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Isolation and Characterization of Humic Acid from Soil Humus from Ahuru Area, Ambon Island, and its Application as Adsorbent for Metal Ions Cu(II) and Pb(II)

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Abstract

Research on the isolation and characterization of humic acid from soil humus in the Ahuru area, Ambon Island, has been conducted. The isolation and purification of humic acid were carried out using an extraction method based on its solubility in a 0.1 M NaOH solution and precipitation in 6 M HCl. Based on the research findings, the humic acid content was determined to be 8.53%. Characterization was performed using an FTIR spectrophotometer to analyze the absorption profile and functional groups present in the isolated humic acid. The characterization results revealed that humic acid contains alcoholic and phenolic OH groups, aromatic C=C, carboxylic C=O, and conjugated alkenes with ketone C=O. The isolated humic acid was then utilized as an adsorbent for Cu(II) and Pb(II) metal ions at an optimum pH of 5, with a contact time of 60 minutes for Cu(II) metal ions and 90 minutes for Pb(II) metal ions. The study results indicated that the adsorption pattern for Cu(II) metal ions followed the Langmuir adsorption isotherm model, with an adsorption capacity of 928.54 mg/g at a concentration of 200 mg/L. Meanwhile, the adsorption capacity of humic acid for Pb(II) metal ions was 795.97 mg/g at a concentration of 200 mg/L.

Keywords: Adsorption, humic acid, Cu(II) metal ion, Pb(II) metal ion, FTIR, Langmuir, adsorption capacity.

INTRODUCTION

The continuous advancement of industry, along with technological development, has led to an increase in pollution. The large amount of industrial waste being discharged contributes to environmental pollution as it contains heavy metals. Heavy metals have a specific gravity greater than 5 g/cm^3, are toxic, and can accumulate in the bodies of living organisms (Duffus, 2002).

In order to mitigate the risks posed by metal contamination, especially that originating from human activities (anthropogenic sources), remediation or environmental restoration measures using adsorbents are necessary. One of the most effective adsorbent materials is humic acid. Kabata-Pendias and Pendias (1984) explained that heavy metals present in soil or sediment can undergo ion exchange and absorption processes, particularly on fine particles with a large surface area and negatively charged groups, such as humic acid, thereby reducing the potential hazards caused by toxic heavy metals. (Kabata-Pendias & Pendias, 1984).

Humic acid is a highly heterogeneous and complex natural organic material with varying functional group compositions, depending on several factors, including the type of plant or organic matter that forms humus, temperature, time, and the decomposition process. Consequently, the number of metal ions that can interact with these functional groups also varies. Several studies have been conducted on the isolation and application of humic acid.

The application of humic acid as an adsorbent was studied by Setyowati and Ulfin (2007), who investigated the adsorption of Al ions using humic acid (Setyowati & Ulfin, 2007). The study results indicated that the optimum conditions for aluminum adsorption by humic acid were achieved with a contact time of 105 minutes, at pH 6, and a concentration of 300 ppm. Another study by Yuliyati and Natanael (2016) on the determination of the adsorption capacity of humic acid

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for Pb(II), Cu(II), and Fe(II) metal ions revealed that the optimum contact time for Pb(II) metal ions was 100 minutes, whereas for Cu(II) and Fe(II) metal ions, the optimum contact time was the same, at 60 minutes (Yuliyati & Natanael, 2016).

Not much research has been conducted to determine the potential and types of humic acid in Maluku Province. Ambon Island has the potential to be a significant producer of humic acid, considering its climate and dense vegetation. The greater the diversity of plant species growing in an area, the better the quality of humus soil. A study by Male et al. (2022) on the isolation and characterization of humic acid from the Airlouw and Waai areas on Ambon Island, as well as Kairatu on Seram Island, revealed that the humic acid from these three locations contained carboxylic acid and hydroxyl (-OH) functional groups. The highest humic acid content, at 42.05%, was found in the Kairatu area (Male, et al., 2022). Recognizing this potential, researchers are interested in conducting further studies on the isolation and characterization of humic acid from humus soil for its application as an adsorbent for Cu(II) and Pb(II) metal ions. Research by Male et al. (2017) indicated that the waters of Ambon Bay had been polluted with heavy metals such as Cd and Pb (Male et al., 2017), and Haupea et al (2022) who researched Pb(II) content in the waters of Hitu Village (Haupea, et al., 2022). Similarly, the waters of Saparua Island have been contaminated with Cu and Pb metals (Anakotta, et al., 2025). Maluku's waters have also been contaminated by the toxic metal mercury due to illegal gold mining on Buru Island (Male, et al., 2013; Reichelt-Brushett et al., 2017; Mariwy, et al., 2019; Irsan et al., 2025) and illegal cinnabar (HgS) mining on Seram Island (Male, et al., 2024).

METHODOLOGY

Soil sample collection and characterization

Soil humus samples were collected from the Ahuru Area, Ambon Island, at coordinates S 03º 19' 13.39" – E 127º 04' 23.22". The samples were taken from the top layer of soil, which is the darkest in color, indicating a high content of organic compounds. The samples were collected using a plastic spoon from the surface soil (0-10 cm) of the tropical rainforest, then stored in polyethylene bags and transported on ice to Pattimura University, Ambon, where they were immediately frozen. The samples were dried at 35–40 °C for 48 hours before analysis.

Soil sample preparation, humic acid isolation, humic acid purification, determination of humic acid cation exchange capacity, and heavy metal adsorption by humic acid were carried out at the Inorganic Chemistry Laboratory, while characterization using FTIR was conducted at the Organic Chemistry Laboratory, Faculty of Science and Technology, Pattimura University. Measurement of heavy metal concentrations using AAS (Atomic Absorption Spectrometer) was performed at the Baristand Laboratory, Ambon. The samples were cleaned of visible impurities, washed with 1 M dilute HCl to remove lime ($CaCO_3$), rinsed repeatedly with distilled water, filtered, and dried at a temperature of 60 °C. The dried soil samples were then ground and sieved using a 100 mesh sieve and stored in a desiccator.

Humic Acid Isolation and Purification (Santosa, et al., 2014)

Several soil samples were shaken for 24 hours with a 0.1 M NaOH solution, with a soil sample to NaOH solution weight ratio of 1:10. The supernatant was then separated from the soil residue by centrifugation at 3,000 rpm for 15 minutes. The supernatant was collected and centrifuged again at 3,000 rpm for 15 minutes. The collected supernatant contained fulvic acid and humic acid, and these two acid compounds were separated by acidifying the supernatant with 6 M HCl to a pH of 1.5. The precipitated fraction was humic acid, while the remaining solution contained fulvic acid and other organic acids.

Purification of humic acid was carried out three times by dissolving it in a 0.1 M NaOH solution and precipitating it with HCl solution at pH 1.5. The humic acid was then washed with a mixture of 1 M HCl and 1 M HF in a 1:1 volume ratio. The resulting humic acid was re-dissolved in a 0.1 M NaOH solution, diluted, and passed through a Dowex 50-X8 cation exchange column. Finally, the solution was dried and weighed.

Determination of Cation Exchange Capacity (SNI 13-3494-1994)

6 g of silica sand was washed using a hot 0.1 M HCl solution and then washed again with distilled water until the pH was neutral. An ion exchange column was filled with 2 cm of glass wool, followed by a 0.2 cm layer of silica sand. Solution 1 N ammonium acetate was added to the silica sand and glass wool until the height reached 1 cm. Humic acid (0.25 g) was then added, and the column walls were rinsed with 1 N ammonium acetate until the height reached 5 cm. The column was then eluted successively with 100 mL each of 1 N ammonium acetate and ethanol. Both eluates were discarded.

The sample was eluted with 100 mL of 10% potassium chloride solution. 50 mL of the collected eluate was pipetted, then added to 30 mL of 10% NaOH solution and 50 mL of distilled water, and distilled. The resulting distillate was treated with 5 mL of 0.1 N HCl solution and 25 mL of distilled water, bringing the volume to 75 mL. The distillate was then titrated twice with 0.1 N NaOH solution using methyl orange (MO) as the indicator. The cation exchange capacity is calculated using the formula.

$$\mathrm{KTK}\left(\frac{\mathrm{me}}{100\mathrm{g}}\right) = \mathrm{Vt}\, xN\ NaOH\ \frac{\mathrm{Ve0}}{\mathrm{Ve1}}\ x\ \frac{100}{m\ AH}\ \ldots\ldots.\ (1)$$

where:
Vt = volume of titrant used
Ve0 = volume of eluate collected
Ve1 = volume of eluate pipetted
N NaOH = normality of NaOH
m AH = weight of humic acid sample

Preparation of Cu^{2+} and Pb^{2+} stock solution 1000 mg/L

The preparation of a 1000 mg/L Cu^{2+} stock solution was done by dissolving 0.3929 g of $CuSO_4{\cdot}5H_2O$ in distilled water and then diluting it to a final volume of 100 mL. The same method was applied for the Pb^{2+} stock solution by weighing 0.1599 g of $Pb(NO_3)_2$. From each stock solution, 2, 4, 6, 8, 10, and 20 mL were pipetted and each was diluted to 100 mL to produce solutions with concentrations of 20, 40, 60, 80, 100, and 200 mg/L, respectively

Capacity and Isotherm of Cu(II) and Pb(II) Adsorption (Yuliyati and Natanael, 2016; Rahmawati and Santoso, 2013)

A total of 10 mg of humic acid was interacted with 50 mL of Cu(II) and Pb(II) solutions with concentrations of 20, 40, 60, 80, 100, and 200 mg/L. The solution was adjusted to pH 5 for the adsorption of Cu(II) and Pb(II) onto humic acid. The solution was stirred with a magnetic stirrer and interacted for 60 minutes for Cu(II) and 90 minutes for Pb(II). The mixture was then separated using filter paper, and the filtrate was measured using an AAS instrument. From the AAS data, the final concentration of the sample (Ce) was determined, and the percentage and adsorption capacity were calculated using the following formula:

$$\mathrm{Q} = \frac{\mathrm{Co-Ce}}{\mathrm{Co}}\ \mathrm{x}\ 100\%\ \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots.\ (2)$$

$$\mathrm{q} = \mathrm{Co} - \mathrm{Ce}\ \mathrm{x}\ \frac{\mathrm{v}}{\mathrm{m}}\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.\ (3)$$

with:
Q = adsorption percentage
q = adsorption capacity
C0 = initial solution concentration
Ce = final solution concentration
(C0–Ce)= adsorbed solution concentration
v = metal solution volume
m = weight of humic acid

RESULTS AND DISCUSSION

Purification and Characterization of Humic Acid

Humic acid isolated from the soil in the Ahuru area, Ambon Island, yielded a content of 8.53% with a blackish-brown color (Figure 1). The humic acid content in this study was still higher than that isolated from coal by Yuliyati et al. (2016), which had a content of 7.12% (Yuliyati & Natanael, 2016). Another study by Rahmawati (2011), which isolated humic acid from peat soil in Sambutan Village, also yielded a relatively low content of 5.8% (Rahmawati, 2011).

Figure 1. Isolated humic acid

Spectroscopic characterization with FTIR aims to determine the functional groups present in the humic acid sample before and after being passed through the column. The IR spectrum of the humic acid sample is shown in Figure 2.

The infrared spectrum of humic acid after passing through the reduction column (Figure 2a) shows the presence of OH groups from alcoholic and phenolic compounds, with absorption at 3315.63–3415.93 cm^{-1}, exhibiting strong and broad intensity due to intramolecular hydrogen bonds in the humic acid. However, the possibility of the presence of an –NH group in this region cannot be ruled out. The absorption at 1031.92 cm^{-1}, which corresponds to the C-O stretch, further confirms the presence of alcohol in humic acid. Meanwhile, the absorption at 1643.35 cm^{-1} is identified as the stretching vibration of the –N-H amide group or from aromatic C=C, carboxylic C=O, and conjugated alkene with C=O ketone. Additionally, the aromatic –C=C group is marked by a weak absorption band at 1556.55 cm^{-1}. The presence of carboxylate is also supported by the absorption at 1384.89 cm^{-1}, which results from the C-O stretching of carboxylate and OH deformation in phenol. According to Ismillayli et al. (2015), the presence of carboxylate may be due to the ash in humic acid, which transforms the carboxylic acid into its salt form (Ismillayli, et al., 2015).

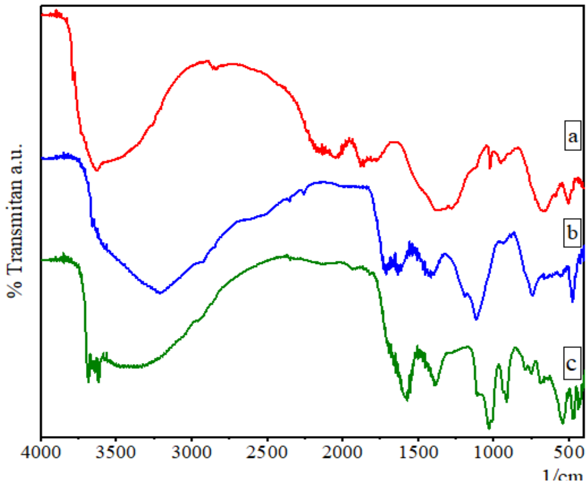


Figure 2. IR spectrum of (a) humic acid after passing through the column, (b) humic acid before passing through the column, and (c) standard humic acid (AH-90).

The spectrum of purified humic acid exhibited an unusual absorption band at 1083.99 cm^{-1}, indicating the presence of silicate impurities, supported by an absorption band at 1107.14 cm^{-1}, which identified the Si-O stretching vibrations. The Si-O stretching vibration indicates the presence of silica, which was isolated together with humic acid. This is possible because the concentration of the HF solution used in the silica dissolution process during humic acid purification was not high enough. The IR spectrum of humic acid before being passed through the reduction column (Figure 2b) shows absorption bands for functional groups that are similar to those in humic acid after passing through the reduction column, such as the OH group with an absorption band at 3271.27 cm^{-1}, the absorption band at 1643.35 cm^{-1}, which is interpreted as aromatic C=C and alkene conjugated with ketone, and C-O stretching, which is also seen at 1384.89 cm^{-1}.

The difference between humic acid before and after passing through the reduction column is observed in the presence of the O-Na group, which is only found in humic acid before being passed through the column, identified at 1415.75 cm^{-1}. This absorption band proves that the purification process using cation resin, particularly in removing Na^{+} ions, was successful. Humic acid before and after being passed through the column was then compared with commercial standard humic acid (AH-90). An absorption band at 1415.75 cm^{-1} was also observed in AH-90 because AH-90 is also enriched with minerals such as aluminum, silica, nitrogen, phosphorus, sodium, magnesium, and calcium, as indicated by the appearance of absorption peaks at 1445.68 cm^{-1} corresponding to O–Na functional groups. Furthermore, Si–O and Al–O vibrational bands are observed at a wavenumber of 1112.93 cm^{-1}, while the presence of Ca–O and Mg–O minerals is indicated by absorption at 543.93 cm^{-1}. These findings are consistent with the function and role of AH-90 in supplying essential nutrients such as N, P, K, and S to the soil, as well as carbon as an energy source for soil microorganisms. Consequently, AH-90 can be utilized as a complementary fertilizer to enhance plant growth (Hermanto, et al., 2012)

The results of the IR spectrum of standard humic acid (Figure 2c) show that, in addition to containing the functional groups typical of humic acid as reported by Stevenson (1994), the IR spectrum data indicate that the structure of humic acid contains functional groups such as –OH (alcohol and phenolic), aromatic hydrocarbons, ketones, carboxylates, and amines (Stevenson, 1994).

Cation Exchange Capacity Value

To calculate the cation exchange capacity, the following data were used: Titrant volume (Vt) of 4.2 mL, NaOH concentration of 0.1 N, collected eluate volume (Ve0) of 100 mL, pipetted eluate volume (Ve1) of 50 mL, and humic acid mass (m AH) of 0.25 g. Using Equation (1) to calculate the cation exchange capacity, the obtained value was 336 me/100g, which is higher than the CEC value of humic acid extracted from compost, and Ali and Mindari (2016), which was 85.72 me/100g (Ali & Mindari, 2016). According to Hanafiah (2005), the high CEC of humic acid is due to the large number of negative charges from carboxyl and phenolic groups in its mineral colloids (Hanafiah, 2005). The higher the CEC value of humic acid, the greater its ability to exchange cations.

Table 1. Data on the adsorption results of Cu(II) and Pb(II) metal ions by humic acid

Concentration of metal ion solution (mg/L)	Cu(II) Metal Ion			Pb(II) Metal Ion		
	C_0-Ce (mg/L)	Q (%)	q (mg/g)	C_0-Ce (mg/L)	Q (%)	q (mg/g)
20	18.7996	93.9980	93.9980	17.0222	85.1110	85.1110
40	37.7728	94.4320	188.8640	38.7728	96.9455	193.8910
60	57.2659	95.4432	286.3295	54.0893	90.1488	270.4465
80	73.6114	92.0142	368.0570	67.8948	84.8685	339.4740
100	91.4217	91.4217	457.1085	72.4508	72.4508	397.2540
200	185.7077	92.8538	928.5385	159.1932	79.5966	795.9660

Description:
C0-Ce = concentration of adsorbed metal (mg/L)
Q = adsorption efficiency (%)
q = adsorption capacity at equilibrium (mg/g)

Determination of Adsorption Capacity of Cu and Pb Metal Ions by Humic Acid

The determination of adsorption capacity was conducted by varying the concentration of Cu(II) and Pb(II) metal ions to assess the adsorption capacity of humic acid under optimal pH and contact time conditions. The experiment was carried out at pH 5 and a contact time of 60 minutes for Cu metal, while for Pb metal, the contact time was set to 90 minutes, referring to the research conducted by Yuliyati and Natanael (2016) with the same procedure for determining optimal pH and time. The results obtained from measurements using AAS were used to calculate the absorbed concentration, adsorption percentage, and adsorption capacity, as shown in Table 1 and Figure 3.

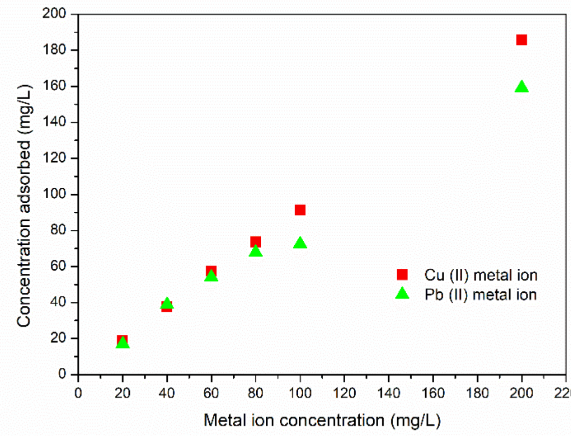
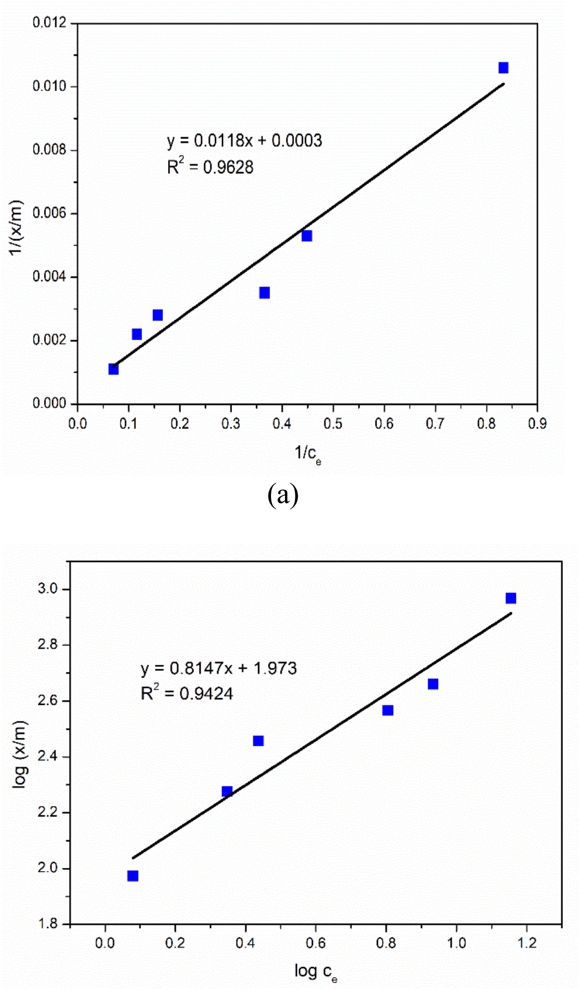


Figure 3. Graph of the relationship between solution concentration and the amount of metal absorbed.

Figure 3 shows an increase in the number of metal ions adsorbed as the concentration of the interacting metal ions increases. However, as the concentration absorbed increases, the adsorption efficiency decreases at solution concentrations of 80-200 mg/L for Cu metal and 60-200 mg/L for Pb metal. This occurs because, at higher concentrations, the number of metal ions in the solution is no longer proportional to the amount of humic acid available, causing the surface of the humic acid to reach its saturation point. There is also the possibility of a desorption or re-release process between the adsorbent and the adsorbate.

The optimum absorption condition was achieved at a concentration of 60 mg/L for Cu(II) metal ions and 40 mg/L for Pb(II) metal ions, with absorption efficiencies of 95.44% and 96.95%, respectively. This indicates that at low concentrations, the ratio of metal ion moles causes the surface area of the humic acid sites to become wider, and adsorption is influenced by the low initial concentration. It can be concluded that the adsorption process follows a nonlinear pattern, meaning the number of adsorbed ions is not proportional to the number of non-adsorbed ions and does not follow a constant ratio.

To explain the adsorption of metal ions by humic acid, two commonly used adsorption isotherm equations are the Langmuir and the Freundlich isotherms. The Freundlich isotherm is based on multilayer absorption on the surface of heterogeneous adsorbents, while the Langmuir isotherm assumes monolayer coverage of the adsorbent on a homogeneous surface. The Langmuir type 2 isotherm is based on the relationship of 1/Ce to 1/(x/m), while the Freundlich isotherm is based on the relationship of log Ce to log (x/m). Based on the parameters obtained from the Langmuir and the Freundlich isotherms (Table 2), Langmuir isotherm curves and Freundlich isotherm curves are presented in Figure 4, and the correlation coefficient values (R^2) are compared.



(a)

(b)

Figure 4 (a) Langmuir type 2 isoterm, and (b) Freundlich isotherm of adsorption of Cu (II) metal ions by humic acid.

From the regression coefficients obtained for each equation, it can be determined that the adsorption of Cu(II) metal ions by humic acid follows the Langmuir equation (chemical adsorption). The regression coefficient for the Langmuir equation is 0.9628, which is greater than the regression coefficient from the Freundlich equation, which is 0.9424. In accordance with Langmuir's theory, the adsorbent surface contains active sites proportional to the surface area, and each active site can only adsorb one molecule. El-Eswed & Khalili, (2006) also reported that the adsorption of Cu(II) onto solid Azrac acid (AZHA) at pH 3.7 fit the Langmuir-Freundlich model. The result Indicated that the adsorption capacity (maximum adsorption, q_{max}) for Cu (II) on humic acid is approximately 0.1 to 1.0 mmol/g and reported a high correlation coefficient $R^2 > 95\%$.

The modification of the Langmuir equation by Sohn and Kim (2005) (Table 3) has also been applied in the adsorption of Cu(II) metal ions based on the relationship $({}^{1}/C_e)^{\mathbf{a}}$ with variations in the value of ***a*** and the data were plotted against ${}^{1}/(x/m)$, resulting in the values shown in Table 2. Figure 5 shows the relationship between 1/(x/m) and $[1/C]^{\mathbf{a}}$, where the exponent ***a***, according to Sohn and Kim (2005), is an appropriate parameter for determining the best linear regression in a given system. As shown in Table 4, the value of a=1.6 provides the highest correlation coefficient R^2 of 98.07%. The Langmuir equilibrium model is based on the assumption that adsorption occurs on a homogeneous surface (Sohn & Kim, 2005).

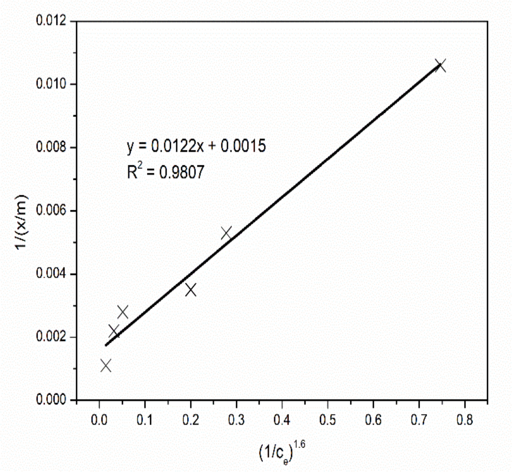


Figure 5. Modified Langmuir isotherm by Sohn and Kim (2005) with a=1.6.

The Langmuir and the Freundlich isotherm parameters for Pb(II) metal ions are shown in Table 5 and Figure 6. Based on the correlation coefficients shown in the curve, it can be observed that the adsorption of Pb(II) metal ions by humic acid does not follow either the Langmuir or the Freundlich isotherm, as the correlation coefficient (R^2) values are ≤ 0.9. The R^2 value for the Langmuir isotherm is 0.6885, while for the Freundlich isotherm, it is 0.6478.

Table 2. Langmuir and Freundlich isotherm parameters for Cu(II) metal ions

Co (ppm)	**Ce (ppm)**	**Co-Ce (ppm)**	**x/m (mg/g)**	**1/Ce**	**1/(x/m)**	**Log Ce**	**Log x/m**
20	1.2004	18.7996	93.9980	0.8331	0.0106	0.0793	1.9731
40	2.2272	37.7728	188.8640	0.4490	0.0053	0.3478	2.2761
60	2.7341	57.2659	286.3333	0.3657	0.0035	0.4368	2.4569
80	6.3886	73.6114	368.0570	0.1565	0.0028	0.8054	2.5659
100	8.5783	91.4217	457.1090	0.1166	0.0022	0.9334	2.6600
200	14.2923	185.7080	928.5390	0.0699	0.0011	1.1551	2.9677

Table 3. Modified Langmuir isotherm parameters by Sohn and Kim (2005) for Cu(II) metal ions.

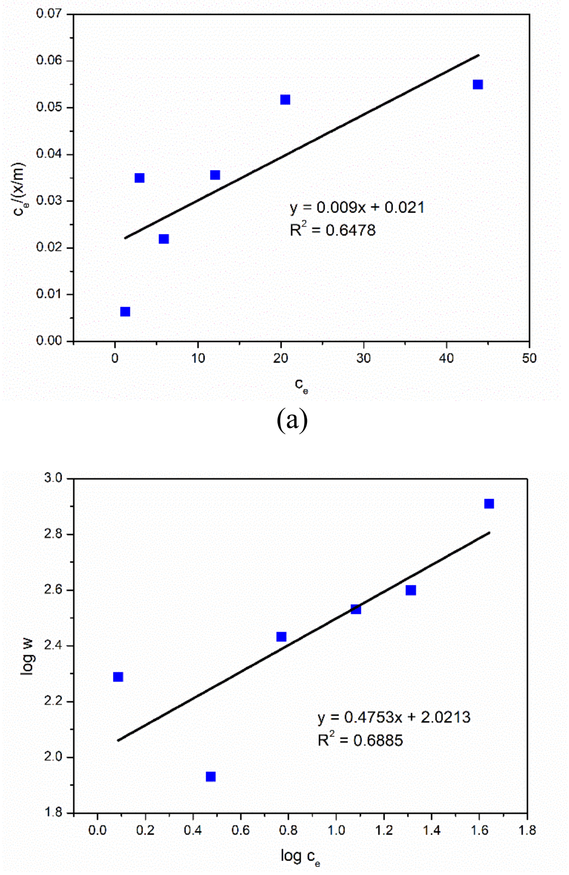
1/(x/m)	**$(1/Ce)^a$ (mg/L)**					
	1	**1.2**	**1.4**	**1.6**	**1.8**	**2**
0.0106	0.8331	0.8032	0.7744	0.7466	0.7198	0.6940
0.0053	0.4489	0.3825	0.3259	0.2777	0.2367	0.2016
0.0035	0.3658	0.2991	0.2402	0.2000	0.1636	0.1338
0.0028	0.1565	0.1080	0.0745	0.0514	0.0355	0.0245
0.0022	0.1166	0.0758	0.0493	0.0321	0.0209	0.0136
0.0011	0.0699	0.0411	0.0241	0.0142	0.0083	0.0049

Table 4. Modified Langmuir isotherm equation by Sohn and Kim (2005) for various values of *a*.

Value variation of a	**Linear Equation (y = ax+b)**	**R^2 (%)**
1	y = 0.0118x + 0.0003	96.28
1.2	y = 0.0118x + 0.0009	97.47
1.4	y = 0.012x + 0.0012	98.03
1.6	y = 0.0122x + 0.0015	98.07
1.8	y = 0.0125x + 0.0018	97.71
2.0	y = 0.0128x + 0.0019	97.07

Table 5. Langmuir and Freundlich isotherm parameters for Pb(II) metal ions.

Co (ppm)	**Ce (ppm)**	**Co-Ce (ppm)**	**x/m (mg/g)**	**Ce/(x/m)**	**Log Ce**	**Log W**
20	2.9778	17.0222	85.1110	0.0350	0.4739	1.9299
40	1.2218	38.7728	193.8910	0.0063	0.0870	2.2876
60	5.9107	54.0893	270.4470	0.0218	0.7716	2.4321
80	12.1052	67.8948	339.4740	0.0356	1.0830	2.5308
100	20.5492	72.4508	397.2540	0.0517	1.3128	2.5991
200	43.8068	159.1930	795.9660	0.0550	1.6415	2.9090



(a)

(b)

Figure 6. (a) Langmuir isotherm and (b) Freundlich isotherm for the adsorption of Pb(II) metal ions by humic acid.

CONCLUSION

This study shows that the humic acid content isolated from soil humus in the Ahuru region, Ambon Island, is 8.53%. The infrared spectrum data of pure humic acid indicate the presence of alcoholic and phenolic –OH groups, amide –N-H, aromatic C=C, carboxylate C=O, and conjugated alkene with ketone C=O, which are consistent with the hypothetical structure of humic acid isolated in previous studies. The adsorption pattern for Cu(II) metal ions follows the Langmuir adsorption isotherm model, with an adsorption capacity of 928.54 mg/g at a concentration of 200 mg/L, while the adsorption capacity for Pb(II) metal ions is 795.97 mg/g at a concentration of 200 mg/L.

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