



# **BIOSORPTION PROPERTY OF NONWOVEN DUCK (*Anas platyrhynchos domestica*) FEATHER FABRIC AS A FILTRATION MEDIUM FOR LEAD CONTAMINANTS IN WATER**

**Fritz Ian F. Torrevillas<sup>1</sup>, Wendyl M. Aligato<sup>2</sup>, Ronald B. Ganoy<sup>3</sup>,  
Reizel Quinn C. Padua<sup>4</sup>, Ashley M. Fernandez<sup>5</sup>, Gabrielle C. Adorable<sup>6</sup>,  
Arnold II P. Cavan<sup>7</sup>, Jemrard M. Esgana<sup>8</sup>, Jade Marie Lourwase C. Blas<sup>9</sup>,  
Ryujiro P. Ota<sup>10</sup>**

*Immaculate Heart of Mary Academy, Manuel L. Quezon St., Central, City of Mati, 8200 Davao Oriental, Philippines.*

*ORCID No.: Fritz Ian F. Torrevillas 0009-0000-2344-5465, Wendyl M. Aligato 0009-0008-7897-5736,*

*Ronald B. Ganoy 0009-0009-4658-9909, Reizel Quinn C. Padua 0009-0006-1884-0560, Ashley M. Fernandez 0009-0008-0215-5942,*

*Gabrielle C. Adorable 0009-0007-1460-7005, Arnold II P. Cavan 0009-0006-0814-334X, Ryujiro P. Ota 0009-0002-5138-1731,*

*Jade Marie Lourwase C. Blas 0009-0008-5917-1409, Jemrard M. Esgana 0009-0006-5346-0192*

<sup>1</sup>*Senior High School Students, Immaculate Heart of Mary Academy, City of Mati, Davao Oriental, Philippines*

<sup>2</sup>*Research Teacher, Master of Science in Teaching major in General Science, Immaculate Heart of Mary Academy,  
City of Mati, Davao Oriental, Philippines*

<sup>3</sup>*Master of Arts in Education major in Teaching Science, Immaculate Heart of Mary Academy, City of Mati, Davao Oriental,  
Philippines*

<sup>4</sup>*Senior High School Students, Immaculate Heart of Mary Academy, City of Mati, Davao Oriental, Philippines*

<sup>5</sup>*Senior High School Students, Immaculate Heart of Mary Academy, City of Mati, Davao Oriental, Philippines*

<sup>6</sup>*Senior High School Students, Immaculate Heart of Mary Academy, City of Mati, Davao Oriental, Philippines*

<sup>7</sup>*Senior High School Students, Immaculate Heart of Mary Academy, City of Mati, Davao Oriental, Philippines*

<sup>8</sup>*Senior High School Students, Immaculate Heart of Mary Academy, City of Mati, Davao Oriental, Philippines*

<sup>9</sup>*Senior High School Students, Immaculate Heart of Mary Academy, City of Mati, Davao Oriental, Philippines*

<sup>10</sup>*Senior High School Students, Immaculate Heart of Mary Academy, City of Mati, Davao Oriental, Philippines*

**Article DOI:** <https://doi.org/10.36713/epra26522>

**DOI No:** 10.36713/epra26522

## **ABSTRACT**

*Heavy metal contamination in water is a global issue that poses significant health risks, necessitating sustainable, low-cost filtration alternatives. This study investigated the use of nonwoven duck feather fabrics as an alternative waste-filtration medium for the adsorption of lead from synthetic wastewater. An experimental quantitative research design was employed to evaluate the biosorption capacity of nonwoven duck feather fabric (*Anas platyrhynchos domestica*). Specifically, the nonwoven duck feathers were first pretreated with NaOH to enhance their adsorption capacity. With polypropylene binder fiber, the pretreated duck feathers were bound to 7x7 cm-sized fabrics with varying feather-to-binder ratios (70:30, 75:25, 80:20) using a convection oven. To simulate contaminated wastewater, 10 synthetic wastewater samples were prepared using distilled water and lead nitrate and sealed in plastic containers. Using Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES), the initial lead concentration in the samples was analyzed. After the initial concentration of the samples was measured, the nonwoven duck feather fabrics were placed in plastic containers for 1 hour to adsorb lead from the synthetic wastewater. The samples are then reanalyzed by ICP-OES to quantify the final lead concentrations in the synthetic wastewater. The data is then treated with Kruskal-Wallis to obtain the results. The results showed that nonwoven duck feather fabrics in ratios of 70:30, 75:25, and 80:20 feather-to-binder ratios are capable of adsorbing lead from wastewater. However, there was no significant difference in adsorption capacity or percentage removal among the three ratios.*

**KEYWORDS:** Heavy Metal Contamination, *Anas Platyrhynchos Domestica*, Lead (Pb) Removal, Keratin Biosorbent, Biosorption, Duck Feather Fabric

## *Recommended Citation*

*Torrevillas, F. I. F., Aligato, W. M., Ganoy, R. B., Padua, R. Q. C., Fernandez, A. M., Adorable, G. C., Cavan, A. P. II., Esgana, J. M. Blas, J. M. L. C., & Ota, R. P. (n.d.). Biosorption property of nonwoven duck (*Anas platyrhynchos domestica*) feather fabric as a filtration medium for lead contaminants in water.*



## INTRODUCTION

Heavy metal contamination of water resources is a widespread and pressing environmental issue, affecting both ecosystems and human health on a global scale (Hikmat et al., 2023; Jumoke & Ajayi, 2025; Lubal, 2024). These metals are not only toxic but also bioaccumulative, posing long term risks as they move through food chains and persist in the environment (P. Zhang et al., 2023). Additionally, conventional filtration materials for heavy metal removal, such as activated carbon remain expensive despite their widespread use in water treatment industries (Pet et al., 2024).

Globally, areas with significant industrial activity encounter severe issues associated with heavy metal contamination. The Yangtze River Basin in China has undergone significant water quality deterioration due to industrial effluents (Di et al., 2019) whereas the Niger Delta in Nigeria persists in facing oil-induced pollution, leading to increased concentrations of mercury and lead in aquatic environments (Chinedu & Chukwuemeka, 2018). Numerous physiochemical techniques employed for the removal of heavy metals, including ion exchange, reverse osmosis, and membrane filtering are expensive and often generate secondary pollutants (Geremew, 2017; Rahman et al., 2025; Tripathi & Ranjan, 2015; P. Zhang et al., 2023).

In the Philippines, heavy metal pollution is also a serious concern. Rivers such as the Meycauayan in Bulacan and the Alinsao in Zambales have been found to contain high concentrations of heavy metals (Pleto et al., 2020). Mining regions in Benguet and Palawan contribute to the release of toxic metals, adding to the country's growing problem of water equality management (Diwa et al., 2023). In Leyte and Metro Manila, heavy metal contamination in water bodies remains a serious concern, yet filtration technologies like membrane systems and chemical precipitation are often too costly for widespread use (Siddique et al., 2025).

The Davao Region exhibits localized effects of heavy metal exposure. Research in the Davao Gulf and its surroundings has indicated that cadmium (Cd) and lead concentrations in surface waters exceed permissible limits, while downstream sediments contain cadmium (Cd), copper (Cu), iron (Fe), magnesium (Mn), and zinc (Zn), with some levels exceeding ecological safety criteria (Badong & Bersabal, 2018). Investigations of mangrove clam (*Pegophysema philippiana*) populations indicated detectable concentrations of cadmium and lead in Sta. Cruz, Davao del Sur, is ascribed to regional agricultural and industrial endeavors (Balingit et al., 2024). Evaluations of tap water at Davao Oriental State University (DOrSU) indicated lead concentrations of 0.01 mg/L, compliant with the regulatory standards of PNSDW, WHO, and USEPA; nevertheless, identified as over suggested carcinogenic risk thresholds (Balingit et al., 2024).

These localized findings highlight an urgent need to address the research gap by advancing sustainable, low-cost filtration approaches, such as those utilizing abundant poultry byproducts like duck (*Anas platyrhynchos domestica*) feathers, whose keratin-rich structure has shown potential for heavy metal adsorption while also reducing solid waste disposal impacts (Alvarez et al., 2023; Basak et al., 2021).

This study aims to assess the biosorption capacity and percentage removal of nonwoven duck feather fabric in removing lead from synthetic wastewater. This research seeks to provide mechanistic and experimental evidence supporting the potential of nonwoven duck feather fabrics as a filtration medium for lead contaminants in water.

## Research Questions

1. Is there a significant difference in the biosorption capacity of nonwoven duck (*Anas platyrhynchos domestica*) feather fabrics in removing lead from synthetic wastewater under controlled experimental conditions?
2. Is there a significant difference in the removal efficiency of lead for nonwoven duck (*Anas platyrhynchos domestica*) feather fabrics prepared with varying fabric-to-binder ratios?
3. Is there a significant difference in the percentage removal of lead in varying fabric-to-binder ratios of nonwoven duck feather fabric while keeping pH, temperature, and contact time constant?

## METHODS

### Study Design

This study employed an experimental quantitative research design to evaluate the biosorption capability of nonwoven duck feather (*Anas platyrhynchos domestica*) fabric as a filtration medium for the removal of lead from synthetic wastewater. The experiment investigated the effect of varying feather-to-polypropylene binder ratios (70:30, 75:25, and 80:20) on lead removal efficiency and adsorption capacity. A control setup consisting of synthetic wastewater without fabric contact was included to establish baseline lead behavior independent of biosorption. All experimental conditions, including fabric mass, solution volume, contact time, pH, and temperature, were kept constant to isolate the effect of fabric composition.

Data analysis involved descriptive statistics and inferential testing to assess differences in adsorption performance among treatment groups. Normality and homogeneity of variance were evaluated for ANOVA but does not meet the requirements. Alternatively, the Kruskal–Wallis test was used as a non-parametric test due to sample size considerations.

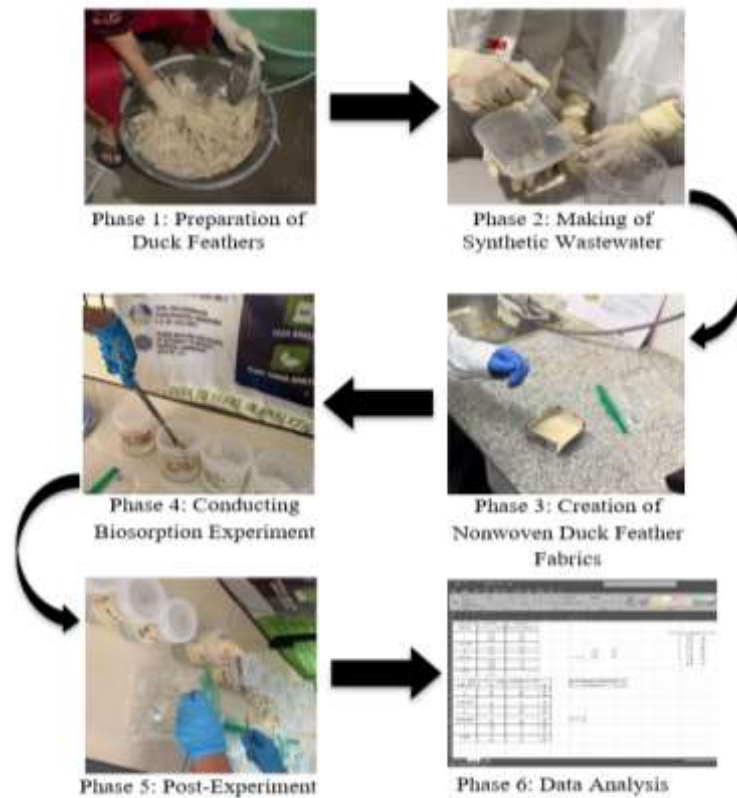


Figure 1. Flowchart of the Data Collection Process

### Instrumentation

Duck feathers were collected from Agdao Livestock Market in Davao City, Philippines. The raw materials were thoroughly rinsed with tap water to eliminate extraneous debris and subsequently submerged in a detergent solution for 30 minutes to facilitate degreasing and further purification (A). After the detergent bath, the feathers were rinsed and air-dried for 24 hours. After it was dried, NaOH pretreatment was utilized using a 0.1 M (4g/L) solution for 24 hours (B), and washed with distilled water until pH levels are achieved (Baroroh Lili Utami et al., 2020). Measuring the pH level would be done using pH testing strips from the rinse water. Wang et al. (2016) used the air-drying technique for drying the feathers, but did not include the specific length of time. The same technique was used in a clean environment for a length of 48 hours to have sufficient time for removing moisture (C).



Figure 2. Preparing the Duck Feathers

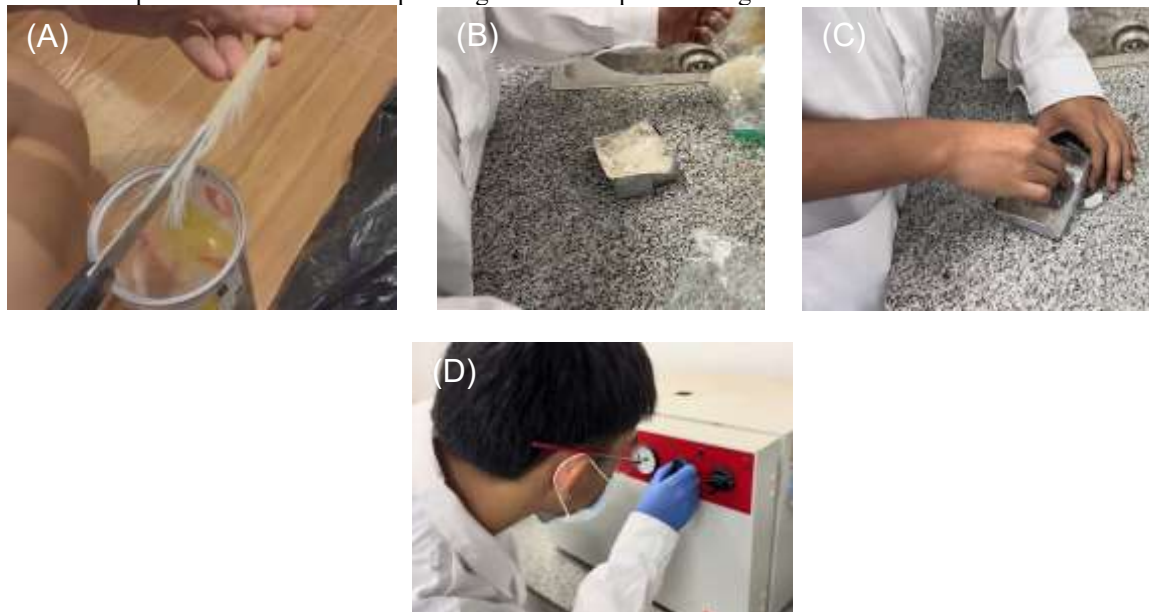
Synthetic wastewater was prepared using distilled water and lead nitrate ( $\text{Pb}(\text{NO}_3)_2$ ). A total of 10 samples were prepared: three per feather-to-binder ratio and one control (no treatment). To prevent contamination and exposure, the researchers used protective equipment such as a hazmat suit, gloves, goggles, and a mask. Due to the 0.2 M  $\text{Pb}(\text{NO}_3)_2$  stock solution being highly concentrated, it was first diluted to 0.01 M by adding 5 mL of the 0.2 M stock to distilled water up to a final volume of 100 mL, then mixing thoroughly (A). For the final synthetic wastewater, 15 mL of the 0.01 M solution was mixed with 300 mL of distilled water (315 mL total) and stirred well to ensure uniform lead ion distribution (A & B).



**Figure 3. Making of Synthetic Wastewater**

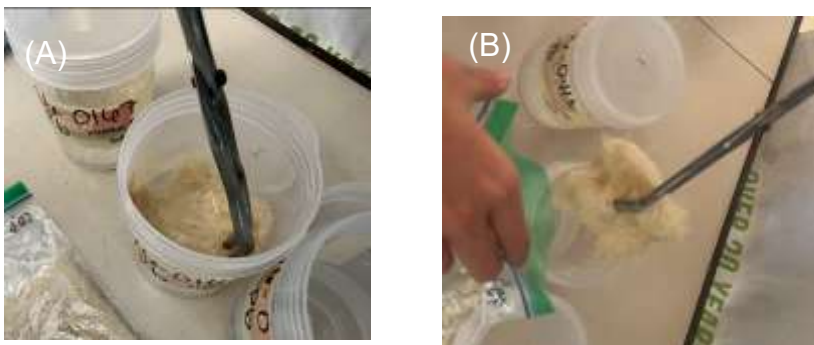
The clean, dried, and pretreated duck feathers were prepared for nonwoven production by cutting and separating the barbs and barbules (A), since the rachis and calamus require additional processing. The barbs and barbules were then layered with a polypropylene binder to promote random distribution and better feather to binder contact before bonding (B). Each sample had a total mass of 2.5 g, with feather-to-binder ratios of 70:30, 75:25, and 80:20. The mixture was placed on a  $7 \times 7$  cm aluminum mold and pre-pressed to flatten layers and reduce gaps for more uniform bonding.

The fabric was thermally bonded in a convection oven at  $180^\circ\text{C}$  for 6 minutes (D), following evidence that this method effectively forms functional feather-based nonwovens (Paşayev et al., 2019). This condition is also below the reported stability limit of duck feather composites ( $\sim 250^\circ\text{C}$ ), minimizing the risk of keratin degradation (Basak et al., 2021). After bonding, the fabrics were cooled at room temperature and stored in Ziploc bags until adsorption testing.



**Figure 4. Creation of Duck Feather Fabrics**

Initial lead concentrations of the synthetic wastewater were measured before adding the fabrics. Analysis was conducted at Davao Analytical Laboratory Inc. (DALinc) in Davao City, Philippines, using Inductively Coupled Plasma–Optical Emission Spectrometry (ICP-OES) with expert assistance. The test needed 100mL of the wastewater sample which makes the final volume of the water to be 215mL during adsorption test and final concentration test. After the initial analysis, nonwoven duck feather fabric pieces were placed in sealed containers with the synthetic wastewater and left for 1 hour under controlled conditions and a fixed contact time (A). Separate samples were prepared for each feather-to-binder ratio to evaluate their effect on adsorption efficiency. After 1 hour, the fabrics were removed using clean equipment to avoid contamination (B), and the containers were sealed for testing. Final lead concentrations were then measured using ICP-OES at DALinc.



**Figure 5. Biosorption Experiment**

**Data Analysis**

The following statistical tools were applied to analyze the collected data and address the study’s research questions: Percentage removal was calculated using the formula:  $((C_i - C_f) / C_i) * 100$ , where  $C_i$  represents the initial concentration of lead and  $C_f$  represents the final concentration of lead in milligrams per liter (mg/L). Adsorption capacity was calculated using the formula:  $q = ((C_i - C_f)V) / m$ , where  $V$  represents the volume of the synthetic wastewater in litres and  $m$  represents the mass of the fabric in grams.

Mean for both percentage removal and adsorption capacity was also calculated for each treatment group. An outlier value was included in the calculation. To determine if there is a significant difference among groups, the Kruskal-Wallis test was used.

**RESULTS**

**The Experimental Setup**

The experiment tested how different material compositions affect the removal of a contaminant from a prepared solution under controlled conditions. Initial levels were measured, the material was exposed to the solution for a fixed time, then final levels were measured to determine removal efficiency and uptake capacity. Results were compared across treatment groups using appropriate statistical analysis.

**Table 1. Control Sample**

Control	$C_i$ (mg/L)	$C_f$ (mg/L)	$\Delta C$ (mg/L)	% removal
1	90.2	79.7	10.5	11.64%

$C_i$  = Initial Concentration     $C_f$  = Final Concentration     $\Delta C$  = Change in Concentration

Table 1 shows that the control sample (without the duck feather fabric) still exhibited a measurable decrease in lead concentration, with  $C_i = 90.2$  mg/L and  $C_f = 79.7$  mg/L, resulting in a  $\Delta C$  of 10.5 mg/L and 11.64% removal. This indicates that a portion of the observed lead reduction can occur even in the absence of the adsorbent, possibly due to baseline effects such as settling, container interactions, or minor procedural losses during handling. Therefore, this control value serves as the baseline reduction that should be considered when interpreting the adsorption performance of the fabric-treated ratios, to ensure that improvements in removal are attributed to the nonwoven duck feather material rather than background changes alone.

**Table 2. 70:30 Fabric Ratio Percentage Removal and Adsorption Capacity**

70:30	$C_i$ (mg/L)	$C_f$ (mg/L)	$\Delta C$ (mg/L)	% removal	q (mg/g)
1	105	91	14	13.3%	1.20
2	124	99.8	24.2	24.4%	2.08
3	135	84.4	50.4	37.33%	4.33
<b>Mean</b>			<b>29.53</b>	<b>23.39%</b>	<b>2.54</b>

$C_i$  = Initial Concentration     $C_f$  = Final Concentration     $\Delta C$  = Change in Concentration    q = Adsorption Capacity

Table 2 shows that the 70:30 feather-to-binder fabric showed consistent lead reduction in all three replicates, with percentage removal ranging from 13.33% to 37.33% (mean = 23.39%). As the initial concentration ( $C_i$ ) increased (105 → 124 → 135 mg/L), the drop in concentration ( $\Delta C$ ) also increased (14.0 → 24.2 → 50.4 mg/L), and this was reflected in higher % removal (13.33% → 24.4% → 37.33%) and higher adsorption capacity (q) (1.20 → 2.08 → 4.33 mg/g). Overall, the ratio achieved a mean  $\Delta C$  of 29.53 mg/L and a mean q of 2.54 mg/g, indicating measurable lead uptake per gram of fabric, but the wide spread in q values suggests that adsorption performance was variable across replicates and likely influenced by differing starting concentrations and replicate conditions.



**Table 3. 75:25 Fabric Ratio Percentage Removal and Adsorption Capacity**

75:35	Ci (mg/L)	Cf (mg/L)	ΔC (mg/L)	% removal	q (mg/g)
1	108	113	-5	-4.63%	-0.43
2	119	90.8	28.2	23.70%	2.42
3	77.7	62.9	14.8	19.05%	1.27
<b>Mean</b>			<b>12.67</b>	<b>12.71%</b>	<b>1.09</b>

*Ci = Initial Concentration Cf = Final Concentration ΔC = Change in Concentration q = Adsorption Capacity*

Table 3 shows that the 75:25 fabric ratio had the widest spread in performance, with percentage removal ranging from -4.63% to 23.70% (mean = 12.71%). Two replicates showed positive removal, but one replicate had negative removal ( $C_i = 108$  mg/L,  $C_f = 113$  mg/L;  $\Delta C = -5$  mg/L), indicating an apparent increase in final lead concentration and raising within-group variability compared with other ratios. This same replicate also produced a negative adsorption capacity ( $q = -0.43$  mg/g), which reduced the overall mean  $q$  to 1.09 mg/g. Despite this anomalous trial, the other replicates still showed measurable uptake ( $q = 1.27$ – $2.42$  mg/g) alongside positive concentration drops ( $\Delta C = 14.8$ – $28.2$  mg/L), suggesting that lead binding was possible under the 75:25 composition, but the results were less consistent and may be more sensitive to small experimental variations.

**Table 4. 80:20 Fabric Ratio Percentage Removal and Adsorption Capacity**

80:20	Ci (mg/L)	Cf (mg/L)	ΔC (mg/L)	% removal	q (mg/g)
1	83.4	69.2	14.2	17.03%	1.22
2	76.6	62.0	14.6	19.06%	1.26
3	72.3	52.0	20.3	28.05%	1.75
<b>Mean</b>			<b>16.37</b>	<b>21.40%</b>	<b>1.41</b>

*Ci = Initial Concentration Cf = Final Concentration ΔC = Change in Concentration q = Adsorption Capacity*

Table 4 shows that the 80:20 ratio produced consistent Pb(II) reduction across all replicates, with positive % removal ranging from 17.03% to 28.05% (mean = 21.40%). The concentration drop ( $\Delta C$ ) was also consistently positive (14.2–20.3 mg/L; mean = 16.37 mg/L), confirming actual reduction in lead concentration in every trial. In the same way, adsorption capacity values were all positive and relatively close ( $q = 1.22$ – $1.75$  mg/g; mean = 1.41 mg/g), indicating stable lead uptake per gram of fabric with lower within-group variability compared to ratios that showed negative or highly scattered results. Overall, the narrower spread in both % removal and  $q$  suggests that the higher feather content contributed to more uniform adsorption performance under the 80:20 composition.

**Table 5. Kruskal-Wallis Test Statistics of Percentage Removal**

Statistic	Value
H-value	1.15*
p-value	0.5611*

*Significant at 0.05\**

Table 5 shows the Kruskal–Wallis test for percentage removal resulting into  $H = 1.15$  and  $p = 0.5611$ . Since  $p > 0.05$ , there is no statistically significant difference in percentage removal among the 70:30, 75:25, and 80:20 ratios. Any differences in mean % removal are likely due to within-group variability rather than a consistent effect of ratio.

**Table 6. Kruskal-Wallis Test Statistics of Adsorption Capacity**

Statistic	Value
H-value	0.622
p-value	0.7326*

*Significant at 0.05\**

Table 6 shows the results of adsorption capacity being  $H = 0.622$  and  $p = 0.7326$ . With  $p > 0.05$ , there is also no statistically significant difference in adsorption capacity ( $q$ ) among the three fabric ratios, meaning the observed differences in  $q$  are not strong enough to conclude that one ratio performs better than the others based on this sample.

## DISCUSSION

### *Effect of 70:30 Ratio on the Adsorption Capacity and Percentage Removal of the Nonwoven Duck Feather Fabric*

The 70:30 feather-to-binder ratio fabrics demonstrated measurable lead reduction across all replicates, with positive percentage removal ranging from 13.33% to 37.33% (mean = 23.39%). The concentration decrease was consistently positive ( $\Delta C = 14.0$ – $50.4$  mg/L, mean = 29.53 mg/L), indicating functional adsorption even at a lower feather fraction. The replicate with the highest initial lead level also produced the largest concentration drop and highest removal, suggesting that higher starting concentrations may enhance the apparent removal under the same contact time. This pattern is consistent with keratin-based adsorption, wherein



functional groups such as amino ( $-NH_2$ ) and carboxyl ( $-COOH$ ) can facilitate ion exchange, electrostatic attraction, and complexation-type interactions with metal ions (Abdulwasii Olawale et al., 2018; Havryliak et al., 2020). In addition, adsorption capacities were uniformly positive ( $q = 1.20-4.33$  mg/g, mean = 2.54 mg/g), confirming that uptake was measurable per unit mass of fabric and supporting the capability of the 70:30 composition to bind lead ions (Abdulwasii Olawale et al., 2018; Baroroh Lili Utami et al., 2020).

#### ***Effect of 75:25 Ratio on the Adsorption Capacity and Percentage Removal of the Nonwoven Duck Feather Fabric***

Among the three ratios, the 75:25 feather-to-binder ratio exhibited the greatest inconsistency, including one replicate with negative removal ( $C_f > C_i$ ) and a corresponding negative adsorption capacity, indicating an apparent increase in measured final lead concentration in that trial. The remaining replicates still showed positive removal and positive adsorption capacity, confirming that lead binding occurred but was less stable across trials. This variability aligns with the sensitivity of adsorption outcomes to experimental and solution conditions such as contact time, pH, dosage, and initial concentration; under a fixed 1-hour contact time and small sample runs, replicate-to-replicate variation may be amplified and can produce unstable or anomalous outcomes (Solgi & Zamaninan, 2020)s. Overall, the 75:25 composition suggests that adsorption is possible, but performance may be more sensitive to minor experimental variations compared with the other ratios.

#### ***Effect of 80:20 Ratio on the Adsorption Capacity and Percentage Removal of the Nonwoven Duck Feather Fabric***

The 80:20 feather-to-binder ratio fabrics showed the most stable performance, with positive percentage removal in all replicates and a narrower spread relative to the other treatments. The consistency of removal indicates more uniform adsorption behavior across trials, which is consistent with the expectation that higher feather content increases keratin-related binding sites and the availability of functional groups capable of interacting with metal ions (Chen et al., 2022; Y. Zhang et al., 2015). Adsorption capacity values were also consistently positive ( $q = 1.22-1.75$  mg/g), supporting measurable lead uptake per gram of fabric and aligning with the more consistent percentage removal observed for this ratio (Abdulwasii Olawale et al., 2018; Baroroh Lili Utami et al., 2020).

#### ***Biosorption Potential of Nonwoven Duck Feather Fabrics for Lead Removal***

Across all feather-to-binder ratio fabrics, the generally positive percentage removal values indicate that lead reduction occurred in most trials, supporting the feasibility of duck feather-based nonwovens as biosorbent filtration media. This pattern is consistent with studies describing duck feathers as keratin-rich materials whose surface functional groups can interact with metal ions (Chen et al., 2022; Y. Zhang et al., 2015), and also having the capability to accumulate heavy metals including lead, which further supports the plausibility of lead interaction and uptake during contact (Sani et al., 2020). In addition to percentage removal, the adsorption capacity values were generally positive across treatments, confirming that lead uptake was measurable per unit mass of fabric, which is expected for keratin-based biosorbents (Abdulwasii Olawale et al., 2018).

However, the results indicated no statistically significant differences among ratios. This suggests that, under the present conditions and limited replicates, within-group variability outweighed between-group differences, and any apparent ranking across ratios may not be stable. Notably, Jin et al. (2013) also reported comparable copper sorption capacities among duck-feather composite nonwovens with 70–80% feather content and noted that binder content in the 20–30% range did not significantly influence copper sorption, indicating that ratio effects within this composition window may be subtle. Despite the lack of statistical difference, all treated samples except for the outlier showed higher concentration change compared to the change in the control variable, indicating that all ratios were able to adsorb lead ions.

In summary, this study successfully evaluated the lead removal efficiency of nonwoven duck feather fabrics across varying feather-to-binder ratios. The consistently positive adsorption capacities and removal percentages across most experimental trials confirm that all three tested ratios (70:30, 75:25, and 80:20) are viable media for lead biosorption. Furthermore, the observed performance fluctuations suggest that maximizing biosorbent efficacy requires a strategic balance between high keratin content and the structural integrity provided by the binder. These findings validate the potential of duck feather-based nonwovens as sustainable, low-cost alternatives for heavy metal remediation, while also showing the importance of further optimization in fabrication and adsorption conditions.

## **CONCLUSION**

In conclusion, the findings of the study suggest that the nonwoven duck (*Anas platyrhynchos domestica*) feather fabric has the capability to adsorb lead from synthetic wastewater. Moreover, based on the results, nonwoven duck (*Anas platyrhynchos domestica*) feather fabric also has the capacity to hold adsorbed lead. Since there is no significant difference in the percentage removal from the data drawn from varying ratios used (80:20, 75:25, 70:30), the researchers failed to reject the null hypothesis, which indicates that there is no significant difference in the percentage removal and adsorption capacity in the tested feather-binder ratios. Regardless of the results showing that there is no significant difference on both percentage removal and adsorption capacity, the study shows that nonwoven duck (*Anas platyrhynchos domestica*) feather fabric, is able to adsorb lead and has potential to be used as a filtration medium.

**REFERENCES**

1. Abdulwasilu Olawale, S., Wosilat Funke, A., Haruna Dede, A., & Habeeb, A. (2018). Isotherm Studies of the Biosorption of Pb (II) and Cu (II) Using Chicken Feather. *Asian Journal of Advanced Research and Reports*, September, 1–9. <https://doi.org/10.9734/ajarr/2018/v1i413094>
2. Alvarez, S., Raydan, N. D. V., Svahn, I., Gontier, E., Rischka, K., Charrier, B., & Robles, E. (2023). Assessment and Characterization of Duck Feathers as Potential Source of Biopolymers from an Upcycling Perspective. *Sustainability (Switzerland)*, 15(19). <https://doi.org/10.3390/su151914201>
3. Badong, V., & Bersabal, K. (2018). Environmental Assessment of Heavy Metals Accumulation in the Nearshore and Typical Estuarine Environment in Davao City Philippines. In *Journal of Science and Arts Year (Vol. 18, Issue 4)*. [www.josa.ro](http://www.josa.ro)
4. Balingit, R. F. P., Tampus, A. D., Pedrosa-Gerasmio, I. R., Maceren-Pates, M. D., & Bersaldo, M. J. I. (2024). Bioaccumulation of heavy metals and health risk assessment of the mangrove clam, *Pegophysema philippiana* (Reeve, 1850), in Davao region, Philippines. *AACL Bioflux*, 17(1), 407–420.
5. Baroroh Lili Utami, U., Heru, S., & Cahyono, B. (2020). Study of Duck Feather Modification using NaOH to Removal Iron in Acid Mine Drainage (AMD). *E3S Web of Conferences*, 202, 1–11. <https://doi.org/10.1051/e3sconf/202020205002>
6. Basak, A. K., Hossain, M. R., Pramanik, A., Shah, D. R., Prakash, C., Shankar, S., & Debnath, S. (2021). Use of duck feather waste as a reinforcement medium in polymer composites. *Cleaner Materials*, 1(December), 100014. <https://doi.org/10.1016/j.clema.2021.100014>
7. Chen, H., Gao, S., Li, Y., Xu, H. J., Li, W., Wang, J., & Zhang, Y. (2022). Valorization of Livestock Keratin Waste: Application in Agricultural Fields. *International Journal of Environmental Research and Public Health*, 19(11). <https://doi.org/10.3390/ijerph19116681>
8. Chinedu, & Chukwuemeka. (2018). Oil Spillage in the Niger Delta, Nigeria. In *Journal of Health & Pollution (Vol. 8, Issue 19)*.
9. Di, Z., Chang, M., & Guo, P. (2019). Water quality evaluation of the Yangtze River in China using machine learning techniques and data monitoring on different time scales. *Water (Switzerland)*, 11(2). <https://doi.org/10.3390/w11020339>
10. Diwa, R. R., Deocaris, C. C., Geraldo, L. D., & Belo, L. P. (2023). Ecological and health risks from heavy metal sources surrounding an abandoned mercury mine in the island paradise of Palawan, Philippines. *Heliyon*, 9(5). <https://doi.org/10.1016/j.heliyon.2023.e15713>
11. Geremew, B. (2017). A Review on Elimination of Heavy Metals from Wastewater Using Agricultural Wastes as Adsorbents. *Science Journal of Analytical Chemistry*, 5(5), 72. <https://doi.org/10.11648/j.sjac.20170505.12>
12. Havryliak, V., Mykhaliuk, V., Petrina, R., Fedorova, O., Lubenets, V., & Novikov, V. (2020). Adsorbents based on keratin for lead and cadmium removal. *Current Applied Science and Technology*, 20(1), 136–143. <https://doi.org/10.14456/cast.2020.3>
13. Hikmat, K., Aziz, H., Mustafa, F. S., & Omer, K. M. (2023). RSC Advances efficient and low-cost removal approaches to eliminate their toxicity: a review. 17595–17610. <https://doi.org/10.1039/d3ra00723e>
14. Jin, X., Lu, L., Wu, H., Ke, Q., & Wang, H. (2013). Duck feather/nonwoven composite fabrics for removing metals present in textile dyeing effluents. *Journal of Engineered Fibers and Fabrics*, 8(3), 89–96. <https://doi.org/10.1177/155892501300800311>
15. Jumoke, M., & Ajayi, E. (2025). Environmental and Public Health Impacts of Heavy Metal Contamination in Coastal and Freshwater Edible Species. 16(4), 1–23.
16. Lubal, M. J. (2024). Health Effects of Heavy Metal Contamination in Drinking Water. 45(10), 16–25. <https://doi.org/10.56557/UPJOZ/2024/v45i104041>
17. Paşayev, N., Kocatepe, S., & Maraş, N. (2019). Investigation of sound absorption properties of nonwoven webs produced from chicken feather fibers. *Journal of Industrial Textiles*, 48(10), 1616–1635. <https://doi.org/10.1177/1528083718766843>
18. Pet, I., Sanad, M. N., Farouz, M., ElFaham, M. M., El-Hussein, A., El-sadek, M. S. A., Althobiti, R. A., & Ioanid, A. (2024). Review: Recent Developments in the Implementation of Activated Carbon as Heavy Metal Removal Management. *Water Conservation Science and Engineering*, 9(2), 1–15. <https://doi.org/10.1007/s41101-024-00287-3>
19. Pleto, J. V. R., Migo, V. P., & Arboleda, M. D. M. (2020). Preliminary Water and Sediment Quality Assessment of the Meycauayan River Segment of the Marilao-Meycauayan-Obando River System in Bulacan, the Philippines. *Journal of Health and Pollution*, 10(26), 1–9. <https://doi.org/10.5696/2156-9614-10.26.200609>
20. Rahman, M. S., Bansal, N., Rahman, M. H., & Mortula, M. (2025). Date Seed-Derived Activated Carbon: A Comparative Study on Heavy Metal Removal from Aqueous Solutions. *Applied Sciences (Switzerland)*, 15(6). <https://doi.org/10.3390/app15063257>
21. Sani, A., Abdullahi, I. L., & Salmanu, T. (2020). Assessment of heavy metals profile in feathers of birds from kano metropolis, nigeria, in 2019. *Environmental Health Engineering and Management*, 7(4), 257–262. <https://doi.org/10.34172/EHEM.2020.30>
22. Siddique, A. B., Al Helal, A. S., Patindol, T. A., Lumanao, D. M., Longatang, K. J. G., Rahman, M. A., Catalvas, L. P. A., Tulin, A. B., & Shaibur, M. R. (2025). Assessment of Heavy Metal Contamination and Ecological Risk in Urban River Sediments: A Case Study from Leyte, Philippines. *Pollutants*, 5(1), 1–32. <https://doi.org/10.3390/pollutants5010007>
23. Solgi, E., & Zamaninan, A. (2020). Biosorption of Chromium and Nickel from Aqueous Solution by Chicken Feather. *Archives of Hygiene Sciences*, 9(2), 97–108. <https://doi.org/10.29252/archhygsci.9.2.97>
24. Tripathi, A., & Ranjan, M. R. (2015). Bioremediation & Biodegradation Heavy Metal Removal from Wastewater Using Low Cost Adsorbents. 6(6). <https://doi.org/10.4172/2155-6199.1000315>
25. Wang, H., Jin, X. Y., & Wu, H. B. (2016). Adsorption and desorption properties of modified feather and feather/polypropylene melt-blown filter cartridge of lead ion (Pb<sup>2+</sup>). *Journal of Industrial Textiles*, 46(3), 852–867. <https://doi.org/10.1177/1528083715598896>
26. Zhang, P., Yang, M., Lan, J., Huang, Y., Zhang, J., Huang, S., Yang, Y., & Ru, J. (2023). Water Quality Degradation Due to Heavy Metal Contamination: Health Impacts and Eco-Friendly Approaches for Heavy Metal Remediation. In *Toxics (Vol. 11, Issue 10)*. Multidisciplinary Digital Publishing Institute (MDPI). <https://doi.org/10.3390/toxics11100828>
27. Zhang, Y., Zhao, W., & Yang, R. (2015). Steam Flash Explosion Assisted Dissolution of Keratin from Feathers. *ACS Sustainable Chemistry and Engineering*, 3(9), 2036–2042. <https://doi.org/10.1021/acssuschemeng.5b00310>