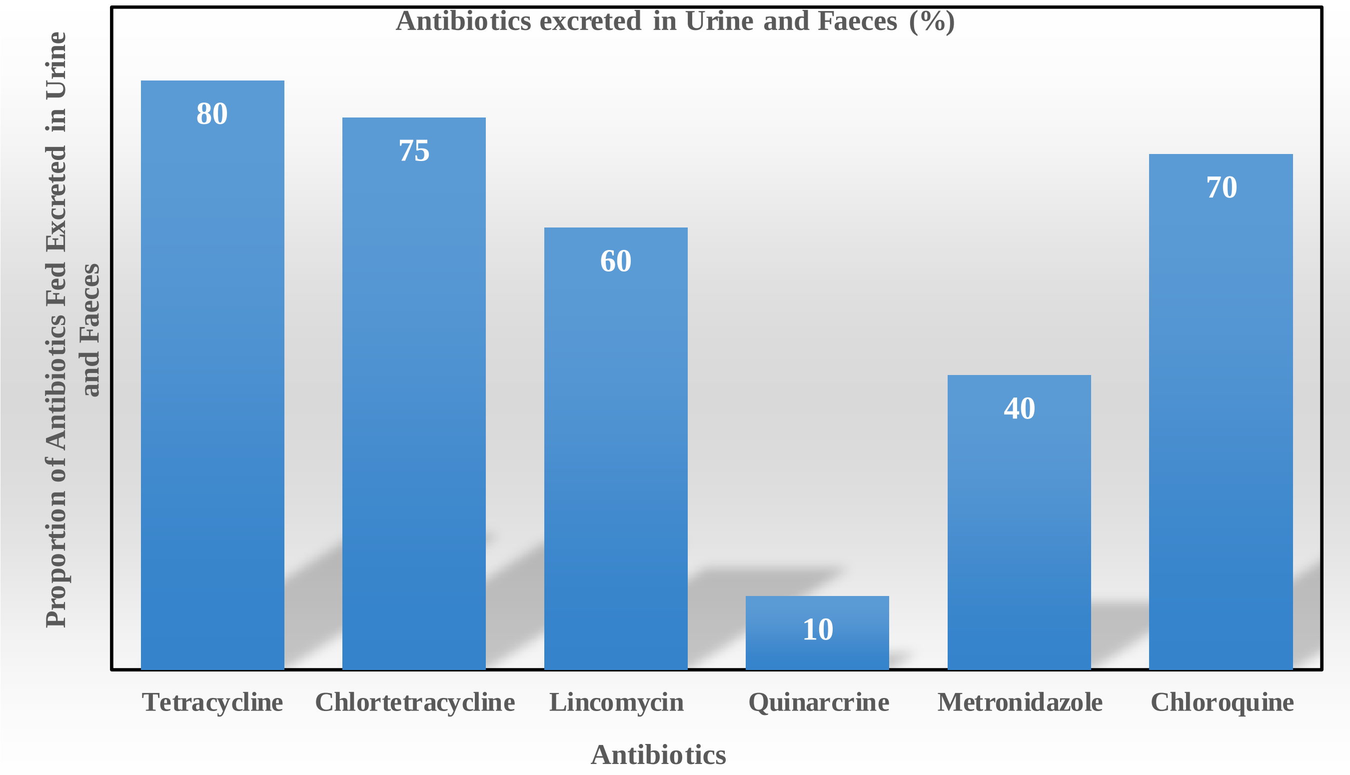

Fig. 3 Proportion of Antibiotics excreted in Urine and Faeces (Kumar et al., 2005)

Bacteria have the ability to distribute or transfer the ARG (antibiotic resistance genes) through horizontal gene transfer. Bacteria exchange genes by transduction, which is the uptake of extracellular DNA from dead cells, conjugation, which is the transfer of DNA between two germs through mating, and transformation, which is viral-mediated DNA transfer. These are examples of the mobile genetic elements that bacteria possess, such as transposons and plasmids. Hospital effluent contained plasmids that were resistant to the antibiotic tetracycline (Rhodes et al., 2000).

4. Antibiotics and its types

A medication known as an antibiotic stops or reduces the growth of microbes. Antibiotics are a subset of the broader category of antimicrobials, which also includes antiviral, antifungal, and antiparasitic medications. Antibiotics are substances made by or derived from microorganisms, which are insects or pathogens like bacteria and fungi. In a key development for medical science, Alexander Fleming created the first antibiotic in 1928 (Bayarski., 2006). Since many

antimicrobials are ineffectively absorbed by animals in the digestive system, they are frequently found in high amounts in cattle excreta. Antimicrobial classes that are frequently found in manure wastes include tetracyclines, sulfonamides, b-lactams, macrolides, and ionophores (Lee et al., 2007).
The major classes of antibiotics are Aminoglycosides, Cephalosporins, Fluoroquinolones, Macrolides, Penicillins and Tetracycline.

5. Different methods for removal of antibiotics

5.1 Adsorption
Adsorption is the surface process that causes a material from its gaseous or liquid environment to accumulate (as an atom, molecule, or ion) on the solid surface. The adsorbate is the material that builds up on the solid surface, and the adsorbent is the solid surface that is used for the adsorption process (Ahmad et al., 2015).
Adsorption procedures can be classified as either chemisorption (chemical adsorption) or physisorption (physical adsorption) according to the manner in which the adsorbates are adsorbed onto the surface of the adsorbent. Physisorption is caused by weak intermolecular interactions as dipole–dipole, Van der Waals, hydrophobic, electrostatic, and hydrogen bonding between the adsorbent and adsorbate (Zhang et al., 2016). A reversible process called physisorption, sometimes referred to as desorption, can produce monolayer or multilayer adsorption. Adsorbate and adsorbent engage in robust chemical interactions during the irreversible process of chemisorption, on the other hand. Ionic and covalent bondings are two instances of these potent interactions (Yagub et al., 2014).

5.2 Advanced Oxidation Processes
The removal of antibiotics from wastewater is increasingly being accomplished through the use of advanced oxidation processes, or AOPs. Numerous treatment technologies, such as ozonation (O_3), UV/H_2O_2, Fenton (Fe^{2+}/H_2O_2), photo-Fenton processes (Fe^{2+}/H_2O_2/UV), and other methods like ultrasonic and radiation, can be used to efficiently treat wastewater (Anjali et al., 2019).

5.3 Ozonation
Ozonation has been widely used to disinfect wastewater and water by killing organic debris, bacteria, viruses, algae, and fungi. To get rid of the antibiotics in the advance oxidation process, ozonation (O_3) and various combinations of ozone like O_3/H_2O_2, O_3/UV, or O_3/H_2O_2/UV along with catalysts (O_3/catalysts) are widely utilised and researched**.** Ozone is typically used at high pH levels to enhance the generation of hydroxyl radicals (•OH), which have the potency to oxidise antibiotics. Hydrogen peroxide (H_2O_2) and ozone are used to generate a lot of •OH, which eliminates a lot of different kinds of contaminants from water and wastewater. The main variables affecting the ozonization processes are temperature, ozone dose, and pH, which also affects how the contaminants mineralize (Anjali et al., 2019). It has been demonstrated that ozonation has a significant potential to cause medicines in drinking water and wastewater to oxidise. With the exception of iodinated X-ray contrast medium, O_3 dosages ranging from 5 to 15 mg L^{-1} caused the majority of medicines in wastewater to completely vanish (Huber et al., 2005).

5.4 Fenton process
Fenton processes are one of the most significant and successful AOPs for treating wastewater. These procedures have been used to handle antibiotics both in lab settings and on plants in pilot programmes. In an acidic media (2.8–3.0), a combination of H_2O_2 as an oxidant and Fe^{2+} as a catalyst causes a reaction that yields •OH, a more reactive oxidant that is thought to be the dominating oxidant and is in charge of oxidising organic contaminants. When Fe^{+2} is present, the chain reaction occurs and H_2O_2 is broken down. Fe^{2+} and H_2O_2 interacted to produce Fe^{3+} and •OH with the intermediates (Anjali et al., 2019).

5.5 Photodegradation
For organic pollutants, photodegradation is a universal mechanism of decomposition that includes direct photodegradation, sensitised photodegradation, and photo-oxidation. Numerous parameters, including water composition (including inorganic compounds, types and amount of dissolved organic matter), temperature and pH, photosource, photocatalyst, structure, and properties of organic contaminants, all have an impact on the photolysis process of antibiotics. The primary method of TC removal is photolysis (Ajala et al., 2023).

5.6 Biological Treatment
Livestock dung is commonly treated using aerobic composting and anaerobic digestion. In fact, it has been reported that antibiotics are removed from animal faeces during anaerobic digestion and composting (Liu et al., 2018). The anaerobic digestion (AD) technique has been used to treat wastewater with more than 1500 mg/L of chemical oxygen demand (COD). Furthermore, AD has a lower sludge yield, requires less energy input, and provides biogas as a sustainable energy source. Therefore, swine wastewater with a high concentration of COD and a high level of antibiotics is often treated using anaerobic techniques (Zhu et al., 2021).

6. Conclusion
Antibiotics are mostly produced by the pharmaceutical industry. Antibiotic effluent from the pharmaceutical industry is challenging for conventional wastewater treatment plants to clean. Although neither humans nor animals can fully metabolise antibiotics, they can nevertheless improve public health and quality of life. The leftover unprocessed antibiotics could contaminate wastewater by excreting from the bodies. As a result, scientists developed a number of substitute technologies to do rid of antibiotics. In the end, a number of reported techniques have been developed to extract antibiotics from wastewater. However, in order to further enhance the removal of antibiotics from wastewater, the author suggests the future study concentrate upto on accelerating the removal process by utilising contemporary nanotechnology. But the widespread use of nanomaterials raises questions, particularly about their potential effects on the environment. This problem still needs to be taken into account for future studies. Aside from that, every antibiotic wastewater technology has advantages and disadvantages of its own.

7. Future Prospects
Antibiotic elimination is a prevalent use for the majority of these technologies. Sadly, the processes involved in eliminating antibiotics are either unclear or lacking. More research is required to understand what happens to after the treatment of

antibiotics in order to prevent secondary contaminants. Since most commonly used antibiotics are colourless and odourless, it may be difficult to determine whether an antibiotic discovered in wastewater is receiving adequate treatment. The tenable recommendation is to use the existing removal technology to identify and monitor pollution removal in real-time. Using nanotechnology in large amount is utmost concern, especially in environmental impact. This has been very challenging and has to be considered for future research. Large-scale use of nanomaterials raises questions, particularly about potential effects on the environment. This problem still needs to be taken into account for further studies.

Contribution of authors

Pooja Adwani (Research scholar): Review literature, Writing and Formal analysis. **Jiwan Singh** (Supervisor): review, editing and validate the article.

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Conflict of interest

The writers don't have any competing interests.

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