Journal of Ecology and Toxicology

Review Article Open Access

Management of Food Wastes in the Global Economy as Potential Biosorbents

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Abstract

The usage of affordable and environmentally friendly adsorbents is becoming more and more necessary in wastewater treatment applications. It has been thoroughly examined and reviewed both conventional adsorbents and biosorbents derived from various natural and agricultural sources. Reviews on biosorption using industrial wastes, especially those from the food and pharmaceutical industries, are lacking. The current review assesses these wastes' potential as biosorbents for the elimination of various hazardous pollutants. While discussing the variables affecting biosorption, sources and uses of various biosorbents are provided. A review of equilibrium, kinetics, and biosorption mechanisms is also provided. Even though these biosorbents are widely used to remediate heavy metals and dyes, additional study is still needed on other types of contaminants. The process's ability to be scaled up and its economic viability should also be studied further. Enhancing the biosorbent's mechanical strength, stability, life span, and repeatability should receive more focus. By providing workable options for pollutant immobilisation or biosorbent regeneration, environmental concerns regarding the disposal of used biosorbents should be addressed.

Food producers, processors, retailers, and customers have all expressed a strong interest in the issue of food waste. Since it immediately affects the profitability of the entire food supply chain, food waste is seen as both an economic problem and a sustainability issue related to food security. Consumers in industrialised nations are one of the biggest causes of food waste and are ultimately responsible for all wastes generated along the entire food supply chain. Understanding all of the many food waste sources present throughout the food supply chain is crucial for ensuring food security and reducing food waste. The current review analyses several publications that are currently available in the literature, quantifies waste levels, and looks at trends in food waste for a variety of food sectors, including grains, fisheries, meat and poultry, grains, fruits and vegetables, and fish. Large-scale food waste processing is hampered by a number of factors, including those that contribute to food waste, efficient, cost-benefit methods of utilising food waste, sustainability and environmental concerns, and public acceptance. So, in order for government regulators and stakeholders in the food supply chain to actively establish effective waste utilisation policies, we stress the need for additional research to identify and report food waste.

Keywords: Environmental; Biosorbents; Wastewater treatment

Introduction

Water contamination and the resulting scarcity of fresh and clean water resources for both the present and future generations are two of the most difficult environmental issues caused by increased industrial activity. Heavy metals, organics, and dyes are just a few of the toxic substances found in industrial effluent that could be harmful to aquatic life and humans. The World Health Organization (WHO) suggested upper limits for these chemicals in water streams. Due to their complex aromatic structure, which makes them difficult to degrade biologically, dyes are one of the most polluting categories [1]. They are manufactured in vast quantities across a variety of businesses, including those that generate food, cosmetics, pharmaceuticals, paper, textiles, and leather. Recently, it was revealed that global dye production had surpassed 700,000 tonnes annually. Anionic, cationic, acid and reactive, and nonionic dyes are the different categories for dyes. The health of humans could be harmed by phenols and other phenolic chemicals, which are extremely poisonous [2]. If present in drinking water, phenols can have a noticeable odour and flavour even at extremely low concentrations. The primary producers of phenols include numerous businesses, including those that deal with iron and steel, petroleum, paint, paper and pulp, and pharmaceuticals. The most dangerous phenolic chemicals are thought to be nitrophenols and chlorophenols. Another risky class of contaminants are heavy metals. Examples of the most harmful and carcinogenic substances that may be present in industrial effluents are lead, mercury, cadmium, chromium, copper, and arsenic. Because metal ions are nonbiodegradable, they build up and their concentrations rise along the food chain [3]. The metal plating and finishing, automotive, semiconductor, textile, and steel industries are the primary industrial sources of the majority of these metals.

Physical, chemical, or biological methods can be used to remove these contaminants from various industrial effluents. A few physical processes are membrane filtration, adsorption, chelation ion exchange, and coagulation. Biochemical processes include aerobic, anaerobic, or enzymatic processes, whereas chemical processes include oxidation, advanced oxidation, and electrochemical treatment [4]. The main drawbacks of these procedures, also referred to as traditional treatment methods, are their high energy needs, high capital costs, and poor efficiency. There have been numerous reviews of conventional treatment approaches elsewhere. Numerous strategies have recently been put forth by different researchers for the creation of novel and affordable adsorbents [5].

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Received: 05-Sep-2022, Manuscript No: jety-22-73750, **Editor assigned:** 07-Sep-2022, PreQC No: jety-22-73750 (PQ), **Reviewed:** 21-Sep-2022, QC No: jety-22-73750, **Revised:** 23-Sep-2022, Manuscript No: jety-22-73750 (R), **Published:** 30-Sep-2022, DOI: 10.4172/jety.1000135

Citation: Jhangir K (2022) Management of Food Wastes in the Global Economy as Potential Biosorbents. J Ecol Toxicol, 6: 135.

For various reasons, biosorption has emerged as an appealing standard approach. It was a successful replacement for the traditional ones since it was inexpensive, extremely effective, and simple to apply. Humans require food to survive, and food waste has been identified as one of the biggest problems the world is now experiencing. One in nine people worldwide go to bed hungry every night, and currently, 21,000 people die every day from reasons related to hunger. However, around one-third of all food produced today is thrown in the trash. In addition to being a major economic and environmental issue, the enormous amount of food that is wasted has humanitarian implications as well [6]. Due to the limited availability of natural resources, it is imperative to find environmentally friendly, economically viable solutions that will increase food production, enhance distribution systems, and encourage efficient methods of managing the food supply chain. Food waste must be drastically decreased in order to ease the burden of the rising need for food production. The total effectiveness of the food supply chain can be greatly increased by reducing food waste, which is an important element. According to experts in the field, if we want to feed the estimated 12.3 billion people in 2100, we must focus on sustainable food production, smart management, and appropriate food distribution . Therefore, minimising food waste becomes a top concern since, in the absence of action, waste will continue to be produced across the food supply chain. As long as they can afford to, businesses in the food supply chain and the general public will continue to throw away food. Since it can be difficult to discriminate between edible and inedible food components, defining food waste can be challenging. A dish that is deemed edible in one area of the world may be deemed inedible im another. There will always be unavoidable non-edible components like citrus fruit zest, fruit stones, bones, and eggshells because not every component of an agricultural or livestock product is totally edible. In many instances, the line between edible and nonedible is hazy and depends on dietary preferences, regional eating customs, and geographic location. Food that is not consumed by the end user, including the inedible portions of the food, is referred to in the study as "food waste." A significant environmental issue is the disposal of various industrial wastes and byproducts [7]. The most difficult issue facing industry might occasionally be attributed to the costs of waste treatment, removal, and accumulation. Due to the enormous amount of waste and byproducts produced by the food industry, this problem is particularly prevalent. A dual-purpose solution from an environmental standpoint is introduced by using industrial wastes as affordable, efficient biosorbents. In other words, using these free waste materials to cleanse wastewater effluents gives these wastes value and aids in resolving a significant environmental problem.

Application of Biosorbents

Agricultural waste, industrial solid wastes, and biomass make up the broad subclass of low-cost adsorbents known as biosorbents. Many scientists have found that dead biomass works well as a biosorbent to remove various contaminants. It has gained popularity because it can be used in the presence of harmful compounds or when nutrients are scarce without significantly affecting how well it can bind to those substances. It has been used to clean wastewater and purify water by using these wastes as biosorbents. The table lists the biosorbent's kind and industrial source, the feed solution's composition, the type of sorbate that was the target of the process, and the operating conditions that led to the greatest amount of removal. These variables include pH, temperature, adsorbent dosage, and the amount of contact time necessary to achieve equilibrium. Additionally, compared to living biomass, dead biomass is more easily desorbed. Living biomass such as fungi, algae, and other microbial cultures with various strains have also been employed as inexpensive biosorbents. Many researchers from all around the world have been interested in agricultural-based biosorbents, which comprise a sizable category of wastes. Such wastes had to be accessible locally in order to be used. In spite of their massive yearly global production, research on industrial food processing and pharmaceutical wastes is lacking. Therefore, our current work's primary driving force was the dearth of pertinent reviews. In the next years, it's anticipated that biosorbents of these origins would increase by about 5% annually. For instance, over 2.5 108 tonnes of food processing waste are reportedly produced in Europe each year. A volumetric estimate indicates that 20–60% of processed fruits and vegetables are wasted. Approximately 44.3 billion pounds of food waste were reported in 2011 in the food manufacturing sector in the United States.

Operating Factor

Solution pH and Ionic Strength

The charge on the functional groups of the biosorbents and their dissociation on the active sites are both influenced by the pH of the sorbate solution, which is crucial to the biosorption process. It also has an impact on the sorbate's degree of ionisation and solubility. Numerous researchers have looked into how pH affects absorption capacity and removal percentage. It was discovered that the absorption capability of heavy metals as Cd, Pb, Ni, Cu, and Zn rises with increasing pH in both the acidic and neutral range (pH 2–7). Because of the attraction forces between the positively charged dye and the negatively charged functional groups on the biosorbent, cationic dyes are more readily absorbed and removed at high pH levels. One investigation on the removal of phenols by olive pomace demonstrated that raising pH improves the effectiveness of the removal process. The addition of NaCl and perchlorate salts dramatically reduced biosorption because of competition between the salt ions and the sorbate ions on the active sites, according to the few studies that have been done on the impact of ionic strength.

Initial Sorbate Concentration

A driving force for overcoming the mass transfer resistance and subsequently increasing the absorption is the rise in the initial concentration of the sorbate. Both dyes and heavy metals have been implicated in this behaviour. One investigation involving Hg sorption onto desiccated coconut trash found a linear association between concentration and absorption. The percentage clearance, however, was shown to decrease with increasing concentration for the heavy metals Cd, Zn, and Ni onto tea, olive cake wastes, and wine processing sludge, as well as for Cr and Basic Blue dye onto Aspergillus awamori mycelium and antibiotic fungal waste, respectively. Both fresh malted sorghum mash waste and mango seed kernel powder displayed the same response when Methylene Blue dye was added.

Temperature

The impact of temperature is significant when dealing with wastewater effluents that are released at high temperatures as a result of processing. Due to an increase in surface activity and consequently the availability of more active sites, biosorption's absorption capacity and removal efficiency increased with temperature for endothermic processes.

Current Waste Utilization and Terrestrial Food Waste in the Food Supply Chain

Crop waste starts on the farm and spreads all the way up the food chain. Each of the six steps in the food chain, from farm to fork, results in the production of food waste. Even during the agricultural or harvest stage, food waste can be extremely large in affluent nations. Produce sizing and aesthetic standards, produce quality laws, production surpluses, and economic variables, among others, can all contribute to food waste. For instance, an estimated 17.7 million tonnes of agricultural produce from Italy was left in the ground in 2009, which is equivalent to about 3.25% of all produce production. Surprisingly, some studies have suggested that the waste generated by the agro-food industry may account for up to 40% of the entire production value. the entire food supply chain (only examined particular phases and waste kinds), and were carried out by various academics around the world using various evaluation techniques. For instance, several studies on fruit and vegetable waste omit to account for grains and waste from roots and tubers. Others have attempted to reduce and streamline data collection by accounting for wastes produced by grains and roots/ tubers. Many consumer and retail waste assessments contain very little information about farm practices, processing waste, and wastes resulting from storage and transportation. Despite their significance, consumers and retailers cannot be viewed as the sole parties in the food supply chain who cause waste. Processing fruit, vegetable, and grain wastes is possible using a number of recycling and utilisation techniques. Utilizing food waste aims to minimise the amount of waste sent to landfills and maximise practical advantages. Although there is a lot of material regarding different waste recycling procedures for handling agricultural waste, there isn't much research evaluating the financial advantages of the various waste utilisation techniques. Now, there are very few publications available that cover the commercial use of agricultural waste and how to get beyond the obstacles that currently stand in the way of successful food waste management strategies. It has also been tried to create biogas from leftover fruit and vegetable waste. But the production of commercially viable biogas on a broad scale is still in its early stages. Agrowastes have yet to be transformed using this kind of processing plant; currently, city wastes are recycled through anaerobic digesters to produce biogas. The key drivers behind this are (2) establishing efficient means of transportation between waste sources and facilities, as well as (1) supplying the facility with a steady flow of agricultural wastes. In order to effectively deliver a steady flow of biogas, the facility needs a constant supply of feedstock.

Dairy Waste in the Food Supply Chain

Due to the dairy industry's global significance, its effects on the environment have been thoroughly investigated. Raw milk is the key product that the dairy sector produces. Consumer milk, butter, cheese, yoghurt, condensed milk, dried milk, and ice cream are among the goods made from raw milk that are processed. Despite substantial research, a thorough grasp of the levels of waste created across the whole dairy business is still lacking. In the life cycle of milk and dairy products, the agricultural stage is frequently cited as the major source of wastes. However, studies in the UK and Spain have determined that poor product quality during the summer, poor forecasts, incorrect packaging, and breakages at the point of use are the primary reasons of milk waste. In order to reduce milk wastes, procedures including evaporation, centrifugation, ultrafiltration, reverse osmosis, and bioconversion are used to collect fat, protein, and carbohydrates from the wastewater created during the processing of milk. The quantity of milk and dairy wastes released into the environment can be greatly reduced by these recapture procedures. In addition to improving financial returns, waste reduction can have a big impact on how effectively products are processed. For instance, cheese is a food product that is made from milk and is consumed all over the world both as a standalone food item and as a component of many other food products. Acidified milk is combined with an enzyme to create solid cheese, or casein, during the cheese-making process, and the liquid that remains is referred to as whey.

The Food Supply Chain's Use of Aquatic Food Waste and the Level of Waste Utilization

Fish Waste in the Food Supply Chain

Even now, fish is one of the most traded commodities on international markets. Fish has traditionally been an imported food source. Worldwide employment in aquaculture and the broader fishing industry was estimated at 54.8 million persons in 2010. At the moment, fish makes up 6.5% of all proteins ingested by people globally and approximately 16.6% of all animal protein. Carbohydrates, cholesterol, and reduced saturated fat content are all highly considered benefits of fish. A variety of vital micronutrients, including polyunsaturated omega-3 fatty acids, vitamins, and minerals are all found in fish, in addition to high-quality protein. Fish and other seafood are in high demand, and global yearly consumption is rising as a result of the nutritional and health benefits they provide. Fish waste of all kinds and volumes is created at every stage of the food supply chain, from fishing to eating. Each year, fisheries and aquaculture in the world create over 130 million tonnes of fish waste. Wastes are created as a result of bycatch, on-board processing, transit, storage, retailers, and consumers. By-catch or accidental catching of marine species during wild fishing is the first step in the formation of fish waste. By-catch garbage has been thoroughly researched, yet despite corporate and environmental regulations, there is currently no efficient solution. Globally, commercial fishing activities are thought to trash 17.9 to 39.5 million tonnes of entire fish annually.

Wastes Made of Aquatic Plants in the Food Supply Chain

Food wastes from aquatic plants are frequently ignored by the field. Aquatic plant meals like algae have been consumed for thousands of years by both humans and animals. Early Greek literature from the Bellum africanum, composed around 45 B.C., mention the Greeks gathering seaweed from nearby shorelines and feeding it to their cattle. Many aquatic plants are extremely strong in protein and are a highly nutritious diet that can provide numerous benefits as a food supplement in addition to having potent therapeutic capabilities. Algae and microalgae have been mentioned as potentially abundant sources of natural antioxidants in the hunt for sources. Due to its positive health properties, both algae and microalgae are well known and consumed in many nations.

Discussion

The use of food wastes on an industrial scale at the local, national, and worldwide levels is little mentioned in the literature. Fruit and vegetable wastes, for instance, have been the subject of in-depth research and reporting in the literature. However, the production of food wastes and its use in the aquaculture, livestock, poultry, and dairy industries are rarely recorded and require more study. Most of the data on food waste that is now available is incomplete, and there is even less data on waste utilisation in the various food supply chains. Before any economic modelling can be done to assess the viability of new goods and waste-transforming infrastructure required to generate a commercially viable business outcome, these information is required. The desorption procedures are used to recover sorbate material or regenerate the biosorbent for reuse. Addition of acids, bases, inorganic salts, or solvents for metal recovery can be used to perform desorption. In this stage, which often comes after the adsorption step, the efficiency of the reagent employed in desorption is evaluated by measuring the metal recovery rate or metal uptake. The bulk of the trials that were reported used HCl as their primary eluent. The most encouraging results revealed that after ten cycles of adsorption and desorption, olive mill waste maintained its adsorptive capacity for Cd (II) and Pb (II). After HCl elution, Na2HCO3 was used to neutralise the solution. According to other researchers, modified orange peel that had been exhausted was able to adsorb Pb (II) up to 91.5% after the fourth cycle.

Finding out what kind and how much garbage there is is the first step in creating a successful waste management strategy. It is now possible to start creating an efficient waste management plan if waste levels and their location in the food supply chain are recognised. Before successfully utilising garbage, a good plan must take into account a number of crucial variables. In the end, the key challenge in creating a waste management strategy that creates a new product from food waste is to consider a number of strategic variables, such as potential new markets, market trends, existing market developments, and creating a product that is competitive in the market. Additionally, each stage of product development needs to be properly taken into account. When it comes to manufacturing, a company must take into account commercial potential based on a carefully considered growth strategy, especially if innovation is a crucial component of the product. The product line and related services will also need to be carefully studied for packaging and distribution with a view to deterring competitor duplication and providing protections to maintain market share. From a governmental standpoint, measures that support sustainable consumption patterns and sustainable communal lifestyles, encourage new employment development initiatives, and boost the economy may need to be developed. Consumers' selection processes are heavily influenced by the diversity, variety, and anticipation of high-quality produce. The "hidden costs" of food waste management are frequently referred to as undervaluing and underreporting. Since businesses won't become aware of the issue until it affects their bottom line, investigating these "hidden costs" typically acts as a catalyst for establishing the scope of the waste problem. Generally speaking, companies in the food industry manage their waste by maintaining high levels of profitability. They typically accomplish this goal by lowering their energy use, using less raw materials, and enhancing recycling practises. Businesses will also research the advantages of managing trash in terms of recovery and value addition vs the expense of disposal.

Conclusion

Waste products from commercial food and drug manufacturing facilities are promising biosorbents for the treatment of wastewater effluents. They are able to interact with metal ions and colour pollutants by physical and/or chemical sorption because they contain functional groups like hydroxyl, carboxyl, and amine. In the majority of earlier research, the Langmuir isotherm, which predicts single-site binding, best described the sorption equilibrium. The majority of sorption kinetics were quick and mostly matched the pseudo-second order model, which indicated a chemisorption mechanism. The model took into account surface response, film diffusion, and pore diffusion mechanisms. The sorbent's chemical and physical characteristics, as well as its diverse working circumstances, all have an impact on biosorption. The impact of these characteristics in batch systems was extensively researched by several researchers. The use of continuous column systems was only briefly studied, though. The latter is crucial for scaled-up applications. The majority of researchers also used artificial aqueous solutions rather than actual wastewater effluents, where ion competition and interference could have a considerable impact on biosorption efficiency. The stability of the sorbent on a physical, mechanical, and chemical level is a factor that was disregarded. The repeatability of the biosorbent is greatly influenced by the mechanical strength of the biosorbent as well as its resistance to chemicals and microbial degradation, especially in continuous operations where the biosorbent is repeatedly recycled and reused. When deciding whether to pursue a food waste utilisation strategy that aims to produce value-added products, the consumer is the most crucial element that needs to be properly taken into account. Experience has proven that despite being able to see the advantages of new items, consumers are frequently hesitant to adopt them. Numerous studies have demonstrated that consumers do not skimp on product performance or quality. Because of this, it's crucial to properly comprehend consumer behaviour or habits when creating and promoting any new product. Consumer inquiries frequently centre on whether environmental regulations were followed throughout the manufacturing of items, as indicated by surveys that consistently reveal consumers to be particularly concerned about the environment and if new products are ecofriendly.

Acknowledgement

The author would like to acknowledge his Department of Molecular Biology, National Research Centre, Institute of Health Biosciences, Japan for their support during this work.

Conflict of Interest

The author has no known conflict of interest associated with this paper.

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