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Efficiency of Biochar and *Bacillus* sp. in The Remediation of Cadmium (Cd) Contaminated Soil

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Abstract

Background: *Soil contamination occurs when chemical produced by humans pollute and alter the natural conditions of the soil. Contamination caused by heavy metals is very dangerous and can cause harm to the life of organisms through the food chain. This study aims to determine the effectiveness of biochar and Bacillus sp in reducing Cd heavy metal levels. This study used contaminated soil with Cd levels of 2.59 ppm, pH 7.52, C-organic 1.30%, and CEC 18.35 Cmol/kg.* **Methodology:** *The research method used a factorial randomized block design with 2 treatment factors, each consisting of 3 levels: the first factor is biochar dosage, comprising B0 (without biochar), B1 (biochar 20 tons/ha, and B2 (biochar 40 tons/ha) and the second factor is bacterial concentration, comprising C0 (without Bacillus sp), C1 (Bacillus concentration 10^5), as well as C2 (Bacillus concentration 10^8). Further analysis if there are different ANOVA results, the BNJ 5% Test will be performed.* **Findings:** *the results showed that the combination of biochar 40 tons/ha with bacillus 10^5 (B2C1) was able to reduce Cd heavy metal levels by 52% over a 4-week incubation period, in addition to reducing heavy metal levels, it also increased soil pH. Cations that are on the surface of the biochar will exchange ions with heavy metals in the soil. Carboxyl –COOH functional groups found in biochar can be released as H^+ ions, forming complexes with heavy metal ions and heavy metal ions will be bind to the surface of Bacillus sp. cells containing carboxyl groups, renderingthe the heavy metals unavailable.* **Contribution:** *this study reveals the combination of biochar and Bacillus, where biochar provides an optimal microbial habitat, thuereby increasing remediation efficiency. In addition to knowing the interaction between organic materials with heavy metals and the development of natural and sustainable remediation.*

Keywords: *Bacillus* sp.; *Biochar; Heavy Metals; Remediation*

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INTRODUCTION

Soil pollution occurs when chemical produced by humans contaminate and alter the natural conditions of the soil. Typically, this pollution is caused by spills of liquid or solid waste, both organic and inorganic. This waste enters and is absorbed into the soil and cannot be decomposed, causing damage to the soil (Puspawati & Haryono, 2018).

Pollution caused by heavy metals is very dangerous and can cause harm to organisms through the food chain. Toxins produced by heavy metals can interfere with the metabolism of organisms because these toxic substances serve as a barrier to enzymes in metabolic and physiological (Wijayati & Purwanti, 2022). This impact is strongly related to the biological availability of heavy metals, which is ultimately influenced by the amount of metal ions in the soil. The measurement of the concentration level of free metal ions in the soil solution is very important. The concentration of metal ions depends not only on the total metal in the soil, but also on the type of metal present in the soil. In addition, several environmental factors such as pH, concentration of solution in the soil, and soil colloids also affect (Nazir *et al*., 2015).

Heavy metals generally affect the environment and living things. These heavy metals are important to support physiological and biochemical processes in living beings, but in very small quantities. If the amount exceeds a certain concentration threshold, these heavy metals can become very dangerous (Jaishankar et al., 2014). Heavy metals are pollutants that cannot be broken down or destroyed, so they can accumulate both in the body of organisms as well as in nature. The toxicity of heavy metals can be influenced by several factors, including the solubility of heavy metals in liquids, the form of the compound, and several other chemical and physical properties (Rusman & Efrizal, 2020).

Cadmium (Cd) is a pollutant and non-essential heavy metal with high tosicity. Cadmium is soluble and easier to move into the soil than other heavy metals. Sources of cadmium pollution in the environment are caused by human activities such as the use of energy from fossil fuel sources and mineral mining. While in agricultural land cadmium pollution caused by the use of chemical fertilizers, chemical pesticides, and irrigation water contaminated (Henao & Herrera, 2021). Naturally, the soil contains cadmium metal (Cd) with a low average, which is 0.4 mg/kg. In uncontaminated soil, cadmium levels range from 0,06 to 1,1 mg/kg (Aji & Lestari, 2020).

The presence of heavy metals such as Cd in excessive amounts in the soil will accumulate in the food chain, adversely affecting living beings. The concentration of heavy metals in soil contaminated by Lapindo mud contains cadmium (Cd) at 28,84 mg/kg (Fitra et al., 2013). According to research Purnomo & Soegiyanto (2017), the heavy metal centent in agricultureal land located near the mudflow was 2,360-3.002 ppm (Cd). Soils contaminated with heavy metals usually has low soil fertility. Heavy metals in the soil will poison the microorganisms so that the population decreases and the impact on biological activity in the soil becomes inhibited. In addition, there are several types of heavy metals that change the pH of the soil to be more acidic or alkaline than the optimal range of soil pH for plant growth. The change in pH makes the availability of nutrients limited. Heavy metals in agricultural lands are caused by excessive use of fertilizers and pesticides. For this reason, it is necessary to make efforts to clean up excess heavy metal contamination in the soil.

One way to improve land polluted with heavy metals is by doing bioremediation. Bioremediation is a process of improving polluted land that involves the use of certain microorganisms that have been selected to be able to grow on certain types of pollutants, so as to reduce the concentration of these pollutants. A wide range of microorganisms have demonstrated the ability to remediate heavy metals, including bacterial species such as *Bacillus* sp., *Pseudomonas* sp., and *Escherichia coli*; filamentous fungi such as *Penicillium chrysogenum*, *Rhizopus stolonifer*, and *Aspergillus oryzae*; and yeasts such as *Saccharomyces cerevisiae* (Rahadi et al., 2019).

Use *of Bacillus* sp. chosen because *Bacillus* sp is able to remediate various pollutants, *Bacillus* can produce catalase enzymes that function to break down harmful substances that can accumulate in bacterial cells and reductase enzymes that play a role in lowering heavy metal toxicity levels by changing the chemical structure of heavy metals into non-toxic forms (Uno & thalib, 2020). *Bacillus* sp. Is capable of accumulating approximately 87% of cadmium (Cd) heavy metal (Lata et al., 2021).

Organic materials such as rice husk biochar can also be used as a remediator to remediate land contaminated with heavy metal. Rice husk biochar is a biological charcoal derived from Rice Management. Biochar made from rice husk has a compostition of 50 % cellulose, 25-30 % lignin, dan 15-20 % siliaca and has a moisture content of up to 10-15 % (Karam et al, 2022). Biochar rice husk has a relatively high ash content that affects the pH and mineral composition of biochar. Additionally, the carbon content in rice husk biochar affects the storage of the amount of carbon used as adsorption of pollutants in the soil (Puspita et al., 2021). Due the these issues, this study was conducted to assess the effectiveness of biochar combined with *Bacillus* sp in suppressing the availability of Cd heavy metals in the soil.

METHOD

This study was conducted in Sepande Village, Candi District, Sidoarjo Regency in the incubation process. Soil analysis was carried out at the Land Resources Laboratory and the manufacture of bacterial isolates at the Soil Health Laboratory of the Faluktas Agriculture UPN "Veteran" East Java in November 2023 – January 2024. The materials used in this study are CD contaminated soil, biochar, *Bacillus* sp isolates. media nutrien agar (NA), media nutrient borth (NB), dan aquades. The tools used in this study include sieve, cetok, analytical scales, Beaker cups, measuring flasks, test tubes, vortices, pH meters, atomic absorption specrofometers (SSA), pipettes, erlenmeyer, and petri dishes. The observation parameters consist of pH (elektrometer/pH meter), Cd levels (SSA), CEC (kolorimetri), dan C-organic (Walkey and Black) for analysis before treatment, analysis after treatment consist of pH dan Cd.

The research method used is a factorial shelf that includes 2 kinds of treatment factors that consist of 3 levels, the first factor is the dose of biochar consisting of B0 (without biochar), B1 (biochar 20 tons/ha, and B2 (biochar 40 tons/ha) and the second factor is the concentration of bacteria consisting of of C0 (without Bacillus sp), C1 (Bacillus concentration 10^5), as well as C2 (Bacillus concentration 10^8).Both treatment factors with each of which has been determined were obtained 9 combinations of treatments that were repeated 3 times so that 27 experimental units were obtained.

Table 1. Combination of Remediation Treatment of Heavy Metal Contaminated Land

Biochar Dose	Konsentrasi *Bacillus* sp. Concentration		
	C0	**C1**	**C2**
B0	B0C0	B0C1	B0C2
B1	B1C0	B1C1	B1C2
B2	B2C0	B2C1	B2C2

Further analysis if there are different ANOVA results, the BNJ 5% Test will be performed. Heavy metal content of allowance efficiency calculation is done by the following formula (Fadlilah et al., 2018):

$$\text{Removal efficiency: } \frac{(\text{Co}-\text{Ce})}{\text{Co}} \text{ x } 100\ \%$$

Description:
Co = initial concentration parameter
Ce = final concentration parameter

Research Procedure

Preliminary analysis on soil research was conducted to determine the condition and initial characteristics of the soil before treatment. The analysis is carried out using disturbed soil samples at a depth of 0 - 20 cm. The soil sample will be air-dried for approximately 7 days. Then the soil is pounded and sieved using a 0.5 mm sieve. The fine soil is analyzed in the laboratory to obtain information on the initial condition of the soil before remediation. The analysis included Cd, pH, CEC, and C-organic heavy metal content.

Soil Sampling

Soil samples used using disturbed soil samples. Soil samples were taken compositively at Five sampling points at a depth of 0-20 cm on polluted land in Besuki Village, Jabon District, sidoarjo regency. Then the soil sample is air-dried for approximately 7 days.

Preparation of the soil for incubation

Preparation of the soil to be incubated is carried out one week before treatment. Soil that has been dried by the wind is loosened and sifted using a 2mm sieve to obtain soil that has fine grains. The soil is then put into a polybag as much as 4 kg equivalent weight of air dry soil in each polybag.

Preparation of *of Bacillus* sp. suspention

Rejuvenation of Bacillus sp. Bacteria

Bakteri *Bacillus* sp bacteria that are inactive due to the storage process in the refrigeration chamber must be bacterial rejuvenation aimed at obtaining active Test bacteria. Bacterial isolates used are isolates *of bacillus* sp Bth 22 collection from Dr. Ir. Arika Purnawati, MP. Rejuvenation of bacterial isolates was carried out by scraping OSE needles on bacterial isolates *of Bacillus* sp. on the new oblique na medium in the test tube. The bacterial isolates to be used for testing were incubated at room temperature for 24 hours.

Preparation of Bacillus sp. Bacterial Suspension

The Preparation of Bacillus sp. Bacterial suspention begins with calculating the density of the bacterial suspension by adding 10 ml of sterile aquades to a test tube containing a 24 hour old Bacillus sp isolate and rubbing the surface of the isolate medium using an ose needle. Then, take 1 ml of suspension and put it into a test tube containing 10 ml of sterile aquades and perform a serial dilution to 10^8. Next, take 1 ml of suspension using a micropipette at the last dilution and spread it on a petri dish containing Na medium to count the number of colonies after 24 hours. The calculation of the required colony is at a bacterial density of 10^5 and 10^8 CFU/ml. Prepare a *Bacillus* sp. Suspetion by taking 1-2 inoculan of 48 hour old bacteria on slanted NA medium and mixing the into NB (Nutrient Broth) medium in an erlenmeyer flask. The mixture of bacterial isolates and NB medium was homogenized using vortex and incubated for 24 hours.

Application of Biochar & Bacillus sp. on Soil

Biochar and *Bacillus sp.* were applied by mixing biochar and soil until evenly blended. The bacterial inoculum was applied by evenly sprinkling 20 ml/kg of *Bacillus* sp. liquid inoculum on the incubated soil. The treated soil was maintained by keeping the soil moisture to 60% by using aquades.

RESULT AND DISCUSSION

Soil Characteristics Before Treatment

This study used soil contaminated with heavy metal cadmium (Cd) from lapindo mud contaminated land area in Besuki Village, Jabon District, Sidoarjo regency. The chemical properties of the soil play a major role in the movement of heavy metal fractions. Several environmental factors can affect the speed of absorption of heavy metals and change physiological conditions, making the presence of heavy metals dangerous. Chemical characteristics analyzed in this study include pH H_2O, Cd^{2+}, cation exchange capacity (CEC), and C-organic. Soil analysis before treatment is important to determine the characteristics and initial condition of the soil before the study. The results of the preliminary analysis of the soil before treatment are shown in Table 2.

The characteristics of the soil before treatment (Table 2) show that the soil used for research had a pH of 7.52, which is classified as neutral category. PH analysis is useful to determine the degree of acidity and alkalinity in the soil. pH in the soil has an important influence for the activity of microorganisms and the availability of nutrients in the soil. In addition, the pH value of the soil affects the mobility and solubility of heavy metals in the soil. Heavy metals tend to be more mobile and soluble and easily absorbed by plants under acidic pH conditions (<6), while at alkaline pH (>7) heavy metals tend to precipitate and reduce their availability in plants (Nur, 2013).

Table 2. Soil Analysis Result Before Treatment

No.	Parameter	Unit	Result	Criteria (*)	Threshold Value
1.	pH H_2O	-	7.52	Neutral	-
2.	Cd^{2+}	ppm	2.59	Contaminated	0.50
3.	CEC	$Cmol.kg^{-1}$	18.35	Moderate	-
4.	C-Organic	%	1.30	Low	-

Note (*): Criteria soursed from Juknis Kimia Tanah BPSITP (2023) and threshold values sourced from Ministry of State For Population And Environment Of Indonesia, And Delhousie University, Canada (1992) .

Heavy metals are naturally contained in the soil in relatively low amounts. Cadmium content in non-polluting soil is 0.1-1, some types of soil affect the content of heavy metals (Suastawan et al., 2016). Logam berat yang terdapat dalam lumpur Lapindo antara lain yaitu Fe, Cd, Pb, Cr, Zn, Ni, Hg, and As (Ciptawati et al., 2022). In addition, lapindo mud also contains harmful gases that have a pungent odor. The results of soil analysis before treatment showed that the soil contains heavy metal cadmium (Cd) of 2.59 ppm including exceeding the threshold so that the soil is contaminated with heavy metal Cd. Based on Ministry of State for Population and Enviromental of Indonesia-Dalhousie University Canada (1992), soil is considered contaminated if it exceeds the critical threshold, which for cadmium is 0.50 ppm.

The results of CEC analysis before treatment showed that the soil has CEC denagan moderate criteria with a value of 18.35 $Cmol.Kg^{-1}$. cation exchange capacity is the ability of the soil to absorb and Exchange cations, including positively charged heavy metal ions such as Cd^{2+} and Pb^{2+}. The CEC value is influenced by soil texture, pH, and organic matter content (Hareva & Zebua, 2024).

C-organic content in the soil before treatment based on (Tabel 2) showed that the soil has a C-organic content of 1.30% which is included in the low category. The presence of C-organics in the soil affects the activity of microorganisms, nutrient availability, and heavy metal activity. C-organic will form a complex with heavy metals so as to reduce the toxicity and mobility of heavy metals in the soil. According to Sari et al., (2023) the C-organic form includes all organic matter that resides in and on the soil surface. Organic matter is derived from natural carbon compounds that include various types of organic compounds such as litter and biomass of microorganisms.

The Effect of Biochar and Bacillus sp. Application on Soil pH

pH is a measurement of the degree of kemasaam or wetness that is useful to determine the relationship of heavy metals and chemical elements in the soil. the pH of the soil can indicate whether or not a lot of OH^- ions and H^+ ions in the soil. The higher the H^+ ions the soil conditions will be more acidic and vice versa, the higher the OH ions$^-$, the more alkaline the soil conditions will be. If the amount of H^+ ions and OH^- ions have the same amount of soil has a neutral condition.

pH can affect the adsorption of heavy metals cadmium and lead in the soil through complex chemical and physical mechanisms. Cd^{2+} heavy metal ions are more soluble when H^+ ions and CD^{2+} ions compete to fill adsorption sites in colloids under acidic pH conditions. Cd^{2+} ions will precipitate under alkaline pH conditions because they from hydroxide ($Cd(OH)_2$) and carbonate complexes ($CdCO_3$) (Cheng et al., 2020).

Table 3. Average pH after administration of biochar and *Bacillus* combination at 2^{Nd} and 4^{Th} Week

Treatment	**pH H_2O**	
	2^{Nd} Week	**4^{Th} Week**
B0C0	6.28a	6.26a
B0C1	6.65b	6.90b
B0C2	7.26c	7.29c
B1C0	7.37cd	7.57d
B1C1	7.54d	7.75de
B1C2	7.56de	7.77def
B2C0	7.65ef	7.83e
B2C1	7.80efgh	7.97efg
B2C2	7.78efg	7.96ef
BNJ %	**0.66**	**0.34**

Note: the numbers followed by the same letter show no real difference on the 5% BNJ test

The results of the analysis of the combination of biochar and *Bacillus* sp. against pH showed no real difference at Week 1 and Week 3, while at Week 2 and Week 4 showed real different results (Table 3). The treatment of B0C0 has a slightly acidic pH and the treatment of B2C1 and B2C2 has a slightly alkaline pH. PH increase occurred in each treatment at each week except for treatment b0c0 which decreased pH at Week 4. The increase in pH in each treatment occurs as a result of the provision of organic materials, namely biochar and *Bacillus* sp., where the pH value determines whether the heavy metal will dissolve or precipitate. Menurut Yuliana et al., (2022) soil at acidic pH heavy metals will become easily dissolved and the mobility of heavy metals is higher so that the heavy metals are in the form available to plants. Giving biochar rice husk can increase the pH of the soil, the increase in pH is because biochar rice husk is able to increase alkaline cations such as Ca^{2+}, Mg^{2+}, and K^{+}, and reduce Al^{3+} dissolved in the soil.

The combination of biochar with *Bacillus* sp. it can increase the pH of the soil. Menurut Amalina et al., (2024) this is because biochar has a relatively alkaline pH ranging from 8-10, so when applied to soils that have an acidic pH biochar will act as a pH neutralizer by reducing H^{+ions}. While *Bacillus* is a bacterium that is able to produce enzymes and metabolites to help the decomposition of organic matter and nitrification process, through the activity carried out by Bacillus is able to convert acidic compounds into alkaline compounds or compounds that are less acidic so that indirectly the biological activity of *the Bacillus* improves soil pH conditions.

Table 4. Average soil pH at single biochar and *Bacillus* treatment at 1St Week and 3Rd Week

Treatment	**Incubation period**	
Biochar	**1St Week**	**3Rd Week**
B0 (0 ton/ha)	6.62a	6.83a
B1 (20ton/ha)	7.36b	7.59b
B2 (40ton/ha)	7.59bc	7.83c
BNJ%	**0.09**	**0.11**
***Bacillus* sp.**	**Incubation period**	
	1St Week	**3Rd Week**
C0 (without *bacillus* sp.)	6.96a	7.24
C1 (Consentration 10^5)	7.23b	7.44
C2 (Consentration 10^8)	7.38c	7.57
BNJ%	**0.09**	**0.11**

Note: the numbers followed by the same letter show no real difference on the 5% BNJ test

The results of pH variation on each single treatment factor in (Table 4) showed that each treatment biochar and *Bacillus* sp. noticeable impact on pH changes every week. The addition of biochar with a dose of 20 tons/ha and 40 tons/ha was able to increase soil pH. Menurut Surianti et al., (2021) the dose of biochar used has an impact on the effectiveness of increasing soil pH. The greater the amount of biochar applied, the more significant the effect on soil pH and organic matter. The use of biochar dose of 20 tons/ha showed better results in increasing soil pH compared to biochar dose of 10 tons/ha.

The Effect of Biochar & *Bacillus* sp. Application on Cadmium Heavy Metals

The presence of heavy metals in the soil comes from natural sources and Human daily activities. Heavy metals in the soil can be found in a variety of forms that exhibit diverse chemical and physical characteristics, as well as related to availability to organisms, chemical interactions, and potential toxicity. The geochemical fraction of heavy metals in the soil is able to estimate the amount of heavy metals available for absorption by soil microorganisms and the level of risk of soil as a source of heavy metal contamination. The distribution of heavy metals in the soil is controlled by Fitriatian et al., (2019) the reaction of heavy metals in the soil which includes (1) ion exchange, adsorption and desorption, (2) dissolution and deposition of minerals (3) mobilization and immobilization of biological factors, (4) complexation, and (5) absorption by plants. The presence of heavy metals is able to affect soil fertility. Heavy metals have resistant and toxic properties so they are not easily decomposed. The presence of heavy metals will interferewith microbial activity in the soil.

Table 5. Cd heavy metal content after biochar and *Bacillus* sp. application

Treatment	**Cadmium (Cd)**			
	1St Week	**2Nd Week**	**3Rd Week**	**4Th Week**
B0C0	2.54	2.36	2.28 e	2.21 e

B0C1	2.45	2.30	1.87 de	1.73 d
B0C2	2.46	2.24	1.84 d	1.76 c
B1C0	2.43	1.92	1.71 c	1.36 b
B1C1	2.40	1.84	1.41 ab	1.24 ab
B1C2	2.42	1.85	1.43 ab	1.23 ab
B2C0	2.41	1.90	1.57 b	1.28 ab
B2C1	2.39	1.81	1.36 a	1.14 ab
B2C2	2.37	1.83	1.38 ab	1.19 a
BNJ %	**tn**	**tn**	**0.11**	**0.14**

Note: the numbers followed by the same letter show no real difference on the 5% BNJ test

The results of the analysis of the variety of cadmium levels after treatment showed significantly different results against cadmium at Week 3 and Week 4, at Week 1 and Week 2 showed no different results. Generally the optimal time of the adsorption process is 24 hours and the adsorption process will continue to increase after biochar 24 hours, this is due to the influence of biochar on soil pH (Luo et al., 2011). Based on the results in (Table 5) shows that the treatment of b0c0 (control) does not show a significant decrease in heavy metal cadmium, while in the treatment of B2C2 decreased by 0.78 ppm with the removal efficiency of heavy metal cadmium reached 52 % in the treatment of B2C1 (biochar 40 tons / ha and *Bacillus* 10^5). In the combined treatment of biochar 20 tons / ha and *Bacillus* 10^8 decreased cadmium levels reached 1.23 ppm with an elimination efficiency of 49 %. Levels of heavy metals after treatment with an incubation period of 4 weeks are still classified as polluted, this is because biochar and bacillus require sufficient time to decompose metal ions Bclosely into forms that are not available.

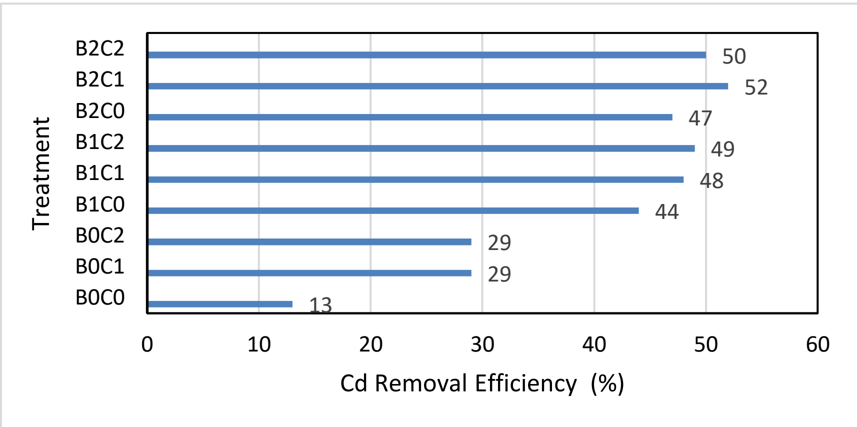

Figure 1. Cd Heavy Metal Removal Efficiency

According to Cheng et al., (2020) mechanisms of heavy metal absorption of cadmium by biochar through ion exchange, functional group complexation, reduction and precipitation. Cations that are on the surface of the biochar will exchange ions with heavy metals in the soil. Carboxy –COOH functional groups found in biochar can be released as H^+ ions to form complexes with heavy metal ions, carboxylate group reaction with cadmium Cd^{2+} as follows:

$$-COOH\ release\ H^+ \rightarrow -COO^- + Cd^{2+} \rightarrow {}^{-COO}_{-COO}\!> Cd$$

The use of rice husk biochar as a remediator of contaminated soil can reduce the content of heavy metals cadmium and lead. Menurut penelitian Jiang et al., (2012) the use of rice husk biochar is more efficient in the immobilization of Cd, Pb, and Cu heavy metals. Sedangkan penilitian Cui et al., (2011) said that the use of biochar with a dose of 40 tons/ha obtained a significant reduction of Cd heavy metals 61.9% compared with doses of 0 and 20 tons/ha of 37.1 %.

Addition of microorganisms such as *Bacillus* sp. can help biochar in reducing heavy metal levels. The Bacillus has a cell wall containing peptidoglycan with carboxyl and phosphoryl groups that can electrostatically bind heavy metal ions. Positively charged beran metals such as Cd^{2+} will interact and be adsorbed on the surface of bacterial cells making them less chemically available in the soil. In addition the bacillus is able to accumulate heavy metals through an active mechanism in the bacterial cell that involves the transport of metal ions in the cytoplasm (Oktavia et al., 2022).

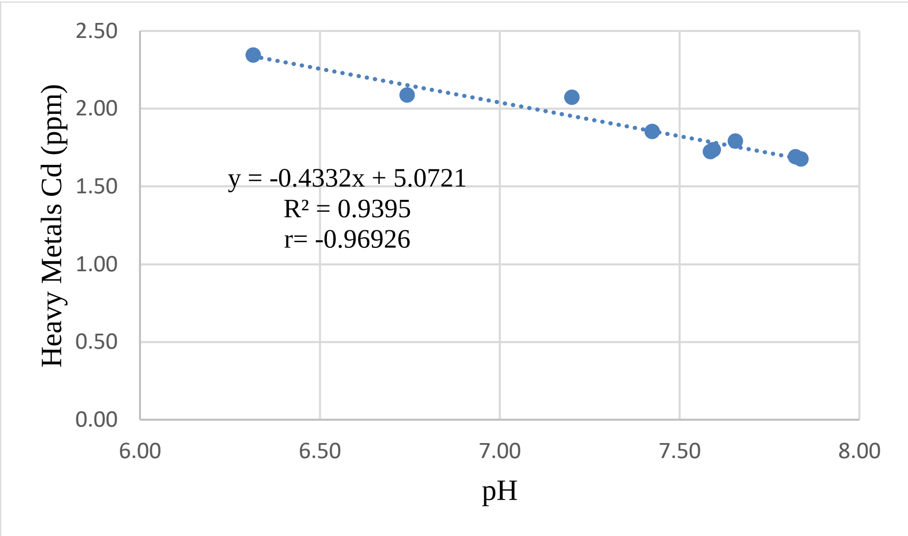

Figure 2. pH relationship with heavy metals Cd

The test results of the coefficient of determination R^2 in (Figure 1) between pH and Cd heavy metal is 0.9395 which shows that the pH value is very influential on the reduction of Cd heavy metal levels by 94%. The results of the correlation Test between pH and Cd heavy metals showed a negative correlation with the value of r = -0.96926 which means that the closeness of the relationship between pH and Cd is quite strong. The relationship between the two is that the higher the pH value, the lower the presence of Cd heavy metals, this is because the solubility and presence of heavy metals are strongly influenced by soil pH. A decrease in thebioactive availability of Cd in the soil can reduce the risk of heavy metal transfer to plants and the food chain. The use of organic materials such as biochar and *Bacillus* sp. able mgurangi availability of heavy metals while reducing the effects of toxicity to soil fertility support microbes.

Heavy metals will tend to be more soluble and easy to accumulate at low pH (<6), and will precipitate and decrease solubility at high pH (>8) so that their presence becomes unavailable in the soil. Changes in pH can affect the soil in binding heavy metals, where at high pH soils usually have better cation exchange capacity so that they can bind heavy metals more effectively (Widiyatmoko, 2011). In addition, high pH affects the increase in microbial activity in the remediation process, so it can help reduce the concentration of heavy metals in the soil.

CONCLUSION

The use of biochar & Bacillus sp. able to reduce the level of heavy metal cadmium (Cd) in the soil. The best treatment in this study was a combination of biochar with a dose of 40 tons / ha and *Bacillus* 10^5 B2C1 was able to reduce heavy metal cadmium levels from 2.39 ppm to 1.14 ppm with removal efficiency reaching 52% and soil pH increased to slightly alkaline pH conditions after 4 weeks of incubation period.The use of biochar and *Bacillus* sp can be employed as a soil remediator for various soil types by adjusting soil health conditions optimize dosage and incubation time.

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