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Waste Reduction Based on Adsorption Aqueous Lead Nitrate by Chicken Feather

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Abstract

Background: Chicken feathers can be used as an alternative treatment for metal ions in wastewater with a concentration of lead nitrate. This paper will describe the ability of chicken feathers that were activated by only Sodium hydroxide and by Sodium hydroxide with Hydrochloric acid based on some variation of the weight of chicken feathers to reduce the concentration of lead nitrate and subsequently, characterizing the spectral outcomes. **Method**: A quasi-experimental research with pre-test post-tests equivalent control groups design will be done. The purposive sampling consists of aqueous $Pb(NO_3)_2$ and chicken feathers are used. The 5 mg/L Pb solution was made from $Pb(NO_3)_2$ whose levels had been tested with AAS and were detected at 4.183 mg/L. Variations in chicken feather mass of 1.4 grams; 1.5 grams; 1.6 grams; and 1.7 grams were tested. **Result**: Based on the activation treatment, chicken feathers with a weight of 1.7 grams activated by sodium hydroxide have the highest ability to adsorb aqueous lead nitrate. The spectra match the functional groups of keratin. **Conclusion**: Activation using sodium hydroxide has reached a high adsorption presentation capacity. The spectral results match the functional groups of keratin C-H, C-O, $N\text{-}H_2$ groups.

Keywords: aqueous lead adsorption, chicken feather, hydrochloric acid, sodium hydroxide

INTRODUCTION

Industrial waste comprises the residual byproducts generated during pre-production, production, and post-production activities. Specific categories, such as B3 industries encompassing the chemical, electronic, and paint sectors, are known for producing heavy metals as waste products. Chicken feathers, typically considered waste material, present challenges such as disease transmission, odor emissions, and slow soil degradation. However, they can serve as an alternative material for fish feed and potentially help mitigate heavy metal contamination.

Chicken feathers, when activated with NaOH and HCl, demonstrate the potential to function as effective adsorbents for the heavy metal Pb. This phenomenon is attributed to the interaction between the amino acid cysteine within chicken feather keratin and Pb, forming covalent bonds [1].

Research on chicken feathers highlights their pivotal role in generating value-added products. Numerous studies have explored the feasibility of utilizing chicken feathers as adsorbents through various preparation methods. Leveraging chicken feathers as a cost-effective adsorbent offers promise in addressing environmental and waste management challenges. The unique structural and chemical properties of chicken feathers render them a versatile adsorbent with wide-ranging advantages and applications [2].

Despite being often overlooked, chicken feathers represent a valuable bioresource that can yield diverse by-products for applications in industries, agriculture, energy, and medicine. Effective keratin research necessitates the identification or development of potent keratin-degrading microorganisms. Some studies have shown that genetically modified strains and recombinant enzymes exhibit superior performance compared to wild strains [3].

To address the removal of Pb^{2+} ions from wastewater, several effective methods have been employed. Recent advancements encompass a variety of naturally occurring and synthetically modified materials. These materials include natural substances (e.g., shells, peels, corncobs, and algae), activated carbon, nano composites, magnetic nanomaterials, polymer composites, and chemicals, each demonstrating efficacy in lead removal [4].

One specific study achieved removal efficiencies of 98.7% for Co II, 98.9% for Cu II, 98.7% for Fe II, and 99% for Ni II ions at a concentration of 20 mg/L. These adsorption processes adhered to a pseudo-second-order kinetic model, while thermodynamic analysis indicated their spontaneity and endothermic nature. Modified chicken feathers exhibited robust recyclability, maintaining a high adsorption capacity even after seven cycles using a 0.1 M EDTA solution [5].

Furthermore, activated carbon derived from chicken feathers achieved a lead removal efficiency of 97%, demonstrating a strong affinity for lead ions compared to chromium ions. Efficiency further increased with higher adsorbent concentrations and extended contact times [6]. In another study, an electrosorption capacity of 4.1 mg g^{-1} and a lead removal efficiency of 81% from aqueous solutions were reported. This suggests that electrode materials derived from chicken feathers have potential in capacitive deionization for removing heavy metals, such as Pb^{2+}, from aqueous solutions [7].

Another investigation highlighted mesoporous structures and enhanced oxygen reduction reaction activity in feather rachis-derived samples. This was confirmed through adsorption isotherms and X-ray Photoelectron Spectroscopy (XPS) analysis. The samples exhibited a remarkable 96% current stability in chronoamperometric measurements spanning 15 hours [8]. Additionally, chicken feathers have shown effectiveness in oil spill cleanup, demonstrating favorable performance when compared to industry standards. They are well-suited for both land and aqueous environments in oil spill remediation [9]. Optimal adsorption parameters were determined as follows: initial ion concentration of 300 mg/L, initial pH of 8, adsorbent dosage of 10, and contact time of 480 minutes [10]. Biochars exhibited selective adsorption of Pb^{2+} over Cd^{2+} in a binary metal system, with phosphate precipitation contributing to the selective Pb^{2+} adsorption. Minimal influence was observed from proline, glucose, and pH (4–6) on Cd^{2+} and Pb^{2+} adsorption. Primary adsorption mechanisms included electrostatic interactions, precipitation, and O–H bonds [11].

A study evaluated the malachite green dye's adsorption using a continuous flow column. Optimal conditions were found to be a bed height of 8 cm, a flow rate of 12 ml/min, and an initial concentration of 20 mg/l, resulting in a malachite green uptake of 2.829 mg/g. FTIR analysis was conducted to study the characteristics of the hen feathers [12]. The research concludes that artificial neural network (ANN) modeling serves as a reliable tool for predicting and optimizing adsorption parameters for maximum lead removal from aqueous solutions [13]. Immobilization of *Pseudochrobactrum sp*. IY-BUK1 cells increased degradation and keratinase activity by 50%.

Chicken feathers (GFFs) were identified as effective biosorbents, providing an alternative for GFF disposal and supporting bioremediation [14].

Ni^{2+} asorption data were well-fitted by a pseudo second order kinetic model, indicating the effectiveness of ACCF in removing Ni II ions from aqueous solutions [15]. Positive entropy changes suggest an increase in disorderliness during the adsorption of Pb II and Cu II onto chicken feathers. Negative Gibbs free energy and positive enthalpy values indicate spontaneous and endothermic adsorption. FTIR analysis confirmed the presence of functional groups on chicken feathers, suggesting potential reuse [16]. Alkali-treated chicken feathers were found to be a cost effective alternative for the removal of Cr VI from aqueous solutions, with a maximum sorption capacity of 90.91 mg/g [17]. BSM effectively adsorbed LEVO, with the pseudo second order model fitting best. The adsorption process was influenced by liquid film and intra-particle diffusion. Thermodynamic analysis revealed exothermic and spontaneous LEVO uptake. [18] Structural changes in EGHP, including reduced crystallinity and increased specific surface area, resulted in increased adsorption of RB 19 dyes. Desorption and regeneration studies indicated good adsorption capacity retention [19]. Maximum biosorption capacities for Pb II and Cu II by chicken feathers, determined using the Langmuir isotherm model, were 79.36 mg/g and 61.92 mg/g, respectively [20]. KNB efficiently adsorbed Cd and Pb from wastewater, with mechanisms involving electrostatic interactions, cation-p interactions, complexation, and K^+ exchange. KOH modification enhanced electrostatic attraction, and surface functional groups played a role in Cd and Pb adsorption [21]. The adsorption of heavy metal ions on chicken feathers exhibited physical adsorption forces, with thermodynamic calculations indicating spontaneous and feasible adsorption [22].

Research demonstrated the dissolution of chicken feathers in an aqueous solution of 1-butyl-3-methylimidazolium acetate for keratin recovery and keratin biofilm preparation for potential biomedical applications [23]. In batch adsorption, equilibrium was optimized at pH 6, a dose of 6 g/L, and a contact time of 60 minutes. The Freundlich adsorption isotherm best described the experimental data, with a maximum adsorption capacity of 4.78 mg/g for fluoride [24]. Biosorption capacities for MCFs and XMCFs were significantly higher than for RCFs. Optimal conditions for biosorption included a pH of 2.0, an equilibrium contact time of 90 minutes for RCFs, and 60 minutes for MCFs and XMCFs, with biosorbent concentrations of 16 g/L for RCFs and 12 g/L for MCFs and XMCFs [25].

The results of this research can be used in the processing of industrial waste that contains lead and is yet of a quality that meets acceptable requirements. The primary purpose of treating chicken feathers with a sodium hydroxide solution is to activate protein groups, specifically α-keratin containing cysteine, to enhance their adsorption capacity. This process also serves to remove the waxy layer on the feather surface. Furthermore, using a hydrochloric acid solution is intended for the removal of inorganic impurities. The method used is batch adsorption. There was effectiveness of liquid waste adsorption after activation treatment of sodium hydroxide and hydrochloric acid. The spectral outcomes align with the characteristic functional groups present in keratin. The format of this research paper is as follows: The methods section contains a description of the suggested system. The results and discussion part contains the presentation of the experimental results and commentary. The findings and future work section discusses conclusions and directions for future research.

METHOD

This study employs a quasi-experimental design with an equivalent control group using a pre-test/post-test research framework. The sampling technique is purposive, with the study focusing on samples consisting of aqueous $Pb(NO_3)_2$ and chicken feathers. In this research, the independent variables pertain to the mass variations of chicken feathers, with and without acid activation, distinguishing the experimental and control groups. The primary dependent variables are the levels of Pb and the characteristics of chicken feathers. Several confounding variables are considered, including contact time, solution pH, adsorbent surface area, stirring speed, soaking time, and activator concentration.

The materials utilized in this study include lead nitrate p.a., chicken feathers, hydrochloric acid 37% p.a., sodium hydroxide, fine filter paper, pH indicators, distilled water, and aqua DM. The chicken feathers were meticulously prepared by thorough washing, drying at 60°C for 24 hours, and then cutting into 1 cm^2 pieces. Subsequently, 500 grams of chicken feathers were weighed, and 100 grams of these were soaked and occasionally stirred in a 0.1 N NaOH solution at a 1:6 (w/v) ratio, followed by heating at 70ºC for 20 minutes. The feathers were then neutralized to a pH of 7 using distilled water and dried, resulting in a yield of 91.4 grams of NaOH-activated feathers.

Next, 50 grams of chicken feathers were soaked and occasionally stirred in a 2 N hydrochloric acid solution at a 1:10 (w/v) ratio for 1 hour. The feathers were similarly neutralized and dried, yielding 48.5 grams of hydrochloric acid-activated feathers. The experimental phase involved mixing varying weights of chicken feathers, activated with sodium hydroxide and hydrochloric acid, in 50 ml of lead nitrate aqueous solutions at different concentrations. The mixtures were stirred with a magnetic stirrer for 60 minutes at 1300 rpm, followed by filtration and analysis by Atomic Absorption Spectroscopy (AAS). Furthermore, chicken feathers activated solely with sodium hydroxide were subjected to the same treatment with lead nitrate solutions. The chemical characteristics of the chicken feathers were analyzed using Fourier-Transform Infrared Spectroscopy (FTIR).

RESULTS AND DISCUSSION

Table 1 reveals that activation solely with Sodium hydroxide resulted in a minimum adsorption rate of 93.3% and a maximum of 98.3%, making additional activation with Hydrochloric acid unnecessary. According to Table 2, a chicken feather weight of 1.7 grams, when activated with Sodium hydroxide, exhibited the highest adsorption capability for aqueous lead nitrate. Table 3 illustrates the spectral analysis findings, indicating that the structural components displaying characteristics of the adsorption area for the peptide bond (-CONH-) are evident. The amide I adsorption area, associated with C=O group stretching vibrations, appears within the wavenumber range of 1700-1600 cm^{-1}. In chicken feather biomass, this area is observed at 1639 cm^{-1}. The amide II adsorption area, featuring N-H bonding and C-H stretching vibrations, within the wavenumber range of 1560-1335 cm^{-1}, is evident at 1539 cm^{-1} in chicken feathers. The amide III adsorption area, occurring around 1240 cm^{-1}, results from a combination of C-N stretching vibrations, N-H plane bonding, and influences from C-C stretching vibrations and C=O bonding. The spectral results align with the functional groups of keratin, displaying the adsorption of C-H, C-O, and $N-H_2$ groups, indicating the presence of keratin components.

Table 1. Adsorption persentation description aqueous lead nitrate by chicken feather based on activated treatment

Treatment	N	Minimum	Maximum	Mean	SD	Median
NaOH	24	93.3	98.3	96.3	2.1	96.8
NaOH+HCl	24	92.3	98.3	97.2	1.6	98.2

Table 2. Adsorption persentation description aqueous lead nitrate by chicken feather

Weight	Minimum	Maximum	Mean	SD	Median
1,4 gr NaOH	93.3	93.3	93.3	0.0	93.3
1,5 gr NaOH	98.1	98.1	98.1	0.0	98.1
1,6 gr NaOH	95.5	95.5	95.5	0.0	95.5
1,7 gr NaOH	98.3	98.3	98.3	0.0	98.3
1,4 gr NaOH+HCl	92.3	98.3	96.9	2.3	97.9
1,5 gr NaOH+HCl	94.7	98.3	97.3	1.4	97.6
1,6 gr NaOH+HCl	95.5	98.3	97.4	1.4	98.3
1,7 gr NaOH+HCl	95.7	98.3	97.4	1.3	98.3

Table 3. Peak Area/Height Results

Peak	X (cm-1)	Y (%T)	Area (%T)	Start	End	Base1
1	3740.01	99.9	-37.32	4000	3684.87	4000
2	3285.16	99.22	-242.14	3684.87	3135.5	3684.87
3	2959.75	99.16	145.13	3135.5	2351.08	3135.5
4	1738.06	96.28	-311.75	2351.08	1691.08	2351.08
5	1641.08	96.78	-55.52	1691.08	1584.06	1691.08
6	1531.97	97.57	-50.19	1584.06	1494.9	1584.06
7	1440.4	96.48	-78.96	1494.9	1404.68	1494.9
8	1373.49	96.65	88.33	1404.68	1287.63	1404.68
9	1218.92	97.19	-94.49	1287.63	1136.26	1287.63
10	1076.35	99.33	1.27	1136.26	971.54	1136.26
11	865.58	99.03	-51.57	971.54	826.35	971.54
12	617.16	97.45	-89.08	826.35	555.82	826.35
13	486.21	86.54	-1466.51	555.82	417.98	555.82

Figure 1 in the control group showed that the average decrease in Pb concentration with variations in chicken feathers had decreased significantly.

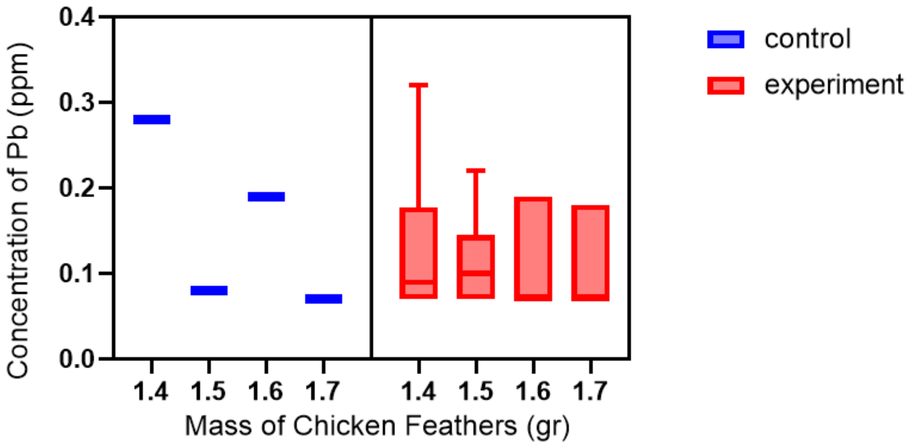

Figure 1. Results of lead level test for experimental and control groups

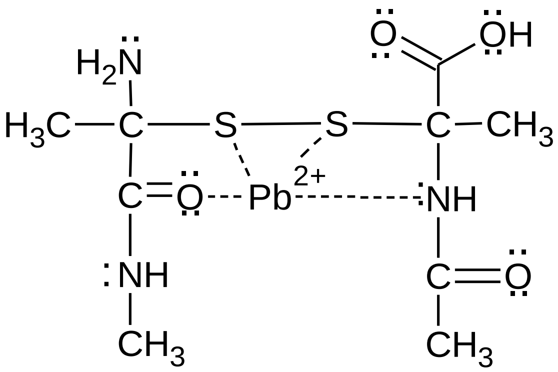

Figure 2. Cysteine covalent bond with Pb^{2+}, after NaOH activation of chicken feathers

Figure 2 shows that Valence bond theory, which helps explain bonding and structure in main group compounds, is also used to describe complex ionic bonds. In the formation of complex ions, the ligands (central atomic pairs to form the complex) filled orbitals overlap with the empty orbitals of the metal ion. The central pair of atoms to form the complex (Lewis base) donates a pair of electrons and the metal ion (Lewis acid) accepts electrons to form one of the covalent bonds of the complex ion (acceptor Lewis base). Such a bond, where one atom in a bond contributes both electrons, is called a coordinate covalent bond. So, a coordination covalent bond or semipolar bond is a covalent bond that is formed by sharing a pair of electrons from one of the atoms/ions/molecules that has a PEB (lone pair of electrons). Other atoms/ions/molecules only provide empty orbitals, for example, Pb^{2+}. Coordinating covalent bonds are depicted with the same electron symbol (-----). This shows that the electron pair comes from the same atom [1].

Many adsorption application technologies have been developed, using biomaterials to reduce heavy metal levels from water bodies (biosorption), such as water hyacinth, coconut shells, chicken feather biomass, seaweed, activated carbon from corn meal, wood charcoal and sand and many others. Apart from chicken feathers, there are other alternatives that can reduce Pb levels, including duck feathers, sago pulp and clay. The metal used as an adsorbate besides using pure metal also uses metal originating from industrial waste.

This study used pure Pb from $Pb(NO_3)_2$, using a chicken feather adsorbent with a batch adsorption technique. Then in chemical activation with HCl and NaOH. In the future, further research will be carried out for the development of science for the utilization of livestock waste for industrial waste (from waste to waste). The purpose used NaOH was removed the wax layer attached to the surface of the chicken feathers and then NaOH 0.1 N 1:6 (mass of chicken feathers/volume of NaOH) saponification would occur.

Nevertheless, it's important to acknowledge the limitations of this research. The application of chicken feather adsorbents has not been widely adopted by large industries, and the use of Atomic Absorption Spectrophotometry (AAS) with limited detection limits may lead to undetectable levels in certain cases. Furthermore, the application of chicken feather adsorbents primarily addresses industrial waste, particularly in the neutralization process and the final treatment stage. These adsorbents offer an alternative for modifying liquid waste treatment units with physicochemical processes.

CONCLUSION

This study underscores the effectiveness of the activation treatment, specifically sodium hydroxide activation, in achieving significant adsorption. It is noteworthy that chicken feathers weighing 1.7 grams, subject to sodium hydroxide activation alone, demonstrated the highest affinity for adsorbing aqueous lead nitrate. The spectral results align with the functional groups of keratin, indicating the presence of C-H, C-O, and $N\text{-}H_2$ group adsorptions.

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