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Review

Potentially Toxic Elements in Pharmaceutical Industrial Effluents: A Review on Risk Assessment, Treatment, and Management for Human Health

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Abstract: Potentially toxic elements (PTEs) are metallic chemicals with densities that are higher than that of water. Water pollution by PTEs due to the discharge of untreated pharmaceutical industrial effluents is a risk to human health and ecological integrity. The present review paper provides an overview of the threats to human health due to water contamination by PTEs such as lead, cobalt, cadmium, nickel, and arsenic originating from pharmaceutical industrial wastewater. This review reveals the associated advantages and shortcomings of the outmoded and the modern methods and the challenges involved in addressing the shortcomings. Additionally, due to the increasing amount of uncontrollable pharmaceutical effluents entering the ecosystem, this paper reviewed the management approach supported by the World Health Organization and the Environmental Protection Agency. Studies revealed that PTEs find their way into human bodies through different pathways, which include drinking water, edibles, and dermal vulnerability at intervals. This paper focuses on how pharmaceutical effluents can be handled and how regulations and strategies can be reinforced step by step. To preserve public health and the environment, a comprehensive study on the environmental evaluation of carcinogenic substances, particularly toxic elements and metalloids, should be supported and advocated. To protect living organisms and the welfare of consumers, efforts should be made to reduce the presence of potentially hazardous elements on land and water.

Keywords: potential toxic elements; pharmaceutical effluents; pathways; health risk assessment; advance treatment

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1. Introduction

There has been increasing concern in recent years regarding water treatment and reuse which necessitates the toughest standards due to the increasing demand for high-quality water worldwide, be it for drinking, sanitation, agriculture, or industrial usage [1]. Increased industrial activities have caused a number of water bodies to become contaminated with pollutants that go above what is permitted for effluent [2]. Among the different contaminants, potential toxic elements have posed the major concerns for environmental and human health due to their non-biodegradability and great accumulation capability [3]. Potentially toxic elements (PTEs), otherwise known as heavy metals, are metallic chemicals with a density that is higher than that of water. These metals are very toxic to people and can hurt them if they go beyond what is considered normal [4]. For instance, some of these metals have atomic masses ranging from 63.546 to 200.590 u. On the periodic table, these metals are positioned in a vertical column between groups III and V with related properties.

Priority metals are naturally present in groundwater, and while some of them are necessary for life, higher concentrations of these metals can actually be quite detrimental. These vital resources of life, such as water and land, are becoming pressured as a result of industrialization, poor water and land use practices, farming techniques, and population growth [5]. Waterbody contamination has become a global issue that has grown in both developed and developing countries, impeding economic growth and negatively harming public health [6]. Both the condition and the features of our finite freshwater resources are being negatively impacted by the discharge of toxic metal ions into the environment. The uncontrolled release of contaminants is threatening the sustainability and availability of drinking water, and this is becoming a worldwide public concern [7]. Due to their bioaccumulative nature, potential hazardous metals have raised health concerns even in minute quantities [8]. Many of these elements, including arsenic (As), cadmium (Cd), chrome (Cr), nickel (Ni), lead (Pb), and zinc (Zn), are non-biodegradable, and the Environmental Protection Agency has designated them as priority contaminants to be controlled [9].

Several industrial processes are discharging PTEs, and pharmaceutical industrial effluents have proven to be a major discussion point. International organizations such as the World Health Organization (WHO) and the United Nations Environmental Programme (UNEP) have comprehensively reviewed the health consequences related to several toxic elements. Over the years, PTEs have been discovered, and their intensely detrimental impacts on human health are well documented, but currently the use of PTEs has greatly increased, giving rise to their discharge into the environment and thus provoking sudden symptoms in the body [10].

The objective of this review paper was to evaluate any potential health risks linked to pharmaceutical wastewater discharge into the environment. A discussion on how to improve water quality by lowering water contamination through monitoring techniques, management choices, and treatment preference selection of toxic metals to safeguard ecosystems reliant on water was reviewed. Analysis of the existing methods for treatment and disposal practices of pharmaceutical wastes has been undertaken on the classification of the treatment methods under well-identified broad specific groups. The overall goal of this paper is to educate and influence the attitudes and actions of pharmaceutical industries, consumers, and farmers against the unauthorized discharge of effluents into the environment.

2. Sources and Entry Pathways of Potential Toxic Elements

Toxicity can be explained as the tendency of a substance to cause harm to a living organism. It is also the degree to which a chemical substance can exert a harmful influence on the life span, development, and replication of living things. Several studies have demonstrated that certain toxic metals have been identified as substances that alter normal body functions, leading to developmental malformations commonly known as cancer and genetic mutations in organisms based on the exposure rate to those metals and the amount taken at a particular time, which affects both humans and animals. The following sections describe the primary sources of pharmaceutical effluents and their end products in the environment [11–13].

- Pharmaceutical manufacturing generates effluents containing human drugs, suspension drugs, and solid wastes containing animal drugs in the form of boluses, and storm water runoff carries finely ground drugs.
- Consumers and clients also dispose used and untreated drugs into water bodies, which pollute the ecosystem and affect human health. Furthermore, numerous households also release wastes through excretion into the wastewater without any precautionary methods.

- Health centers and clinics discharge wastewater and pharmaceutical wastes down the drain.
- Agricultural residues and drugs administered to animals such as fowl, sheep, and cold-blooded animals; discharge of dissolved fertilizers and antibiotics mixed with farm animal feed and water. Figure 1 summarizes the environmental entrance pathways for the pharmaceuticals.

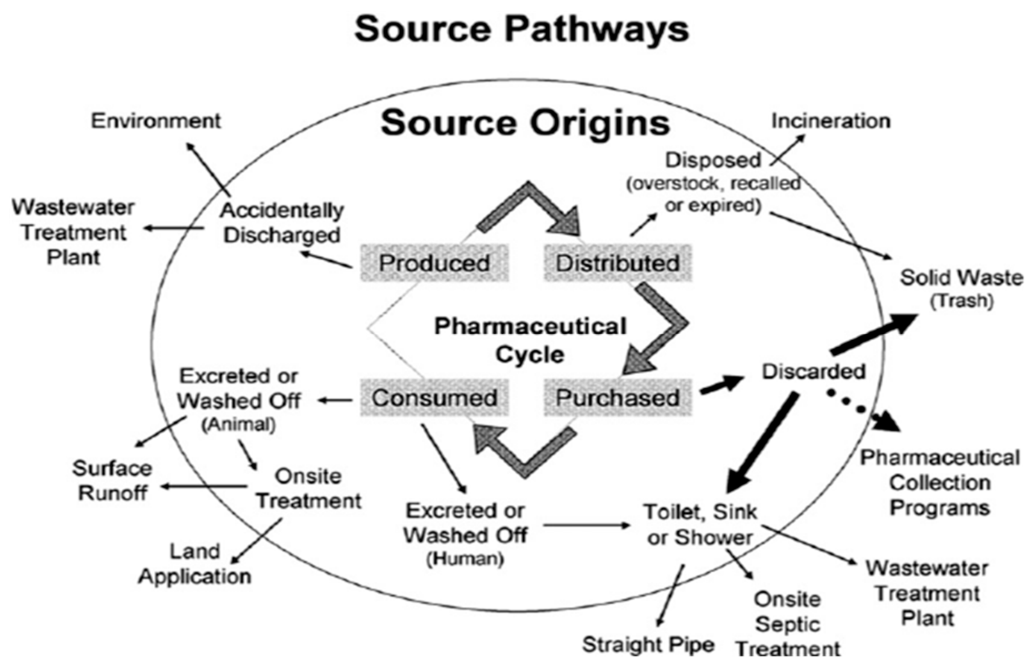

Figure 1. Environmental entrance pathways for pharmaceuticals. Reprinted from [14] with permission from Elsevier.

The sources through which these pharmaceuticals enter the environment may differ from one location to another, but it is widely known that the major pathway of pharmaceutical effluents into water bodies is through the release of unrefined wastewater from consumers and veterinary medicines. Other sources are domestic wastes, farming, and some industries that empty partially untreated effluent into the river. Potentially toxic elements from anthropogenic sources enter the rivers as inorganic complexes [5].

3. Routes of Uptake

Living things can be exposed to PTEs through the respiratory organs such as lungs, skin, and the process of taking in food [15,16]. There are three (3) ways in which these priority metals are taken up by humans and animals, as discussed below:

1. Ingestion: This is the process of swallowing foodstuffs or other substances such as coffee, water, and juice that are polluted by the PTEs (see Figure 2).
2. Skin or dermal adsorption: Skin adsorption is a process by which the harmful substance meets the body through the skin or gills.
3. Inspiration (inhalation): Living things breathe in poisonous gases or vapor as dust fumes in this process.

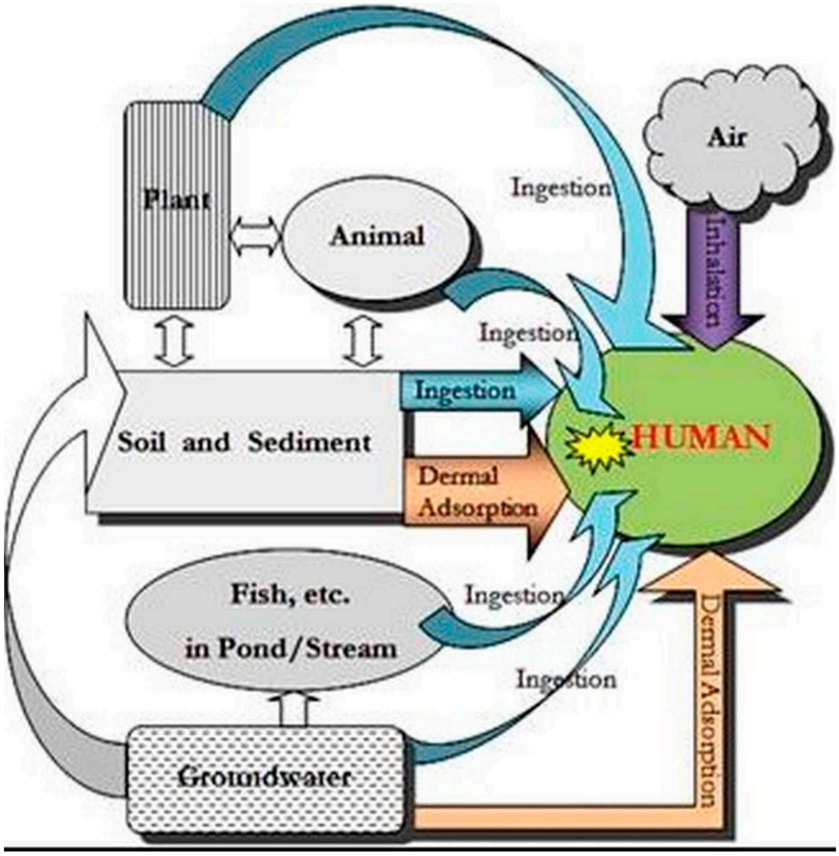

Figure 2. Reprinted with permission from [17].

4. Potentially Toxic Metals in Ground and Surface Water

Potentially toxic elements such as Cr, Pb, and Cd can harm living organisms, in addition to long-lasting organic pollutants such as pesticides and polychlorinated biphenyls (PCBs), which are some of the pollutants found in pharmaceutical effluent discharges. These elements are highly harmful to marine animals, even at trace amounts, because they change the morphology of the organisms' cells [18].

The evaluation of the influence of point-source contaminants on the sustainability of water bodies is becoming particularly crucial. The study of the risk of chemicals in rivers and the effects of adulteration on the freshness of streams is important because these sources of water play significant functions. The society ends up paying a heavy cost for inappropriate pharmaceutical sewage discharge because contaminated water is primarily used for both household and specific purposes by residents living near groundwater and surface water [19].

An examination of the literature revealed that dangerous metal concentrations in fresh water, drinkable water, and aquifers around the world frequently exceed the ranges permitted by regulatory bodies, thereby posing a risk to the ecosystem. The range of arsenic concentrations in groundwater sources was 0.0005–1.15 mg/L [20].

In 2015, according to the World Health Organization, 8.8 million cancer deaths occurred globally. The accumulation of harmful metals above legal limits in bodies of water is among the main reasons people die because these metals affect the central nervous system. The physiology of living tissues in the body is severely affected when foodstuffs or potable water comprising potentially harmful metals surpass their optimum threshold level [21]. The immunological and blood systems in humans and livestock are also harmed when they are exposed to metal combinations.

The existence of toxic metals beyond their maximum limit in the aquatic system is the major source of human endocrine disorders, according to a report by [22]. Potentially dangerous metals, including Pb, Hg, Cd, As, and Cr, put pressure on biological systems and produce cardiotoxicity, which harms tissues and causes age-related diseases such as Alzheimer's disease and mental retardation.

5. Classifications of Potentially Toxic Metals

Several scholars (e.g., [23,24] have discovered that pollutants in groundwater are harmful metals. These harmful components are divided into four classes due to their health implications.

1. Essential: These are metals that play a biological role in living organisms but become hazardous when they exceed their permitted limits; examples are manganese, copper, iron, and zinc.
2. Less toxic: These are metals that are less toxic to human health; examples include tin and bismuth.
3. Highly toxic: These are known as metalloids such as cadmium, lead and arsenic.
4. Non-essential: These are metals that do not have a biological role in human beings; examples include aluminum and lithium.

Due to the obvious severity, permanence, and eventual biomagnifications of hazardous metals in the body, contamination of both land and marine environments by various harmful metals has become among the foremost problematic pollution concerns [25,26].

6. Pharmaceutical Industrial Effluents

Pharmaceutical effluents are liquid waste produced by drug companies during the development of new drugs; pharmaceutical effluent mainly contains the largest proportion of organic and inorganic compounds, animal drugs, and antibacterial drugs. During their synthesis, administration, and disposal, active pharmaceutical ingredients (APIs) are discharged into the surroundings, and there is an indication that API exposure in the environment has adverse implications on living organisms [27,28]. Potentially harmful metals have heavily contaminated the surroundings and their components. The biosphere is the most significant region of the ecosystem since it houses living things. Interactions between plants and animals and their environment also take place in the biosphere. Potentially, metals are detrimental to health, and their consumption has increased as a result of the activities carried out by drug manufacturing companies as well as global industrialization. In this regard, the potency of a contaminant in freshwater, the atmosphere, and food is examined [29,30]. Table 1 provides the distribution of pharmaceutical discharge in the environment.

Table 1. Distribution of pharmaceutical discharge in the environment.

Source	Pharmaceutical manufacturing plants	Waste water treatment plant (WWTP)	Agriculture
Pathways	Point source, e.g., refineries for oil, paper mills and chemicals	Diffuse source, e.g., fertilizer and pesticides in agriculture	
Concentration patterns	Continuous (e.g., WWTPs)	Seasonal (linked with farming practices)	Intermittent (linked with rainfall event)
Pharmaceutical attribute	Persistence (e.g., Half-life and solubility)	Biomagnification	Toxicity (individual effects and mixture effects)
Forms of receiving environment	Streams, lagoons	Aquifers, sea	Soil, sand
Context-dependent factors	Pharmaceutical properties	Illegal medication usage	Waste control and disposal methods

7. Selected Potentially Toxic Metals

7.1. Lead (Pb)

Pb is among the most common elements in nature all over the world. Due to its elemental physical and chemical properties, it has numerous industrial applications. It ranks as the fifth most widely used metal in the world as a result of increased industrial applications; it is used in over 900 industries, including oil refineries, drug manufacturing, and quarrying. There is a rise in the metal ion concentration in industrial effluent due to an increase in outflow from firms operating close to rivers. According to a study by [31], prolonged exposure of children to low concentrations of lead has been linked to reduced intelligent quotient (IQ), and acute lead exposure is known to cause sudden kidney injury. According to [32], acute Pb exposure can cause anorexia, fatigue, sleeplessness, disorganized thinking, dizziness, liver failure, high blood pressure, and joint pain, while chronic Pb exposure can cause congenital defects, intellectual disabilities, weight loss, learning disabilities, behavioral problems, muscle cramps, kidney diseases, neurological damage, and unconsciousness, and may eventually result in death.

7.2. Arsenic (As)

Arsenic is a substance that is found in nature and is broadly distributed across the atmosphere. It is widely distributed in nature because it can exist as a synthetic or natural compound and has variable oxidation states of −3, −1, 0, +3, and +5. It can be found in environmental matrices such as soil, air, water, and natural food sources. Arsenic is sometimes referred to as the "King of Poisons" due to its potent toxicity [33]. Arsenic is exceedingly hazardous in nature; studies have shown that its potential adverse health effects are linked to its exposure, which has gotten a lot of attention in the last two decades [34,35]. Prolonged exposure to low levels of arsenic affects the liver in humans and other mammals. Arsenic also causes swollen kidneys, structural abnormalities, and kidney failure in humans. Arsenic is highly hazardous and carcinogenic, and it is widely available as oxides or sulfides or as an iron, sodium, calcium, or copper salt. Arsenic causes oxidative processes and induces detrimental consequences in individuals, including cell apoptosis and mental retardation, memory deficits, hearing disorders, high blood pressure disorientation in old age, and kidney cancer [16,36].

7.3. Cadmium (Cd)

Cadmium exposure has been reported to be associated with fertility problems because it impairs sperm and lowers pregnancy outcomes. It is a cancer-causing agent and appears to play a role in heart disease and high blood pressure [37]. Cadmium destroys the gastrointestinal system, reduces renal antioxidant activities, and alters chemical fluid in the body, resulting in reproductive organ malfunction. The cognitive function of the brain is affected when Cd is present [38]. Cadmium is hazardous to tissues due to its ability to remove vitamins C and E from their metabolically active locations. Hence, Cd is a hormonal disrupter and is detrimental to child development. Immunological suppression and immune disorders are two symptoms of cadmium toxicity in fish. The accumulation of Cd in wastewater may disrupt body systems, causing short- or long-term problems [39,40].

7.4. Nickel (Ni)

Nickel is among the most common metals on earth and is present in a wide range of metal alloys used in the steel industry, as well as in colorants, taps, and dry cells. Nickel can end up in water bodies due to its presence in wastewater streams [41]. Respiratory illness, lung fever, hypersensitivities, cardiovascular disease, skin irritation, and mishaps are all caused by the excessive absorption of Ni by humans. There is a high risk of developing prostate cancer, nasal cancer, and laryngeal cancer due to human exposure. Ni is only found in trace amounts in the environment, but food plants grown in contaminated soils can accumulate large quantities. Numerous cytotoxic activities carried out by Ni include the production of free radicals, genetic regulation, and the control of transcription factors. It has been discovered that Ni contributes to the control of the expression of a few lengthy non-coding chromosomes. Nickel has also been shown to produce reactive species, which contribute to neurotoxic development [32].

7.5. Chromium (Cr)

Chromium is essential for glucose and fat breakdown, as well as lipoprotein consumption. Its biological function is intertwined with that of insulin, and most Cr-enhanced processes are insulin dependent. An excessive amount, on the other hand, could be harmful [42]. In soils treated with wastewater, toxic levels are typical. Over 7.5 million tons of chromium are thought to be produced annually on an international scale. In the presence of chromium ions, the discharge of collagen-type I, which aids in the repair of broken bones, is reduced. Nose ulcers, pneumonia, and genetic mutation in humans, as well as the destruction of red blood cells and urinary damage, are caused by chromium. While Cr (VI) is associated with a variety of anomalies and disorders, Cr (III) acts as an endocrine activator and is required in trace amounts for appropriate fat and amino acid metabolism [43–45]. Table 2 provides the summary of some studies highlighting the health risks of selected toxic metals.

Table 2. Summary of some studies highlighting the health risks of selected toxic metals.

s/n	PTE	Health Risk	Reference
1	Lead (Pb)	Long-term lead exposure may also give rise to kidney damage; acute exposure of Pb can cause loss of appetite, fatigue, sleeplessness, hallucinations, coma and even cause death	[32]
2	Arsenic (As)	Low concentrations of arsenic for long period damage liver in human and other animals; enlargement of kidney, skin and hair changes	[30] [34]
3	Cadmium (Cd)	Presence of Cd in contaminated water could disturb the necessary mechanisms in the body, possibly resulting in short-term or long-term disorders; it disrupts endocrine function and also affects reproduction rate in humans	[38–40]
4	Nickel (Ni)	Excess uptake of Ni by humans causes asthma, pneumonia, allergies, heart disorder, skin rashes, miscarriage and increases the chances of developing carcinoma and nose cancer	[32]
5	Chromium (Cr)	Cr in humans causes nose ulcers, asthma, DNA damage, hemolysis, damage to liver and kidney, and carcinoma	[42–44]

8. Human Health Risk Assessment of Pharmaceutical Industrial Effluents in the Environment

8.1. Health Risk Assessment

Human health risk assessment is a method of calculating the potential health consequences associated with the exposure of people to chemical hazards.

In the risk assessment process, there are four basic steps:

1. Hazard identification,
2. Assessment of exposure,
3. Toxicity/dose–response assessment, and
4. Characterization of risk.

8.1.1. Hazard Identification

The purpose of hazard identification is to look at the contaminants that are present in a given area, their level of accumulation, and their diffusion rate.

8.1.2. Assessment of Exposure

The purpose of the assessment of exposure is to determine the magnitude, reoccurrence, duration, or timing of individual exposure to pollutants (i.e., PTEs). The average daily dose (ADD) of the toxic elements discovered by consumption and skin contact in the population was calculated in this study to assess exposure.

8.1.3. Toxicity/Dose–Response Assessment

Dose–response analysis determines the toxicity of PTEs based on their exposure strengths. The two critical toxicity indices used are a carcinogen intensity factor called the cancer slope factor (SF) and a non-carcinogenic level termed the reference dose (RfD).

8.1.4. Characterization of Risk

Risk characterization aids in predicting the potential cancerous and non-cancerous health hazards that the vast majority of the population in the research area is vulnerable to; this is done by combining all the data obtained to create statistical evidence of exposure to cancer and the threat proportion [45]. The sudden rise in pollution of priority metals [46] can have disastrous health repercussions on communities and habitats, disrupt crop productivity, and make animal and human drinking water unsafe. Toxic metal, in particular, can build up inside important organs, causing short- and long-term damage. Metals are commonly encountered in corrosive effluents, where water forms electrostatic dipolar ion interactions with priority metals [47]. They can be produced in massive amounts and come from a variety of production processes.

Every day, almost 2 million tons of uncontrolled chemical, wastewater, and farm runoff are released into water bodies [48]. The amount of toxic metal ions released into the environment has increased dramatically over time [49]. Even treated industrial effluent contains potentially toxic metal ions, which have a negative impact on human health and the environment.

9. Advanced Treatment of Pharmaceutical Industrial Effluents

The principal technique used for enhanced treatment of industrial wastewater is based on physicochemical mechanics, which has become the focal point of scientific study and technical applications over time [50,51]. Examples of physical or chemical procedures used to treat industrial effluents are improved oxidation techniques, flotation, activated carbon adsorption, membrane separation, coagulation, and sedimentation, and the characteristics of each process are highlighted and described below.

9.1. Coagulation and Flocculation

Coagulation is a chemical water treatment process used to remove solids by adding coagulant agents and modifying the electrostatic charges of suspended particles in water to form large flocs, which then settle down as sludge. For improved treatment of industrial effluents, it is essential to squeeze and remove bound water from around hydrophilic colloids. As a result, determining the coagulation impact is heavily dependent on the flocculant nature. Polymers and metal salts are frequently used as flocculants. This procedure is effective for removing chromaticity as well as hazardous organic materials [52].

9.2. Flotation

Excluding sedimentation, flotation can eliminate dissolved particles from secondary effluents. The technology creates a large number of tiny bubbles by introducing air into effluent, creating floating floc with a lower density than the wastewater. It can also float to the top of the effluent to separate it. Ion flotation could be a suitable option for removing hazardous metal ions from industrial effluents. Ion flotation is based on the application of surfactant to make ionic metal species in effluent hydrophobic, followed by the removal of these hydrophobic species by gas bubbles [53].

9.3. Activated Carbon Adsorption

Activated carbon offers several benefits as an adsorbent: it features a large surface area, a multi-level pore volume, adsorption ability, and a constant chemical property. As a result, it is commonly utilized as an adsorbent to eliminate contaminants [54]. Activated carbon is used in the treatment of water and wastewater, including hazardous and difficult-to-meet discharge standards pharmaceutical wastewater. This is also a significantly advanced treatment method for industrial wastewater. There are two different types of activated carbon adsorption: chemical and physical. There is no adsorption selectivity, and physical adsorption is reversible. When saturated with adsorbates, activated carbon desorbs easily.

On the other hand, chemical adsorption is irreversible and challenging to desorb since it only adsorbs one or a few different adsorbates [55,56]. Saturation of activated carbon restores its adsorption property through a renewal process for cyclic use. Because of its ability to be reprocessed, greater treatment effect, and wide applicability, this technology is extensively employed for advanced water treatment. However, numerous drawbacks, including high relative prices, low regeneration efficiency, and complicated operation, limit its use [54,57].

9.4. Photocatalytic Oxidation

Ultraviolet photocatalytic oxidation, also known as photochemical oxidation, is a way of combining ultraviolet radiation as a catalyst with a UV-sensitive oxidant. When exposed to ultraviolet light, the breakdown of oxidants produces free radicals with a higher oxidative ability, allowing them to oxidize more and more difficult-to-decompose organic pollutants using only oxidants. Based on the kinds of oxidants used, photochemical oxidation can be classified as UV/O_3, UV/H_2O, $UV/H_2O_2/O_3$, etc. Photochemical reactions take place through diverse and complex reaction mechanisms depending on radical generation principles that are susceptible to experimental settings, and their effectiveness might be harmed by the presence of quenching chemicals in wastewater [58].

9.5. Electrochemical Oxidation

The electrochemical approach is well recognized for the removal of poisonous and hazardous pollutants in water and wastewater. In the field of water treatment, electrochemistry is a novel approach. The technique works on the following principle: during the electrochemical reaction, the reactant loses electrons and is oxidized at the anode surface. The chemical at the cathode surface, on the other hand, will lose electrons and get reduced. In particular, the oxidation of the anode causes the elimination of refractory organic materials. Electrolytic recovery, electrochemical oxidation, electrolytic air flotation, electrodialysis, and micro-electrolysis are examples of traditional electrochemical effluent treatment systems. When compared to other techniques, the electrochemical process, often known as the "environmentally friendly" process, offers a significant benefit. The electrochemical process, for example, is normally carried out at room temperature and pressure, has high efficiency, may be used alone or in conjunction with other procedures, covers a limited area, produces no secondary pollution, and has a reasonably high level of automation. Future electrochemical reaction research will focus on the anode and electrochemical reactor development [59].

9.6. Ultrafiltration (UF)

The ultrafiltration process is utilized in the tertiary treatment of water and wastewater for additional cleaning and treatment. The difference in pressure between the membranes on either side is what propels the movement; the membrane for ultrafiltration serves as the filtering medium. When a fluid travels through the surface of the membrane under a specific amount of pressure, water, inorganic ions, and tiny molecules pass through, while other components are prevented from crossing the membrane barrier.

9.7. Reverse Osmosis (RO)

Reverse osmosis efficiently removes metal ions from water, making it suitable for drinking [60,61]. RO membranes can be classified as either cellulose ester or aromatic polyamide. A variety of organic materials and dissolved inorganic salts can be removed using RO methods. It also has a high rate of water recycling and salt extraction efficiency.

9.8. Electrodialysis (ED)

Electrodialysis (ED) is among the new techniques for removing and recovering metals. Recently, metal-contaminated water has been treated using the emerging technique of electrodialysis [62]. The electrodialysis process (ED) combines electrolysis with dialysis. The dissolved salts in the wastewater are subsequently transported to the anode and the cathode by the direct current electric field. In this manner, separation and recovery are accomplished as the number of anions and cations in the intermediate phase gradually decreases. Numerous benefits include less environmental pollution, less energy and chemical usage, ease of use, and automation. However, because desalination effectiveness is lower than RO, it is limited to the removal of salt from the water. Overview of the benefits and drawbacks of some selected metal treatment technologies is provided by Table 3.

Table 3. Overview of the benefits and drawbacks of some selected metal treatment technologies.

s/n	Technology	Benefits	Drawbacks	Reference
1	Coagulation and flocculation	-Coagulants are relatively economical and easy to operate -It does not call for distinct processes	-Partial removal of metal	[47] [52]
2	Adsorption (activated carbon)	-Numerous adsorbents are accessible -Easy to use and affordable	-Waste products are created -Regenerating agents can be difficult	[63] [54]
3	Electrodialysis	-High effectiveness in separating ions with opposite charges -Can handle metal concentrations that are low -Treatment setup is easy	-High level of energy use -Operational characteristics have an impact on separation effectiveness -Creation of auxiliary streams	[62]
4	Reverse osmosis	-High metal separation effectiveness -Purifies contaminated water	Running cost is high due to high forces -It is important to regenerate	[60] [61]

10. Management of Potentially Toxic Elements in Pharmaceutical Industrial Effluents

Waste management and sewage treatment have recently become major issues for humans. Pharmaceutical metabolites have been found in the water cycle in the past 10 years, which has caused policy makers, water distributors, and communities at large to worry about the potential implications for human well-being. The World Health Organization (WHO) and the Environmental Protection Agency (EPA) both support a significant risk management strategy called the "water quality approach". It implies that, to avoid any associated danger, particularly health problems, pharmaceutical effluents should be managed to a level that meets precise water quality guidelines [64]. With this method, countries are encouraged to take into account their unique cultural, social, and environmental circumstances when developing and implementing effective risk management strategies [65]. However, it is well acknowledged that the degree of wastewater treatment should correspond to the intended application. For this reason, cost-effectiveness studies are crucial for assessing various risk management choices for concrete proof of decision making, treatment preference selection, and distribution of resources, particularly in economically developing nations [66].

If there is no landfill leachate collection, pharmaceuticals improperly disposed of in domestic waste wind up in landfills, where they may eventually be transmitted into water bodies [67]. Regarding the known and conceivable threats to humans and ecosystems, the presence of pharmaceuticals in surface water has sparked alarm among freshwater suppliers, policy makers, and the general public. It has been established that several pharmaceutical effluents have unfavorable impacts on ecosystems, including abnormalities, behavior, fertility, and death. Due difficulties faced in biodegrading toxic metals, which are naturally present in the earth's crust, these materials have contributed to a significant number of environmental pollutants [5,51]. To stop environmental deterioration, the regulatory bodies for the pharmaceutical companies must demand constant supervision and the application of regulations governing the proper discharge of pharmaceutical pollutants. The World Health Organization has listed the issue as among the top ten potential health risks [68]. The rapidly expanding pharmaceutical sector, which serves as a reservoir for antibiotics in the surroundings, plays a vital role; effective treatment of pharmaceuticals in surface water will demand:

- Evaluation of the occurrence, distribution, and environmental effects of additional effluent.
- Uniform data gathering, processing, and storage practices.
- Monitoring priorities for toxins, water bodies, and ecosystems.
- Improved knowledge of the various exposure paths.
- Determining what medicines are present in treated water (septic tanks) compared to untreated water.

11. Evaluation and Monitoring of Possibly Toxic Elements in the Environment

To assess and control pollution, monitoring and evaluation of environmental toxic metal concentrations are required. It is important to regularly evaluate the concentrations of possibly hazardous metals and metalloids in the resident biota as well as in the various environments, such as freshwater, sediments, and soils [69,70]. The prevalence, main sources, and eventual outcome of these toxic metals in the environment, as well as their bioaccumulation in food chains, will all be valuable information that may be gleaned from this environmental investigation. This analysis is additionally employed to determine how dangerous these substances are to both public health and animals [71].

12. Sustainable Developmental Goal on Water Management

To preserve human health and boost water availability, increasing water contamination must be addressed at its source and treated. All areas of life and sustainable development require access to fresh water in quantities and conditions that are both sufficient and of high quality. To set investment priorities, trustworthy surface water resource monitoring is necessary. Enhancing and accelerating efforts to address water quality issues requires a better awareness of the possible links between water contamination and Sustainable Development Goals [72].

Water contamination poses a health threat to living creatures and the ecosystem [72,73]. Sustainable Development Goal 3 aims to safeguard everyone's good health and wellness at every phase of their lives. Evidence suggests that improper wastewater treatment and disposal, which contaminates water supplies, reduces health benefits [74].

According to SDG 6, everyone must have access to water and sanitation services that are managed sustainably. This goal specifically obligates member states to establish widespread access to clean water and sanitation, enhance water quality by lowering water contamination, manage water resources holistically, and safeguard ecosystems reliant on water. Additionally, enhancing sanitation should consider every link in the "sanitation chain", including the user's experience, the management of sewage, and its reuse or disposal. These links include technical elements such as the toilet or wastewater treatment plants as well as human experience [75].

SDG 14 focuses on the sustainable management of water bodies to prevent detrimental effects; as a result, it aims to control fisheries, address ocean acidification, minimize its consequences, and prevent all forms of marine pollution from entering the ocean. SDG 14 calls for improving the protection and wise use of the oceans' natural resources by putting into practice international law, which establishes the necessary legal framework. The largest ecosystem on the globe is the ocean, and it is vital to our survival that the oceans and seas remain healthy. To achieve the Sustainable Development Goals, we must take an integrated approach that prioritizes protecting our oceans and marine resources [76].

13. Management of Pharmaceutical Effluent and Policy Recommendations

Pharmaceutical wastes should be released into the environment more frequently if proper steps are taken to mitigate the dangers as global pharmaceutical demand is stoked by aging populations, improvements in healthcare, and increased livestock production. To ensure successful implementation, in collaboration with relevant governmental organizations, regional governments, and other stakeholders, a nationwide pharmaceutical policy and action plan to reduce environmental dangers should be developed. To maintain freshwater habitats and water quality, regulations that cost-effectively manage pharmaceutical effluents rely on two methods [76].

13.1. Suggestions to Enhance Awareness, Comprehension, and Feedback

1. To lay the groundwork for future pollution reduction initiatives, information, understanding, and reporting on the prevalence, distribution, and hazards to human health and the environment posed by pharmaceutical effluents in groundwater must be improved.
2. Utilize strategic and focused assessment methods to identify any environmental concerns associated with current and future active pharmaceutical components.
3. Promote the use of novel modeling techniques, monitoring techniques, and different resolutions to better comprehend and predict risks. Place a higher priority on chemicals and water bodies.
4. When there is a lack of solid scientific data and serious potential repercussions from inaction, take precautions. Train and interact with communities to control perceptions and take action [76].

13.2. Utilization-Focused Strategies

Reduce the illegal and wasteful usage and disposal of medications by imposing, rewarding, or advocating reductions in these behaviors. They aim is to educate and influence the attitudes and actions of doctors, veterinary doctors, pharmacists, consumers, and farmers. Reduce the consumption and supply of medications that are not essential. Enhance tests and postpone prescribing medications if they are not crucial. Consider banning or limiting the use of synthetic compounds as food supplements in the animal and seafood sectors.

5. Minimize the self-prescription of high-risk medications (such as antibiotics and drugs that affect the hormonal balance) and unauthorized drug sales.
6. Encourage and improve the best methods for handling and storing wastewater and manure from animals given pharmacological treatment.

14. Conclusions

Authorities, water service providers, and communities at large have all expressed concern over the prevalence of pharmaceuticals in the environment. Pharmaceuticals used for human health, such as penicillin, painkillers, stimulants, and chemotherapy drugs, as well as those used in veterinary medicine, are of particular importance, but it has been demonstrated through research that these pharmaceuticals have unplanned, undesirable deleterious effects on living organisms. A significant contributor to global environmental degradation today is emerging pollutants. It is imperative that the organizations in charge of environmental control and reporting, in addition to actions taken to protect global health, respond to the treatment and removal of new pollutants from pharmaceutical industries. Potentially toxic metals (PTEs) are retained after absorption, where they build up in the body. Harmful metals that enter the body through the food chain have a wide range of negative effects on various human organs and tissues. Without effective management and treatment, pharmaceutical effluent discharge could constitute substantial health and environmental dangers to the people who rely on surface and groundwater for drinking and domestic purposes. Potentially toxic metals should be addressed because they can lead to acute or persistent symptoms. To preserve public health and the environment, a comprehensive study on the environmental evaluation of carcinogenic substances, particularly toxic elements and metalloids, should be supported and advocated for. To protect living organisms and the welfare of their consumers, efforts should be made to reduce the presence of PTEs on land and water.

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