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Onion (*Allium Cepa*) Processing Waste as a Sorption Material for Removing Pollutants from Aqueous Media

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Abstract: The paper summarizes the literature data on the use of onion (*Allium cepa*) processing waste as sorption materials to remove various pollutants (metal ions, dyes, antibiotics) from aqueous media. It provides brief literature data on the structure, volume of cultivation, and chemical composition of some components of onion biomass. It was found that onions contain many amino acids, vitamins, polyphenolic compounds, and other biologically active compounds that have various functional groups in their composition. This contributes to the removal of various metal ions (Ca^{2+}, Cd^{2+}, $Cr^{(VI)}$, Cu^{2+}, Hg^{2+}, Mg^{2+}, Ni^{2+}, Pb^{2+}, Zn^{2+}) from aqueous media with native and modified onion processing waste (onion skin). The work shows the possibility of increasing the sorption characteristics of pollutants by treating the *Allium cepa* biomass with various chemical reagents. It was found that the pollutant adsorption isotherms on onion skin are most often more accurately described by the Langmuir and Freundlich models, less often by other models. The kinetics of the process predominantly corresponds to the pseudo-second-order model. It was shown that the use of onion skin extracts modified with various chemical compounds is promising for removing heavy metal ions. The work also shows the possibility of using onion skin modified by plasma and microwave radiation to remove the Methylene blue dye from simulated solutions.

Keywords: onion skin; metal ions; dyes; antibiotics; adsorption; models of adsorption isotherms; thermodynamic parameters.

1. Introduction

The pollution of the World Ocean with various pollutants is currently becoming catastrophic. The source of chemical compounds entering open water sources is untreated wastewater and stormwater. There are many methods to remove and dispose of pollutants from aquatic environments, including physicochemical, chemical, and biological treatment methods.

One effective way to extract pollutants from water media is the sorption method based on the absorption of chemicals by a solid surface due to physical or chemical interaction. Activated carbons currently used in industrial production are unprofitable due to the high cost and the need for regeneration.

The world community is currently developing a new innovative environmental protection area – the use of industrial and agricultural waste as reagents for removing pollutants from water environments. Of particular interest are cellulose-containing agricultural wastes studied as effective sorption materials to remove metal ions, oil and petrochemical products, dyes, pesticides, and other organic substances from aqueous media [1-20].

The scope of research is so large that recently subject reviews are regularly published on using a particular crop processing waste. Thus, in particular, information on the use of buckwheat waste [9], wheat waste [21], banana peel [22], tea waste [23-25], coffee waste [26], fruit peels [27], and waste [28] and others as sorption materials is summarized. The world literature provides information about using onion by-products as sorption materials for various pollutants, but this information is sketchy. In this regard, this review summarizes information about using these wastes as pollutant sorption materials from aqueous media.

1.1. Brief information about the composition and ways of onion waste re-use.

Almond (*Prunus dulcis*) is a shrub or small tree, subgenus Almond (*Amygdalus*), genus Prunus. The shrub (less commonly a small tree) is 4-6m high, very branchy. There are two types of shoots: elongated vegetative and short generative. The leaves are petiolate, lanceolate, with a long-pointed tip.

Onion (*Allium cépa*) is a perennial herb, an Onion (Allium) species of the Onion (*Alliaceae*) family. Onions are one of the most important vegetable crops. The bulb is up to 15 cm in diameter, tunicated. The outer scales are dry, yellow, less often purple or white; the inner scales are fleshy, white, greenish, or purple, located on a shortened scape known as bottom. On the bottom, in the axils of juicy scales, there are buds that give rise to daughter bulbs that form a "nest" of several bulbs. The leaves are hollow, bluish-green. The flowering stem is up to 1.5m tall, hollow, swollen, ending in a multi-flowered umbellate inflorescence. The flowers are set on long pedicels. The perianth is greenish-white, up to 1cm in diameter, consisting of six leaflets, six stamens; the pistil has an upper three-celled ovary. The fruit is a capsule containing up to six seeds. The seeds are black, triangular, wrinkled, small. The plant blooms in June or July. The fruits ripen in August [29]. The volume of global onion production is more than 66 million tons per year [30].

Bulbs and leaves are used as a seasoning in the canning industry for salads, mushrooms, vegetable, and meat dishes, as well as as a spicy and vitamin appetizer and a flavoring additive to soups, sauces, gravies, minced meat. Most often, onions are eaten raw, fried in lard or vegetable oil until golden brown. Raw onions are added to sausage and meat products, farmer cheese, cheeses, bread with lard [29]. Onion processing waste is skins and trash. The need for recycled onions has increased in recent years, resulting in an increase in waste production (over 500,000 tons per year) [31]. The amount of solid onion waste (OSW) is really abundant and constitutes an environmental problem due to its pungent odor and the proliferated growth of phytopathogens.

The composition of the bulb and skin of the onion is given in [32]. It is indicated that, depending on the growth region, the bulb's moisture content is 88.6-92.8%, the protein content is 0.9-1.6%, acids content is up to 0.2%, carbohydrates content is 5.2-9.0%, ash content is 0.6%. The amino acid content in the onion bulb is shown in Table 1.

Apart from amino acids, the following vitamins were identified in the bulb [32]: thiamine-3 mg / kg, riboflavine-0.5 mg/kg, nicotinic acid-2 mg/kg, C-100 mg/kg, folic acid-160 mg/kg, biotin-9 mg/kg, and panthotenic acid-1.4 mg/kg.

It is indicated that the carbohydrate content is from 12 to 22 g/100 g of dry bulb weight. In addition, anthocyanins, such as cyanidin-3-glucoside and cyanidin-3-diglucoside, peonidin-

3-glucoside, were found in bulb composition. Such flavonols as quercetin, kaempferol, kaempferol-4-glucoside etc. have also been found [33]. A number of phenolic compounds (protocatechuic acid, phloroglucinol, pyrocatechol, etc.) and sterols and saponins have been identified in the bulb [32].

Table 1. Amino acids content in onion bulb [32].

Amino Acid	Content, mg/100g
Lysine	4.2-18.8
Leucine	1.9-15.9
Isoleucine	1.9-13.1
Methionine	< 1.1
Phenylalanine	2.4-10.6
Tyrosine	2.6-6.5
Tryptophan	0.8-3.6
Valine	1.7-7.6
Arginine	18-68
Histidine	1.1-8.1
Alanine	1.9-3.8
Aspartic acid	18.6-24.9
Glycine	1.1-2.2
Proline	< 0.8

Considering the fact that dry onion skin has a humidity of 9.0-12.4 %, the content of biologically active substances in it is higher than that in the bulb. Studies have shown that onion skin can be used as an additive in bread [34], as piezoelectric elements [35]. Various ways of onion skin re-use have been proposed [36], including as a source for extracting fiber [37, 38], food ingredients [39], and tannic acids [40]. The possibility of obtaining such valuable compounds as flavonoids (quercetin, quercetin-3, 4'-O-diglucoside, quercetin-4'-O-monoglucoside, kaempferol, myricetin, and others) from onion skin was investigated [41-47]. Results indicate that solid onion waste and flavonol glycosides are potential antioxidants, antidiabetic, anticancer, and sedative agents [41]. The possibility was shown to use antioxidant compounds isolated from onion skins in functional bread production [48]. Isolation of flavonol quercetin and fructooligosaccharides from onion skin has been proposed [49, 50].

Onion processing waste can also be used to produce D-tagatose and bioethanol [51], bisphenols [52], bisindolylmethanes [53], acetic acid [54], etc.

1.2. Using onion waste as sorption materials to remove metal ions and dyes from aqueous media.

As mentioned above, onion processing waste includes many biologically active compounds with various functional groupings in their composition. This contributes to using onion skin as sorption materials to remove metal ions and dyes from aqueous media.

Metal ions. The biosorption potential of chemically modified onion skin (CMOS) for Cd^{2+} from its aqueous solutions at different conditions of initial ions concentration, contact time, pH, and temperature was investigated under batch mode. For this purpose, 100 g of powdered onion skin were treated with 1000 ml of 1 M phosphoric acid and 2 sm3 of 35% formaldehyde solution for 24 h and then kept in a water bath (70 °C) for 30 min. For CMOS, a maximum biosorption capacity (Qmax) of 18.34 mg/g was obtained compared to 11.90 mg/g for untreated onion skin. “The equilibrium biosorption data were analyzed by two-parameter (Langmuir, Freundlich, Temkin, and Dubinin-Radushkevich (D-R)), three-parameter (Redlich-

Peterson, Sips, Toth, and Khan), and four-parameter (Baudu and Fritz-Schluender) isotherm models using linear and nonlinear regression methods. It was found that the most suitable isotherms for describing the biosorption data of the CMOS-system of Cd2 + ions are Freundlich, Sips, and Fritz-Schluender isotherms for two-, three- and four-parameter models, respectively [55]. The order of ranking is determined as follows: Fritz-Schluender > Freundlich >Temkin > Langmuir > Sips > DR > Khan > Redlich–Peterson > Baudu > Toth.

The thermodynamic parameters of activation energy (Ea = 33.10 kJ/mol), Gibbs free energy (ΔGo = -5.48, -6.70 and -7.92 kJ/mol at 303, 313 and 323 K, respectively), enthalpy (ΔHo = 31.49 kJ/mol), and entropy change of biosorption (ΔSo = 0.122 kJ/mol·K), by CMOS were evaluated and looked for that the biosorption process is feasible, spontaneous, endothermic and predominantly physical sorption process, although with some chemosorption element. The biosorption kinetics followed a pseudo-second-order kinetic model, and the biosorption mechanisms were controlled by boundary layer surface diffusion [56, 57].

The adsorption characteristics of Pb^{2+} ions on pre-boiled treated onion skins (PTOS) and formaldehyde-treated onion skins (FTOS) were evaluated. The effects of Pb^{2+} ions' initial concentration, agitation rate, solution pH, and temperature on Pb^{2+} ions adsorption were investigated in batch systems. Pb^{2+} ions adsorption was found to increase with a rise in initial concentration. The point of zero net charges (PZC) was 6.53. The adsorption equilibrium data were best represented by the Langmuir isotherm model for FTOS and the Freundlich isotherm model for PTOS. As evaluated by the Langmuir isotherm, the maximum amount of Pb2+ ions adsorbed was 200 mg/g for FTOS. The efficiencies of PTOS and FTOS for Pb^{2+} ions removal were 84.8% and 93.5% at 0.75 g/dm3 adsorbent dose, respectively, (C0 = 50 mg/dm3). It was found that the adsorption kinetics of Pb^{2+} ions obeyed the pseudo-first-order kinetic model. The activation energy (Ea) was obtained as 25.596 kJ/mol [58].

In addition to metal cations, onion skin dust (OSD) has been studied to remove nitrate ions from simulated solutions. The experiment was confined to the effect of initial nitrate ion concentration, pH, adsorbent dose, contact time, and temperature on the nitrate removal. The optimum pH for the maximum removal of nitrate-ions was pH = 12.0. Contact time of 10 min was selected as optimum contact time and used for all the other experiments. The maximum adsorption capacity of OSD was found to be 5.93 mg/g. The adsorption equilibrium data nicely fitted with Langmuir isotherm with a very high goodness of fit (R2 = 0.908). The values of thermodynamic parameters ΔH°, ΔG° and ΔS° indicated that the nature of nitrate adsorption is dominated through endothermic, spontaneous, and feasible [59].

Experiments were conducted on the comparative adsorption of two or more onion skin metal ions. Thus, there was a study of Cd^{2+} and Pb^{2+} ions removal by onion skin modified with various reagents. In particular, an alumina-modified onion skin composite was synthesized, characterized, and used as an adsorbent to remove Pb^{2+} and Cd^{2+} ions from aqueous solutions via the adsorption process. The results obtained showed that at the optimum conditions of 200 mg/dm3 initial metal ions concentration, 1.20 g/dm3 adsorbent dosage, and 75 min contact time, the maximum removal percentages of 92.05% and 94.89% for Pb^{2+} and Cd^{2+} ions, appropriately, were obtained. Langmuir isotherm produced the best fit with values of monolayer uptake capacities as 9.74 mg/g and 14.17 mg/g for Pb^{2+} and Cd^{2+} ions, properly, and the pseudo-second-order kinetic model produced the best fit with the adsorption [60].

The sorption efficiency and mechanism of onion skin in both raw and modified form at the removal of Cd^{2+}, Cu^{2+} and Pb^{2+} ions in an aqueous medium were investigated. The modification of the study material was done by anchoring ethylene-1,2-diamine. Experimental results confirmed that the metals' best sorption pH range ranged between pH = 4.0-6.0. It was also realized that the sorbent material could remove 90 % of the metals within the first 20 min of contact. Found out that the three metal ions fitted best in the Langmuir model. The sorption capacities for Pb^{2+}, Cd^{2+}, and Cu^{2+} ions were found to be 71.85, 68.03, and 79.36 mg/g in the modified onion skin, respectively, and 87.49, 96.99, and 90.8 mg/g in the same order for the unmodified form. The resulting material was then applied to environmental water samples of varying concentrations (C0 = 2-10 mg/dm3). The maximum percent recoveries were determined as 87.8%, 80.6% and 77.1% for Pb^{2+}, Cd^{2+} and Cu^{2+} ions, respectively [61].

Onion skin is greatly effective for binding heavy metal ions from aqueous solutions. Color leaching can be prevented, and the physical characteristics of the substrate can be ameliorated by treatment with formaldehyde in an acidic medium. Batch and column experiments have been led with Cu^{2+}, Cd^{2+}, Zn^{2+}, Ni^{2+}, Hg^{2+}, and Pb^{2+}. Almost quantitative removal of the metal ions from the solution can be achieved by using the treated onion skin columns. The competition of the different metal ions for the substrate has been examined. The capacity of the substrate in the majority of the metal ions investigated is well above 1mg/g. Thus, it was found that the sorption capacity for Cu^{2+} ions is 3.76mg/g at the initial ion concentration in the solution of 100ppm. For Pb^{2+} ions, this indicator was 10.9mg/g (Co = 110ppm), for Zn2+ ions - 9.42mg/g (Co = 100ppm), Cd^{2+} - 7.9mg/g (Co = 80ppm), Hg^{2+} - 79.85mg/g (Co = 800ppm), Ni2+ - 7.55mg/g (Co = 100ppm) [62].

The use of modified onion skins for binding Ca^{2+} and Mg^{2+} from solutions has been investigated. The effect of time of equilibration, temperature, and pH on the sorption of the metal ions has been studied. Batch and column experiments have been performed, and the adsorption isotherms have been plotted. The capacities with respect to Ca^{2+} and Mg^{2+} ions were found to be 4 and 16 mg/g, respectively, of the substrate when separate column experiments were conducted using 1 dm^3 of a solution containing 1000 mg/dm3 of the respective metal ions at pH = 6. With a solution containing 10 mg/dm3 each of Ca^{2+} and Mg^{2+} ions together, however, the substrate seems to exhibit a greater preference for Ca^{2+} than Mg^{2+} ions. The sorbed metal ions from the substrate can be leached into a solution with a 0.1 N solution of HCl, and the washed bed can be re-used [63].

The usage of polymerized onion skin to remove heavy metal ions from domestic and industrial wastewater to safe levels has been recommended as an inexpensive and productive alternative for commercial ion-exchange resins [62]. In view of the complex organic nature of the onion skin and its considerable capacity to bind Ca^{2+} and Mg^{2+} ions, the possibility of its use for preventing scale formation in boilers is indicated [63].

The preparation and properties of polymerized corn cob powder and its composite (with sawdust and onion skin) ion exchange resins for binding heavy ions have been described. Static (equilibrium) and dynamic (non-equilibrium) tests were carried out with solutions of Pb^{2+}, Ni^{2+}, Cu^{2+}, Mg^{2+}, Zn^{2+} and Ca^{2+} ions. Results showed that the concentrations of these metal ions were greatly reduced and the exchange capacity of the cation resin for the metal ions studied was of the order of 1 mg/g. Therefore, the ion-exchange resin is an effective potential substitute for the expensive commercial resins used to treat metal-contaminated wastewater [64].

Also, the extract of onion skin was modified with various acids. The pulverized onion skin was subjected to extraction with acetone in a soxhlet extractor, and the extract was recovered from the extract-solvent mixture by evaporation. The extract was then treated with acids and studied as a sorption material to remove various metals from aqueous media.

Red onion skin extract was chemically modified using thioglycolic acid to develop a suitable, low-cost, and efficient adsorbent to remove Cd^{2+} ions from aqueous solutions. Influences of temperature, contact time, initial concentration of ions, adsorbent dosage, and pH on the removal of Cd^{2+} ions were probed. Optimal adsorption conditions were found at pH = 5 and pH = 4, and 60- and 30-min equilibrium times for the modified and native onion skins. The equilibrium process was well described by the Freundlich isotherm model (R2 = 0.999). The maximum Cd^{2+} ions adsorption capacities from the Langmuir model are 21.28 mg/g (native) and 17.86 mg/g (modified). The adsorption process succeeded the mechanism physisorption. The pseudo-second-order rate equation fitted the kinetic data better than the pseudo-first-order rate equation for the two adsorbents. Thermodynamic parameters, such as ΔG°, ΔH°, and ΔS°, were calculated for adsorption experimental studies. The results showed that the adsorption of Cd^{2+} ions on native/unmodified and modified onion skins was exothermic under the studied conditions [65].

There was a study of adsorption of Cr^{6+} ions by red onion skin extract resin waste modified with citric [58] and maleic [59] acids. The removal process was examined base on the effect of temperature (302 to 343 K), initial ion concentration (2 to 100 mg/dm^3), and agitation time (10 to 60 min). Data analysis from agitation time experiments demonstrated that equilibrium adsorption was achieved within 30 min. Maximum percentage adsorption was marked at 313 K. The regression analysis of the models at different temperatures and concentrations was found to fit the experimental data in the order closely: Freundlich > Langmuir > Temkin. Investigation of the thermodynamic of adsorption reaction revealed values for change in enthalpy, Gibbs free energy, and entropy, reflecting the process spontaneity, exothermic nature, and feasible affinity of the interacting metal ions at the adsorption sites. Dubinin-Radushkevich isotherm was applied in studying the isotherm pathway, and it was observed that physisorption is the dominant pathway. Kinetic study showed that pseudo-second-order best describes the experimental data regarding

The removal of Pb^{2+} ions from synthetic wastewater by red onion skin extract modified with succinic acid was studied as a function of experimental parameters: contact time, pH, and initial metal ion concentration. Maximum metal removal was observed at pH = 6.3, initial metal ion concentration of 20 mg/dm^3, temperature of 28 °C, and 50 min contact time. Kinetic studies indicated that the adsorption of Pb^{2+} ions onto the modified extract followed a pseudo-second-order kinetic model. The removal efficiency rate at the different temperatures is in the order: 28 > 40 > 50 > 60 > 70 °C. The results obtained from the correlation coefficients of the plots indicated that Freundlich adsorption isotherm is the best fit for the experimental data. Calculations of thermodynamic parameters revealed that the sorption process was spontaneous (ΔGo values of -33.629, -20.867, and -5.402 kJ/mol at 28, 50, and 70 °C respectively); and exothermic with a value of ΔHo as -224.22 kJ/mol, while that of ΔSo as -630.4 J/mol·K. Results obtained from plotting the Dubinin-Radushkevich isotherm at different temperatures showed that the dominant mechanism responsible for removing Pb^{2+} ions was particle diffusion since the free energy values are in the range of 24.78 - 30.26 kJ/mol for 28-70 °C [68].

Also, the extract of onion skin was modified with maleic, succinic, citric, and phosphoric acid. At an initial metal ion concentration of 20mg/dm^3, acid treatment increased Cd^{2+} ions removal rate from 59.3% to 75.95%, 92.0%, 94.0%, and 98.45%, respectively, and Pb^{2+} ions from 85.85% to 96.76%, 97.8%, 98.6%, and 99.9% for onion skin samples modified with the corresponding acids. The exchange capacity for the modified and unmodified onion skins was higher for Pb^{2+} ions than for Cd^{2+} ions [69].

The findings from this study have revealed the application of a polyphenolic extract of red onion skin in the synthesis of exchange resin (CERR) for the uptake of Mn^{2+}, Fe^{2+} and Pb^{2+} ions from an aqueous medium. The percentage metal ion uptake increased steadily with time at the initial stage, and thereafter, the values remained relatively constant from about 35 min for Mn^{2+} ions and 40 min for Fe^{2+} and Pb^{2+} ions. For the metal ions studied, a decrease in percentage exchange (from 86.69 to 46.92 % for Mn^{2+}, 77.02 to 46.74 % for Fe^{2+} and 66.34 to 33.23 % for Pb^{2+} ions) with temperature increase in the range of 29 to 70°C was observed, with the optimal exchange occurring at 29°C. Examination of the mechanism of uptake of metal ions using CERR was conducted with Dubinin-Radushkevich isotherm model and showed that metal ions removal with CERR occurred by ion-exchange mechanism, with values of the mean free energy as 8.500, 8.181, and 8.248 kJ/mol for Mn^{2+}, Fe^{2+}, and Pb^{2+} ions respectively [70].

Also, the investigation into the diffusion dynamics of Mn^{2+}, Fe^{2+}, and Pb^{2+} ions uptake from aqueous solution by chemically modified red onion skin extract was carried out. The polyhydroxylic extract of red onion skin was utilized in the synthesis of CERR. Predictions of the mechanism of diffusion dynamics were carried out by applying the data resolved from the fractional attainment of equilibrium at varied times into the Vermeulen diffusion models within the temperature range of 29 to 70°C. The film diffusion coefficient values were lowest at 29°C, indicating the most probable temperature condition for optimum exchange result with the CERR. Deductions from utilizing the Arrhenius type temperature dependence equation gave negative values of activation energy (-7.223 kJ/mol for Mn^{2+} ions, -6.898 kJ/mol for Fe^{2+} ions and -13.957 kJ/mol for Pb^{2+} ions); which suggests that increase in temperature from 29 to 70°C, lowered the rate of the exchange reaction [71].

The study concluded that onion skins, a waste material, have good potential as an adsorbent to remove toxic metal ions from water.

The dyes and other organic compounds have been several studies on the adsorption of dyes from simulated solutions with onion processing waste.

In particular, the use of cold plasma-treated and formaldehyde-treated onion skins as a biosorbent has been investigated to remove "methylene blue" dye from aquatic solutions. The impact of process variables such as adsorbent dosage, initial dye concentration, and pH were examined. The results indicated that the data for adsorption of methylene blue dye onto onion skins fitted well with the Langmuir isotherm model. The sorption capacities for cold plasma-treated and formaldehyde-treated onion skins by Langmuir isotherm were found to be 250 and 166.67 mg⁄g, respectively. The equilibrium time was found to be 150 min for 50 mg/dm3 dye concentrations. The maximum removals for cold plasma-treated and formaldehyde-treated onion skins obtained were 90.94 and 95.54% at natural pH =10 for adsorbent doses of 0.75 g/dm^3, respectively. The rates of sorption were found to conform to pseudo-first-order kinetics [72].

Varying the parameters, such as dye concentration, adsorbent dose, and pH, carried out the potential feasibility of microwave heating treated and pre-boiling treated onion skins for removal of methylene blue. The amount of dye uptake increased with an increase in contact time, adsorbent dosage, and initial dye concentration. Lagergren's first-order and second-order were used to fit the experimental data. Based on the regression coefficient, the equilibrium data was found to fit the Langmuir equilibrium model better than other models. The adsorption capacities were found to be 142.67, and 55.55 mg/g for microwave heating treated onion skins, and pre-boiling treated onion skins by Langmuir isotherm. The equilibrium time was found to be 150 min for 50 mg/dm^3 dye concentrations. The maximum removals for microwave heating treated onion skins, and pre-boiling treated onion skins were obtained 86.34 and 94.13% at natural pH = 10 for adsorbent doses of 0.75 g/dm^3 [73].

A much higher sorption capacity was achieved when The onion membrane removed methylene blue. One gram of onion membrane was obtained from approximately 250 g of onion. The membranes (~4 g/kg of onion) were washed and rinse with distilled water to remove impurities. The amount of dye uptake increased with an increase in contact time, adsorbent dosage, and initial dye concentration. The adsorption capacity of the membrane was examined to be 1.055 g/g with 84.45% efficiency after 1 hour and 1.202 g/g with 96.20% efficiency after 8 hours in contact with a dye solution (0.3 g/dm^3). In addition, models of isotherm thermodynamics, kinetics, and adsorption were used to describe methylene blue adsorption processes. The results point out the data for adsorption of dye onto the membrane fitted well with the Freundlich isotherm and pseudo-second-order kinetic models. The Methylene blue adsorption from temperature to ~50°C is spontaneous and thermodynamically favorable [74].

Results indicated that onion skins and membranes could be used as a biosorbent to remove methylene blue dye from contaminated waters. There was no literature data found on the study of other dyes' adsorption with onion processing waste.

Diclofenac and ibuprofen adsorption onto acids (HCl, H_2SO_4, and H_3PO_4) pre-treated onion skin (OS) was studied as a function of pH, adsorbent dosage, drugs initial concentrations, and contact time. The H_2SO_4-OS showed higher drug adsorption efficiency, followed by others samples. Pseudo-second-order kinetic model fitted well to both the adsorption of the drug data. Freundlich isotherm explained well the adsorption of the drug onto native onion skin. The optimum pH, adsorbent dosage, and contact time were 6.5, 0.05 mg/g, and 220 min, respectively. At optimum condition, the diclofenac and ibuprofen adsorptions were 134.0 and 91.99 mg/g, respectively, which were 81.90% and 65.99% removal of the initial concentrations [75].

4. Conclusions

In summary, the paper summarizes the literature data on the use of onion (*Allium cepa*) processing waste as sorption materials to remove various pollutants (metal ions, dyes, antibiotics) from aqueous media. It provides brief literature data on the structure, volume of cultivation, and chemical composition of some components of onion biomass. Data are given on removing various metal ions (Ca^{2+}, Cd^{2+}, $Cr^{(VI)}$, Cu^{2+}, Hg^{2+}, Mg^{2+}, Ni^{2+}, Pb^{2+}, Zn^{2+}) from aqueous media with native and modified onion processing waste, largely with onion skin. The work shows the possibility of increasing the sorption characteristics of pollutants by treating the *Allium cepa* wastes with various chemical reagents. It was found that the pollutant adsorption isotherms on onion waste are most often more accurately described by the Langmuir and Freundlich models. The kinetics of the process predominantly corresponds to the pseudo-second-order model. It was shown that the use of onion skin extracts modified with various chemical compounds is promising for removing heavy metal ions.

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Conflicts of Interest

The authors declare no conflict of interest.

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