Review Article

A review on various bio-resources as a tool to reduce water pollution via eco-friendly adsorption technology

ABSTRACT

Pollution of water bodies is a raising concern in today's world. Water pollution occurs when harmful compounds enter water bodies and lowers the water quality. It is necessary to treat wastewater before its final disposal into aquatic bodies and environment. Among all the conventional water treatment techniques, adsorption technology attracted much attention owing to its simplicity and eco-friendly nature. Several studies were reported with the application of different kinds of adsorbents in the treatment of both organic and inorganic pollutants in wastewater. However, demand for the development of more suitable adsorbent with selective pollutant removal capacity and good economic feasibility is still rising. Therefore, this review aims to provide a detailed review about the adsorption technology and its mechanisms in pollutant removal process. The adsorption ability of certain important adsorbents were discussed along with future perspectives. Effective, economical, and environmentally friendly wastewater management should be the ultimate objective of any wastewater treatment process. Keeping that in view, this review article highlighted the importance of wastewater management and treatment via adsorption technology.

Key words: Adsorption, Adsorbents, Bio-resources, Contaminants, Pollution, Treatment Wastewater

1. INTRODUCTION

Water pollution can be defined as contamination of water quality caused by floating, particulate and dissolved pollutant matters. The continuous discharge of numerous organic and inorganic contaminants, including dyes, heavy metals, surfactants, medicines, pesticides, and personal care items from industry and municipalities into water bodies is causing the world's water supplies to deteriorate [1]. Organic and inorganic pollutants are the two main categories of wastewater contaminants. Pesticides, phenols, herbicides, petroleum, dyes, oils, biphenyls, fats, proteins, starches, and pharmaceuticals are examples of organic pollutants, whereas chemical fertilizers, PTEs, and an abundance of nutrients are examples of inorganic pollutants [2,3]. They result in deteriorating water quality and significant environmental issues. In order to control aquatic pollution, identification of contaminant source is very important. The two main sources of contaminants in wastewater are (i) natural, such as volcanic activity, soil erosion, and rock weathering, and (ii) mineral contaminant dispersion through anthropogenic activities, such as waste disposal sites, urban runoff, mining, the production of printed circuit boards, agricultural activities, the treatment and electroplating of metal surfaces, fuel combustion, textile dyeing, and semiconductor manufacturing, among others [4, 5].

Wastewater generated from agricultural, industry, and household activities carries more amount of heavy metals, excessive nutrients, toxic inorganic and organic contaminants which can cause threat to environment and human health [6, 7]. Potentially toxic elements, often known as

PTEs, are heavy metals and metalloids that fall into the category of trace elements. These include iron (Fe), lead (Pb), silver (Ag), manganese (Mn), chromium (Cr), cobalt (Co), arsenic (As), aluminum (Al), nickel (Ni), zinc (Zn), tin (Sn), mercury (Hg), cadmium (Cd), zinc (Zn), tin (Sn), iron (Fe), lead (Pb), and aluminum (Al) [8]. These PTEs create variety of negative consequences on the environment and human health. It adversely affect human health because they are absorbed by aquatic organisms, crops, and other plant species, which then enter the human food chain [9, 10]. It is clear that effluents have a substantial impact on both the environment and human health. Wastewater treatment and emission control through the creation of strict rules are very significant. Most nations are very concerned about the effects of wastewater discharge into rivers, lakes, estuaries and ocean. Establishing appropriate regulations to safeguard the quality of water resources is necessary in this scenario since it is essential to the advancement of public health and the environment in all nations.

2. WASTEWATER TREATMENT METHODS

Recycled wastewater is being used in irrigation activity without any kind of treatment. Lack of adequate equipment, facilities, and accessibility for effluent treatment can affect marine environment and fisheries [11. 12]. Therefore, proper treatment of effluent is necessary. Different treatment approaches were employed to treat various kinds of wastewater discharged from commercial, domestic and industrial sectors. Treatment processes include physical, chemical, and biological approaches [13]. There are different degrees of wastewater treatment. It includes preliminary, primary, secondary and tertiary or advanced treatment. The removal of coarse particles and other big items that are frequently present in raw wastewater is the goal of preliminary treatment. Large, entrained, suspended, or floating materials can be removed or reduced in size with the use of preliminary treatment. Along with some fecal waste, these solids include bits of wood, cloth, paper, plastic, rubbish, and so forth. Heavy inorganic materials like sand and gravel, as well as glass or metal, are removed.

By using the physical processes of sedimentation and flotation, primary treatment is intended to remove both organic and inorganic particles. The primary treatment process removes 25–50% of biochemical oxygen demand (BODs), 50–70% of suspended solids (SS), and 65% of oil and grease. Primary sedimentation also removes some organic nitrogen, organic phosphorus, and heavy metals that are linked to solids, but colloidal and dissolved elements are unaffected. The primary goal of secondary treatment is to remove any remaining organic matter and suspended particles from the effluent from initial treatment. The distribution of the solids' sizes is roughly 30% dissolved, 6% colloidal, and about 65% suspended solids. The secondary treatment procedure involves biologically treating wastewater in a controlled environment using a wide variety of microorganisms. For secondary treatment, a variety of aerobic biological processes are employed. These procedures vary mainly in how oxygen is provided to the microorganisms and in how quickly the organisms digest the organic matter. The major portion of BOD and suspended particles present in wastewaters are removed during primary and secondary treatment. However, this level of treatment has increasingly shown to be insufficient to safeguard the receiving waters or to deliver reusable water for industrial and/or domestic recycling. In order to account for further organic and solids removals or to provide for further effluent quality, additional treatment processes have been added to wastewater treatment plants. It includes tertiary treatment and other physicochemical treatment methods. There are several technologies available for treatment of different kinds of wastewater (Figure 1). Even though, multiple technologies are available, the selection of suitable technology depends on the characteristics of wastewater [15, 16]. Each treatment has its own limitations, including those relating to cost, practicality, efficiency, practicability, reliability, environmental impact, creation of sludge, operational difficulty, and the potential formation of harmful byproducts. However, just a few of the several wastewater treatment methods now mentioned are frequently used by industry for technological and financial reasons.

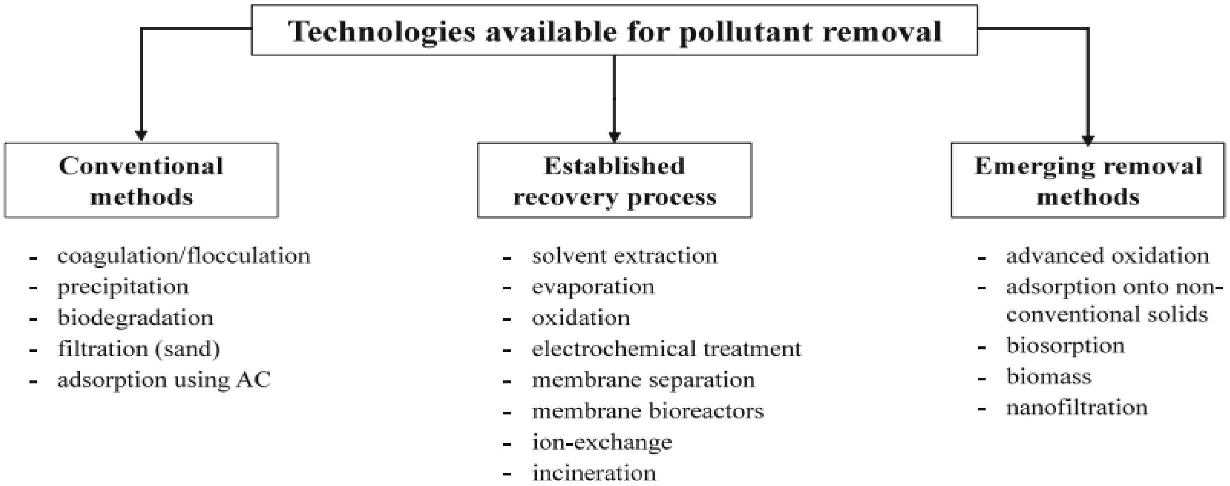

Figure 1. Available pollutant removal technologies in wastewater treatment. Adapted from Crini and Lichtfouse, 2018 [14].

2.1 Adsorption technology

Adsorption is regarded as the best wastewater treatment method due to its adaptability, low cost, and simplicity of use [17]. Both soluble and insoluble organic contaminants can be eliminated using adsorption. The elimination efficiency of this approach could reach 99.9%. These facts have led to the employment of adsorption in the removal of a range of organic contaminants from a number of contaminated water sources. Adsorption is the buildup of a substance at a surface or interface. When treating water, the process takes place where contaminated water meets solid adsorbent. Adsorbent refers to the adsorbing phase and adsorbate represents the pollutant that is being adsorbed. According to Gupta et al. [18], adsorption is based upon their nature of interactions and results in two types of sorption process: weak physi-sorption (adsorption), and strong chemi-sorption (absorption). The chemisorption process typically results in an irreversible monolayer, whereas the physisorption process is reversible and results in the formation of a multilayer. Strong electrostatic interactions, such as ion exchange-type processes, can occur during chemisorption between ions or dipoles and surfaces. Chemical linkages between the solute and the sorbate are created as a result of chemisorption. There is no chemical reaction in physical sorption. Only mild intermolecular forces like Van der Waals interactions may be present. When using the adsorption system for both industrial large-scale treatments and laboratory scale, it is crucial to take into account the modes of interaction between the solid adsorbent and the wastewater [19].

To collect experimental data and for industrial applications, a variety of contacting systems are available. These include batch procedures, fxed-bed-type operations, pulsed beds, moving mat filters, and fuidized beds. However, batch-type contact and fluidized bed procedures are the two most commonly employed systems in solid/liquid adsorption processes. Adsorption procedures for wastewater decontamination can be run continuously in fxed-bed reactors or columns or intermittently in batch reactors [20]. Batch methods are popular for small- and medium-sized process applications since it involves low cost technology. Another intriguing benefit of batch systems is the ability to manage and/or modify the effluent's characteristics, including contact time, pH, ionic strength, and temperature [21]. Despite the huge number of publications devoted to the adsorption of pollutants onto conventional or nonconventional adsorbents, the majority of them concentrate on evaluating adsorption capabilities, and only a small number attempt to explain adsorption mechanisms [22]. Physisorption (physical adsorption), surface adsorption, hydrogen bonds, van der Waals interactions, electrostatic interactions (attraction interactions), ion exchange, coordination, chelation, acid-base interactions, proton displacement, precipitation (surface precipitation, microprecipitation), hydrophobic interactions (π–π interactions, Yoshida's interactions), oxidation/reduction, and complexation are some of the adsorption mechanisms that occur during effluent treatment [23].

2.2 Adsorbents as potential Bio-resources

Different adsorbents can be used as bio-resources to adsorb dissolved pollutants. The adsorbent must be solid, have a large surface area and be porous, be cost-effective, have good physico-chemical properties, be inert and stable to endure chemical, thermal, and climatic changes, and the adsorption process must not produce any hazardous compounds [24]. Depending on an adsorbent's active surface, pore diameter, pore distribution quality, and surface functional group, it can have a variety of different qualities. The materials used as adsorbents are typically categorized as macroporous, mesoporous, and microporous. Poblete et al. [25] defined microporous materials as those with widths of less than 2 nm, mesoporous materials as those with widths between 2 and 50 nm, and macroporous materials as those with widths greater than 50 nm. Natural and manmade adsorbents are two categories used to categorize various adsorbent kinds. Charcoal, clays, clay minerals, zeolites, and ores are examples of natural adsorbents. These natural materials frequently have low cost, a large supply, and great potential for alteration, leading to eventual improvement of their adsorption capacities. Adsorbents prepared from agricultural products and wastes, household wastes, industrial wastes, sewage sludge, and polymeric adsorbents are known as synthetic adsorbents. Each adsorbent has unique properties, including pore structure, porosity and presence of various functional groups. Fruit wastes, coconut shells, scrap tires, bark and other tannin-rich materials, rice husk, sawdust, fly ash, sugar industry wastes, blast furnace slag, chitosan, seafood processing wastes, seaweed and algae, peat moss, clays, red mud, zeolites, sediment and soil, ore minerals, and many other waste materials are also used as adsorbents.

Even though, adsorbents can be prepared from various plant and animal derivatives, the preparation of low cost adsorbents draws much attention. One important criteria for the development of low cost adsorbent is the precursor. Numerous variables affect the precursor that is chosen for the creation of inexpensive adsorbents. The precursor should be easily accessible, reasonably priced, and of a non-hazardous nature. Furthermore, high carbon or oxygen levels in the adsorbent material are crucial for effective adsorption results. Other properties include high thermal stability, strong abrasion resistance, and tiny pore sizes, which increase exposed surface area and, thus, adsorption surface capacity [17]. (Ali et al. 2012). Next, the type of precursors are very important which depends on the nature of its origin. Plant, animal, and other high carbon content materials, such as fruit waste, rice husks, bark, seaweed, algae, peat moss, hair, and keratin, are examples of organic precursors. Petroleum and fertilizer products are examples of industrial organic products. The inorganic precursors include zeolites, ore minerals, metal oxides, hydroxides, clay, waste, and soil.

2.3 Different adsorbents in the treatment of pollutants in wastewater

2.3.1 Wood

Wood accumulates in huge amounts as solid waste and can be used as a feedstock for the production of adsorbents for wastewater treatment. Polysaccharides (pectin, cellulose) and polyphenol complexes (flavonoids, tannins, lignin, terpenes) have particular functional groups that interact with pollutant ions via hydroxyl (-OH) or carboxyl (-COOH) groups. Through the ion-exchange or chelation process, these wastes have a significant metal ion adsorption potential [26]. Toxic elements have been removed using adsorbents made from various forms of forest waste, including bark, chestnut borer, sawdust, pine pectin, and pine needles. Among these biological wastes, chestnut adsorbent has the highest absorption value (16.18 mg/g), while its bark has a value of 9.31 mg/g [27].

2.3.2 Agricultural Waste

Agricultural wastes are a highly common source of raw materials for adsorbent production since they are readily available and inexpensive. They typically have hydroxyl (-OH) and carboxyl (-COOH) functional groups and are mostly made of lignin and cellulose [28]. By offering electron pairs, these groups can join with metal ions to create complexes. Many scientists have employed agricultural wastes to remove harmful elements such As, Cd(II), Cr(IV), Hg, Pb, and Ni. These wastes include grape straw, tea and coffee grounds, nutshells, papaya and plant leaves, waste grains, algae, crab apple shells, rice bowls, and sunflower plants. A type of agricultural waste that is produced in big amounts and requires little to no treatment is used tea or coffee powder. Adsorbents made from agricultural waste can be altered by various chemical pre-treatments to boost the potential of functional groups and hence increase their capacity for adsorption [29]. The production of carbonaceous materials like biochar, which has a greater surface area, pore volume, and pore dispersion, can be efficiently fueled by lignocellulose biomass derived from agricultural waste-based goods [30].

2.3.3 Biochar

Biochar is a carbonaceous porous adsorbent, produced typically as a co-product from waste biomass and can last in the environment for decades [31]. It is a solid created when biomass is pyrolyzed at a temperature below 700 °C with little to no oxygen present [32]. The end product has a high carbon content and has good adsorption properties, enabling it to filter out both organic and inorganic pollutants from wastewater. The growing usage of biochar in many environmental applications shows that it is gaining popularity as an inexpensive, environmentally beneficial substance that is often made from organic wastes like municipal, agricultural, and forestry wastes. Various processes, such as pyrolysis, hydrothermal carbonization, gasification, and torrefaction could turn organic wastes into char [33]. Theoretically, biochar can be prepared from any type of biomass. Different waste materials such as wood, bamboo, coconut husk, straw and sludge have been tested as raw materials for biochar production [34]. Biochar's properties can be controlled by carefully selecting the type of biomass and the production processes. Biochar is produced from biomass under thermochemical processes that include pyrolysis at 300-800°C, gasification, and hydrothermal carbonization. Biochar can be made using slow (700 °C), fast (1000 °C), flash (775

- 1025 °C), hydrocarbonization (350 °C), and gasification processes (700 - 1500 °C) [35]. Since the pore structure of biochar can be preserved during pyrolysis, the biomass (feedstock) will determine the porosity and pore size distribution. The source of the biomass and the circumstances of preparation have a significant impact on the physicochemical characteristics of biochar.

Biochar can be made from a variety of biomass with various physical, chemical, and structural properties. The type of raw materials used and the size of the substrate are two factors that influence the qualities of biochar. The method of pyrolysis (slow, fast, or flash), temperature, heating rate, and pyrolysis length can all have a significant impact on the final biochar's quality [36]. Biochar has an abundance of surface functional groups such hydroxyl, methyl, carbonyl, and carboxyl. Numerous elements, including its high carbon content, aromatic functional groups containing oxygen, and high porosity, may have an impact on its structure. Its surface area, stable molecular structure, and porosity facilitate the adsorption of contaminants on its surface [37]. For the adsorption of pesticides, medications, hormones, and potentially hazardous metals, several scientists investigated the viability of biochar made from animal manure, plant residues, and biosolids [35]. When compared to activated carbons, they demonstrated that biochar exhibited excellent effectiveness for adsorbing contaminants. The electrostatic interaction, ion exchange, pore filling, and precipitation processes can all be used as the basis for the adsorption mechanism of biochar to remove organic and inorganic contaminants. This is dependent on the biochar's physiochemical properties, including dosage, pyrolysis temperature, and effluent pH [38]. Overall, biochar has a number of advantages. It is frequently used as a soil supplement in agriculture. Other benefits of biochar include increase of soil fertility due to improvement of nutrients utilization capacity, carbon sequestration, removal of wastewater pollutants and remediation of contaminated soil or water.

2.3.4 Vegetable and fruit peels

Fruit and vegetable peel waste make up the largest component in the majority of kitchen trash containers. Many fruit and vegetable peels are either fed directly to cattle or are dumped in trash. A serious issue is the production of considerable quantities of vegetable and fruit wastes and byproducts during industrial processing and secondary product manufacturing. Due to their detrimental effects on the environment, they need to be managed or recycled. Fruit and vegetable peels are a renewable and promising resource because they are a natural, cost-effective, and environmentally friendly source of adsorbents that may remove many kinds of water contaminants and minimize pollution [39]. The dynamic functional groups of -OH and -COOH found in cellulose, hemicellulose, and pectin which are related in heavy metal removal (Cd, Pb, As, Cr, Cu, and Ni) are present in fruit shells, such as coconut shells [40]. The ability of fruit shell-based adsorbents to remove Cu(II) from galvanic wastewater was investigated by Feng et al. (2009). The adsorption efficacy in 50 mL wastewater samples containing 14.33 mg/l Cu (II) ions was measured to be up to 97.1%.

2.3.5 Activated Carbon

Activated carbon is a form of carbon that has small, low volume pores with large surface area [41]. It is a type of carbon with broad surfaces and tiny, low volume pores. Chemical and thermal operations carried out at high temperatures can be used to engineer the properties of activated carbon. Its surface can range from 500 to 2000m^2/g. According to Yu and Han [42], activated charcoal may absorb a variety of water contaminants. Typically, coal, coconut shells, lignite, and wood are used in the preparation of activated carbon. Materials that have been carbonized will be heated up throughout the physical preparation process. Carbonized materials can also be prepared chemically by adding chemical reagents. Powder activated carbon (PAC) and Granular activated carbon (GAC) are the two primary types of activated carbon used in the treatment of water. The GAC is the type of activated carbon that is most frequently used to remove impurities. According to Lu et al. [43], activated carbon was first used for commercial purposes in 1900. In 1928, activated carbon was first used in the water supply in the United States. Regularly, one of the two primary activation techniques, such as physical activation or chemical activation, is used to create activated carbon from raw materials such coal, coconut shells, lignite, and wood. In the physical activation process, activated carbons are created from the precursor utilizing gases. Typically, carbonization and activation are applied to the precursor. The precursor is pyrolyzed in the carbonization stage at temperatures between 600 and 900 °C in an inert environment (nitrogen, argon), producing char that is typically non-porous.

The process of activation involves subjecting the material to oxidizing atmospheres (carbon dioxide, oxygen, or steam), typically at temperatures between 600 and 1200 °C. This process eliminates the more disorganized carbon and creates a highly porous structure with a large surface area. The other method for producing activated carbons is chemical activation, which involves impregnation with chemicals such as H_3PO_4, KOH, or NaOH, followed by heating under a gas (typically nitrogen) flow at temperatures ranging from 450 to 900°C. Carbonization and activation processes are thought to occur concurrently in chemical activation. Chemical activation is generally chosen over physical activation due to the lower temperature and shorter time required to activate the material. Because of its ability to adsorb various contaminants such as metal ions, phenols, dyes, pesticides, chlorinated hydrocarbons, humic substances, detergents, organic compounds that create taste and odor, and many other chemicals and organisms, activated carbon is utilized for wastewater treatment [18]. Bamboo, coconut husk, willow peat, wood, coir, lignite, coal, and petroleum pitch are examples of carbonaceous raw materials that are frequently used to make activated carbon. Activated carbon is frequently employed as a filter in the treatment of drinking water as well as in the storage of methane and hydrogen. Other uses for activated carbon include air filtration in gas masks and respirators, compressed air filters, teeth whitening, solvent recovery, decaffeination, gold purification, metal extraction, water purification, medicine, and sewage treatment [44].

2.3.6 Peat

Due to its high porosity and adsorptive ability, peat has attracted attention in the past few decades for use in wastewater cleanup. Moor peat, wood peat, herbaceous peat, and sediment peat are the four categories into which most academics divide peat [45]. It has the advantages of being abundant, affordable, and adaptable. It also has a strong adsorption capacity for a variety of toxins, including PTEs and organic pollutants [46]. Lignin, cellulose, fulvic and humic acids, as well as polar functional groups such alcohols, aldehydes, ketones, carboxylic acids, and phenol hydroxides, are all present in unprocessed peat [47].

2.3.7 Fly ash

Industrial fly ash has a high potential to replace activated carbon or zeolite. Fly ash has an unusual bulk density, particle size, porosity, water holding capacity, and surface area due to its high concentration of silica (60-65%), aluminum oxide (25-30%), and magnetite (6-15%). All of these characteristics make it an ideal tool for use as an adsorbent material [48]. To remove chromium (Cr) and coper (Cu) from industrial effluent, fly ash has been employed. Its removal efficacy is affected by intensity, pH, and temperature. The kinetics of adsorption imply that the process is controlled by diffusion. It has varying concentrations of carbon and minerals [49]. Fly ash and bagasse are used separately and in combination to remove chromium [50]

2.3.8 Ore minerals

Adsorption of organic contaminants was discovered to be a good fit for ore minerals. Bouyarmane et al. [51] investigated the removal of pyridine and phenol from aqueous solution using natural phosphate rock and two synthesized mesoporous hydroxyapatites. Both natural and manufactured apatites demonstrated comparable pyridine sorption capabilities, although phenol loading was proportionate to their specific surface area. This is because of the strong interaction between pyridine and the apatite surface, which prevents further inter-particular diffusion. According to Bouyarmane et al. [51], natural phosphate rock, despite its low specific surface area, can be employed as an efficient sorbent material for diverse contaminants, with higher efficiency and cheaper processing costs than some activated carbons.

2.3.9 Fish scales

A wide variety of natural and synthetic adsorbents have been examined for their ability to remove various types of pollutants from water and wastewater. Bio-adsorbents such as sugar cane baggase, banana pith, water hyacinth root, sawdust, leaf powder, chitin and chitosan and others have been proven to be very effective, inexpensive, and environmentally friendly in the removal of organic and inorganic contaminants from wastewater [52]. Natural materials such as chitosan, zeolites, clay, and industrial waste products such as fly ash, coal, and oxides have also been employed as adsorbents in wastewater treatment [53]. Other interesting materials that can be useful for producing adsorbents are wastes from the fisheries industry, such as fish scales due to their collagen content surrounded by hydroxyapatite and calcium compounds that have adsorptive properties. Various chemical functional groups such as carbonate, phosphate, carboxyl, amide, carbonyl and hydroxyl with binding capability were found in the scales of fish species [54].

The collagen present in fish scales is an insoluble fibrous protein found in connective tissues and in the extracellular matrix and is considered to be a very useful material mainly due to its nontoxicity and well-studied structure [25]. Shu et al. [55] mentioned that fish scales are known with highly ordered type I collagen fibres with various surface functional groups and hydroxyapatite ($Ca_{10}(PO_4)_6(OH)_2$) which results in high affinity to pollutant ions in wastewater treatment. Incentive results on the efficacy of phosphate minerals have been reported for the activity of hydroxyapatite (HAp) as an excellent material for removing long-term pollutants from contaminated water due to its high affinity for heavy metals, low water solubility, high stability and low cost [53]. Even though fish scales exhibit good characteristics to be used as bio-adsorbent in effluent treatment studies, they are usually disposed in landfills due to their insignificant commercial value. Fish scales were widely employed as adsorbent in the removal of heavy metals and dyes from different kinds of effluents whereas, limited studies were reported with the application of fish scales as bio-adsorbent in the treatment of water quality parameters in wastewater samples.

Poblete et al. [25] investigated the COD adsorption potential of activated carbon prepared from fish scales in the treatment of landfill leachate and recorded 37.3% reduction of COD with 1 g/ 500 ml adsorbent dosage at pH 10. Achieng et al. [41] employed fish scale biochar in the removal of anionic indigo carmine dye from aqueous solutions and observed 56.60% removal of dye at pH 2. Preetham and Vengala [56] assessed the adsorption efficiency of fish scales and neem leaves in the treatment of nitrate, nitrite, ammonia and phosphate in synthetic effluent (200 ml). They reported 95 to 99% reduction of all contaminants with an adsorbent dosage of 0.4 g (0.2 g of fish scale and 0.2 g of neem leaves powder), optimum pH of 6 and at 303 K constant temperature.

Subhashree et al. [57] used acid washed fish scale biosorbent in the treatment of seafood processing plant wastewater and recorded >70% removal of nitrite, phosphate, BOD and COD with dosage of 1 g/100 ml at 90 minutes contact time. Sasirekha [58] carried out an investigation for the treatment of dairy wastewater using low cost adsorbents like orange peels and fish scales through carbonization and dehydration methods and reported that the carbonization method is found to be more efficient than the de-hydration method for both, orange and fish scales with high percentage removal of 50.1% and 31.25% respectively. They mentioned that percentage removal of pH, total dissolved solids, total suspended solids, biological oxygen demand, chemical oxygen demand, sulphates and chlorides were higher in case of carbonization method. Khandare and Mukherjee [59] examined the efficiency of fluoride removal in simulated spiked water sample using fish scale biochar.

3. FUTURE PERSPECTIVES

Wastewater treatment via adsorption utilizing bio-resources as low-cost adsorbents is gaining much interest now-a-days since it provide two benefits such as water treatment and waste management. Despite the promising future of low-cost adsorbents, there are some concerns about their success in the near future. The management of the exhausted adsorbent is a critical topic that has not been fully addressed. Furthermore, no information on the topic of managing eliminated contaminants is available. Pollutants should, in our opinion, be recycled or discharged deep into the soil. Pollutants should be collected and stored in steel containers, just like nuclear waste. Some adsorbents cannot function in natural settings. Experimental works using adsorbents need to be conducted to removal pollutants in different concentrations. Several papers covered batch adsorption treatments. However, there are few studies that describe water treatment at the pilot and industrial stages. As a result, the future seeks the design and development of effective columns for large-scale water treatment. Still, there are numerous plant and animal based bio-resources available which are unexplored for their adsorption properties. Therefore, it is a need to properly utilize these bio-resources in order to solve various pollution and waste management issues.

4. CONCLUSION

Water pollution caused by uncontrolled discharge of effluent causes enormous damage. Therefore, proper treatment of wastewater is necessary. The main goal of wastewater treatment is careful disposal of industrial and human effluents without endangering public health or causing unacceptable harm to the environment. Owing to these conditions, adsorption technology gained popularity in effluent treatment studies. Several kinds of bio-resources can be used as adsorbents to treat wastewater loaded with contaminates. Various scientific works have been reported about the adsorption potential of different plant and animal based bio-resources. In this context, the present review highlighted the importance of bio-resources in adsorption technology, its mechanism and its significance in wastewater treatment process. Therefore, this review detailed about the adsorption potential and characteristics of important bio-resources in wastewater treatment along with future scope.

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