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Immobilization of lead by a vermicompost and its effect on white bean (*Vigna Sinenis var. Apure*) uptake

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ABSTRACT: Lead is one of the most dangerous contaminants which has been released to the environment during many years by anthropogenic activities. Adsorption of Pb^{2+} on vermicompost was studied at 11°C, 30 °C and 50 °C by using Langmuir and Freundlich models, that adequately described the adsorption process, with maximum adsorption capacities were 116.3; 113.6 and 123.5 µg/g for each temperature. The differences in FTIR (Fourier Transform Infrared Spectrometer) spectra of vermicompost at pH 3,8 and pH 7.0 in the region from 1800 to 1300 cm^{-1} were interpreted on the basis of carboxyl acid ionization that reduce band intensity around 1725 cm^{-1} producing signals at 1550 cm^{-1} (υ_a) and 1390 cm^{-1} (υ_a) of carboxylate groups. Similar changes were detected at pH 3.8 when ionic lead was present suggesting that heavy metal complexation occurs throughout a cationic exchange reaction. Vermicompost was applied to a soil where white bean plants were planted. After irrigation with lead nitrate solutions the uptake of lead was reduced to 81 % in leaves and stem, while the reduction in the roots was around 50 %. The highest accumulation of lead was found in the roots and the translocations seems to be limited by the presence off vermicompost in the soil.

Key words: *Lead, white bean, isotherms, FTIR, lead uptake*

INTRODUCTION

Lead is a heavy metal highly toxic to many organs of the human body, such as the nervous system, the kidneys, etc. Assenato *et al.* (1986) reported that Pb can decrease sperm counts increasing at the same time the prevalence of morphological abnormal sperm. Also, the absorption of Pb by crops, specially the accumulation in the edible parts, is of a great concern in many countries due to the possibility of entering to the food chain. These facts have made that lead received much attention as one of the most important chemical pollutants of the environment.

The industrial development and population expansion experimented by many Venezuela cities during the last decades have produced a significant increase of lead emissions, mainly associated to the combustion of gasoline containing Pb additives, in consequence, the environmental contamination have become increasingly serious, as was indicated by Fernandez and Ramirez (2002), who reported Pb concentrations in urban soils between 5,000 and 13,000 µg/g, while Almeida *et al.* (1999) quantified blood lead levels above 10 µg/dL in school age children. Remediation of polluted areas and the reduction of health risk have received much attention by environmental scientists including soil chemists, who had focused their work in the evaluation of organic and inorganic adsorbent materials for Pb immobilization in soils or removal from contaminated waters. Among these studies Lister and Line (2001) found that the Langmuir's model described the adsorption of lead by a vermicompost with a maximum absorption capacity of 39.3 mg/g. In a similar work, Serkar *et al.* (2004) showed that an activated carbon prepared from coconut shell can adsorb 26.50 mg/g of Pb (II) from aqueous solution following an endothermic reaction as derived from the thermodynamic functions.

On the other hand, Covelo *et al.*, (2004) observed that the amendment with humified organic matter may reduced the soluble fraction of lead in polluted agricultural soils, which was explained on the basis of chemical processes of adsorption involving the oxygenated functional groups such as the carboxylates which acted as ligands for Pb^{2+} to produce stable

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organometallic complexes (Piccolo and Stevenson, 1982 and Boyd *et al.*, 1981).

Vermicompost with about 30 % of humified organic matter is produced by a special type of composting that uses earthworm, which feed organic residues from farming activities and the microorganisms in the digestive system transform proteins, carbohydrates, fats, nucleic acids, etc. in humus of gray to black colors, with high capacities for cationic exchange and for water adsorption. The molecular structure of vermicompost contains carboxylic acids responsible for the adsorption of heavy metals in a process that involve exchange of protons of weak organic acids for Pb^{2+} ions dissolved in aqueous solutions. (Carrasquero and Flores, 2004).

The purposes of this work were; firstly, to evaluate the effect of pH on the surface electric charge of a commercial vermicompost. Secondly, to determine the ability of the compost for reducing the Pb^{2+} concentration in aqueous solution by using adsorption isotherm; third, to study the adsorption mechanism at a molecular level by evaluating the changes in the infrared adsorption bands of carboxyl acids and their conjugated bases. Finally, to establish the ability of the vermicompost for reducing the uptake of lead by a white bean plant (*Vigna Sinensis* var. Apure) growing in a soil irrigated with an acid lead solution.

MATERIALS AND METHODS

A commercial vermicompost was obtained from the locality of Guanayen, Aragua State, Venezuela. The chemical composition (on dry basis) was: Water, 50%. Organic matter 38%. Total nitrogen 0.8 %. Phosphorous, calcium and magnesium 1.2; 1.0 and 2.4 % respectively. Two kilograms of vermicompost were air dried for three days and sieved to 75 µm particle size.

Effect of pH on the vermicompost surface electric charge (Sposito, 1986):

Determination of point of zero charge (PZC): Fourteen plastic bottles with 2 g of vermicompost were arranged in two groups of seven bottles, the aliquots of acid, base and water were added as indicated in Table 1. Suspensions were mechanically shaken for 1 h and the pH was measured (pH_{water}) using a Corning pH meter provided with a glass electrode. Then, one and two milliliters of 1 mol/L KCl were added to the first and second group respectively in order to have two ionic strengths. After shaking for 30 min the pH was measured again (pH_{KCl}). The value of ΔpH, that represented an estimation of the sign and magnitude of surface electric charge, was calculated by subtracting pH_{water} to pH_{KCl} and plotted against pH_{water} to obtain the PZC from the intersection of the curve with the ordinate axis.

Table 1: Solutions for the determination of PZC

Bottle	Vol. 0.1M HCl (mL)	Vol. 0.1 M NaOH (mL)	Vol. Water (mL)
1	5	0	15
2	4	0	16
3	3	0	17
4	2	0	18
5	0	0	20
6	0	2	18
7	0	3	17

Adsorption of potential determining ions: Acid and basic solutions were prepared in plastic bottles as indicated in Table 2, the initial pH was measured ($pH_{Initial}$) and two grams of vermicompost were added to each solution. All suspensions were shaken for one hour and then the pH was measured again (pH_{final}). By using the mathematical definition of pH, the initial, final and adsorbed amounts of H_3O^+ and OH^- were calculated. The quantity of adsorbed ions was plotted against pH_{final} and a new point of zero charge (pH°) was determined by the intersection of the curves with the ordinate axis, representing the pH condition in which the adsorbent can not retain neither hydroxyls nor H_3O^+ ions. Two series were prepared by adding 0.5 and 1.0 mL of 1 mol/L KCl to evaluate the effect of solutions ionic strength.

Adsorption isotherms for Pb^{2+}

Fourteen plastic bottles which contained 200 ± 1 mg of vermicompost were arranged into two groups of seven bottles. Aliquots of 1000 µg/mL $Pb(NO_3)_2$ were added as indicated in Table 3. The pH in all suspensions was set to 4 with 0.1 mol/L HCl and distilled water was added to make up 10 mL.

Table 2: Solutions for the adsorption of potential determining ions

Bottle	Vol. 0.1M HCl (mL)	Vol. 0.1 M NaOH (mL)	Vol. Water (mL)
1	20	0	0
2	15	0	5
3	10	0	10
4	5	0	15
5	0	0	20
6	0	1	19
7	0	2	18

The mixtures were shaken for 2 h following a filtering through a Wathman N °1 filter paper and centrifuged at 3,000 rpm for 5 min to obtain clear solutions. Lead was immediately quantified by Flame AAS in a Perkin Elmer Analyst 1000 with a specific hollow cathode lamp. Adsorption experiments were carried out in triplicate at 11°C; 30 °C and 50 °C. All solutions were prepared by using analytical grade reagents.

Table 3: Solutions for adsorption isotherms of lead (II)

Bottle	$(Pb^{2+})_{Initial}$ (µg/mL)	Total volume (mL)
1	20	10
2	50	10
3	100	10
4	250	10
5	500	10
6	700	10
7	900	10

Adsorption of lead in a vermicompost column

The equipment employed (Fig. 1) consisted in a cylinder provided with a mechanical stirrer and a deposit of lead solution in order to maintain a constant input flow. The cylinder was filled with 25 g of vermicompost and a lead solution of 50 µg/mL at pH 4.00 was made to flow through the compost at a rate of 10 mL/min. Aliquots of 100 mL of the filtered solution were taken to measure the pH and analyzed for lead by AAS. A total of 700 mL of the lead solution was employed.

IR spectroscopic study of lead-vermicompost interactions

To determine the effect of the pH and the addition of lead (II) ions on the absorption bands in the range of 1200 to 1800 cm^{-1}, three samples of vermicompost (200 ± 1 mg) were placed in test tubes.

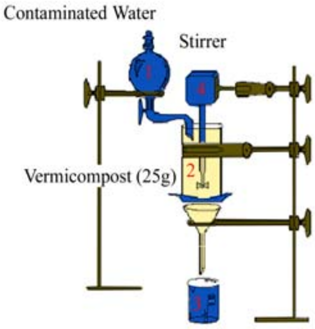


Fig. 1: Equipment for lead adsorption in a vermicompost column

The first tube was filled with 5 mL of a solution of HCl at pH 3.8 ± 0.2. The same volume of distilled water (pH 7.1 ± 0.1) was added to the second test tube and the third tube was filled with the a 10^{-4} M HCl solution (pH 3.8 ± 0.1) which also contained 500 µg/mL of $Pb(NO_3)_2$. All mixtures were mechanically shaken for two hour at room temperature and then the pH was measured again and adjusted to the initial values if necessary. After filtering the solid residue was dried in an electric oven for 3 day at 40 °C. FTIR spectra were recorded using KBr discs (97 mg of dried KCl and 3 mg of vermicompost) in a Perkin Elmer RXI with a resolution of 4 cm^{-1} and 16 scans. KBr spectra was subtracted in all cases.

All experiments described above were carried out in the Laboratory of Applied Chemistry at the Universidad Pedagógica Experimental Libertador, Aragua State Venezuela, between January and March of 2005.

Effect of vermicompost on the uptake of lead by a bean plant

Pot experiment: The pot experiment was conducted in the green house of the Universidad Rómulo Gallegos located in the city of San Juan de Los Morros, Guarico State, Venezuela, from March to April, 2005. An acid soil from Guarico State where corn has been cultivated for many years was employed. The most remarkable characteristics of this soil are its low fertility, organic matter content, cationic exchange capacity and low pH that may favor soluble and bioavailable forms of Pb (Table 4). Twenty five kilograms of soil were air dried for three days, sieved to 2 mm and homogenized. Mixtures were prepared by mixing uniformly 50 g and 150 g of vermicompost (T_1 and T_2 respectively) with enough soil to obtain a mass of 1 Kg that was filled into a 1.5 L plastic pot which had five holes at the bottom. The control treatment (T_0) consisted in one kilogram of soil. Each treatment was prepared in triplicate and incubated in the green house for 4 weeks and watered with 70 mL of distilled water each 4 days. Seedling preparation and plant growth: Seed of white bean (*Vigna Sinenis)* variety Apure were soaked in water for four hours and germinated in the dark for three days. Four seedlings were planted in each pot and irrigated daily with 70 mL of distilled water during fifteen days. After, the water was substituted by Pb (NO_3) solutions as follows: 7 days with a 25 µg/mL solution, the concentration was increased to 50 µg/mL for the next seven days. For the last 36 days a lead solution of 100 µg/mL was employed. In all cases a volume of 70 mL was daily used.

Plant harvest and analysis: During the harvest, the four plants of each pot were completely removed, washed with water and dried between filter papers. Plants were separated into shoots (leaves + stem) and roots, stored into paper bags and dried in an electric at 70 °C for 48 h to determine dry weight. Shoots and roots were grounded and stored in plastic vials until chemically analyzed. For each pot a composite sample was prepared by mixing identical amounts of the four grounded plants. Samples of 200 ± 5 mg were weighed into 15 mL porcelain crucible and ashed at 400 °C for 5 h in a muffle furnace. Once cooled, 2 mL of 10 % HNO_3 were added and evaporated at 60 °C. After the ashes were dissolved in 5 mL of 1 % HNO_3 and centrifuged at 3,000 g for five minutes if necessary. Pb was determined by AAS after extraction with APDC and methylisobuthylketone (Yilmaz and Zengind, 2004). Spiked samples were analyzed in the same way obtaining recoveries between 93 and 99 %.

Table 4: Soil chemical properties

$pH_{(1:2,5)}$	5,1
Phosporous (mg/Kg)^{1}	4
Potasium (mg/Kg)^{2}	17
Calcium (mg/Kg)^{3}	260
Magnesium (mg/Kg)^{3}	101
Organic matter (g/Kg)^{4}	0,8
Clay %^{5}	17,60
Sand %^{5}	45,68
Silt %^{5}	36,72
Cationic exchange capacity (meq/100g)^{5}	0,23

P-Olsen, Molybdate blue method (Jackson, 1964)
K-Olsen, Atom absorption spectrometry (Jackson, 1964)
Ammonium acetate 1 M, Atomic absorption spectrometry.
Chromic acid method
Boyoucos
Ammonium acetate 1 M (Jackson, 1964)

RESULTS

Effect of pH on the vermicompost surface electric charge (Sposito, 1986)

Determination of point of zero charge (PZC): The PZC was 7.5 ± 0.1 (Fig. 2) at the two the ionic strengths. Below PZC the adsorbent exhibited a positively surface charge with a density that depended on ionic strength as is predicted by the Gouy-Chapman model (Sparks, 1985). On the other hand, in an alkaline environment (pH > PZC) a net negatively surface charge dominates, showing an eventual capacity for electric attraction of dissolved cations of heavy metals. However, if solution pH is above PZC, lead hydroxide will precipitates (Ksp = 1.20*10^{-15}) becoming precipitation as the most important mechanism for lead immobilization instead of adsorption, for this reason adsorption experiments had to be carried out in acid solutions.

The presence of positively or negatively charged surfaces in vermicompost has been explained on the basis of the ionization equilibrium of the weak organic acids commonly found in the humified materials (Rivero *et al.*, 1998), such as carboxylic acids that behave as weak electrolytes in aqueous solutions producing a carboxylic/carboxylate equilibrium which depends on the activity of H_3O^+ ions.

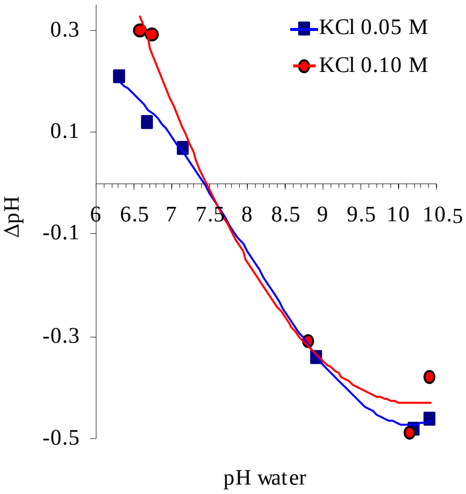


Fig. 2: Effect of pH on the surface electric charge and determination of PZC

Adsorption of potential determining ions

Vermicompost showed a great affinity for H_3O^+ (Fig. 3), neutralizing about 0.018 meq of protons to decrease the pH in two units in solutions equilibrated with one gram of the adsorbent; while less than 0.002 meq of OH^- could increase the solutions pH from 9 to 11, which is a consequence of the relative densities of negatively and positively charge sorption sites as described in the previous experiment. The pH value where the curve crosses de ordinate axis (pH 8.8 ± 0.1) is a point of zero charge (pH) where the adsorbent can not to retain neither hydroxyl nor H_3O^+ ions. The difference between pH° and PZC suggested the presence of surfaces with variable charges, such as those associated with weak organic acids along with surfaces of permanent charge on inorganic materials as for example clay materials. (Sposito and Schindler, 1986).

Adsorption isotherms of Pb^{2+}

Langmuir's isotherm: The linear plot of the specific adsorption, $(x/m)^{-1}$ in the equation (1), against the reciprocal of lead (II) equilibrium concentration (Fig. 4) shows that heavy metal-vermicompost interactions may be described by the Langmuir model at all temperature conditions with significant regression coefficients significant (Table 5).

This model is based on the assumption that the maximum adsorption (b) corresponds to a saturated monolayer of solute molecules on the adsorbent, reaching in this work values between 113.6 to 123.5 mg/g, with the highest value at 50 °C. These results indicated that the adsorbent had a high affinity for lead ions if compared with a vermicompost from Brazil with a maximum adsorption of 38.6 mg/g (Pereira and Arruda, 2002).

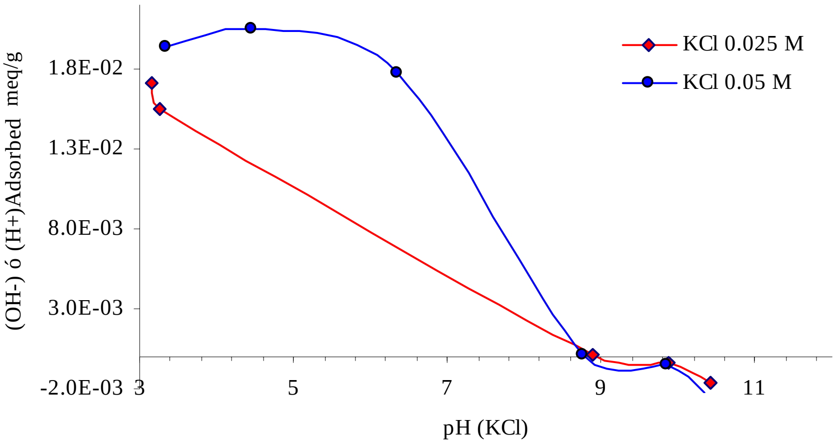


Fig. 3: Adsorption of potential determining ions

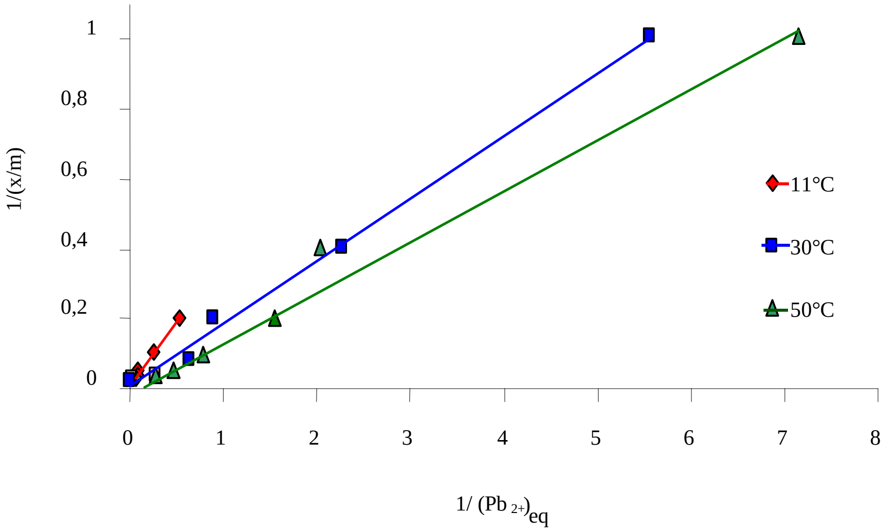


Fig. 4: Langmuir plots for adsorption of lead (II) on vermicompost

Table 5: Equations of Langmuir model for the adsorption isotherms of lead on vermicompost

Temperature (K)	Equation	R^2	a	b = Maximum adsorption (mg/g)
11	$(x/m)^{-1} = 0{,}361\ (Pb^{2+})^{-1} + 0{,}0086$	0,992	0,0236	116,3
30	$(x/m)^{-1} = 0{,}179\ (Pb^{2+})^{-1} + 0{,}0088$	0,995	0,0491	113,6
50	$(x/m)^{-1} = 0{,}143\ (Pb^{2+})^{-1} + 0{,}0081$	0,981	0,0976	123,5

Results also showed that the factor associated with the energy of the adsorption (a) increased with the temperature, suggesting the endothermic character of the adsorption.

$$\frac{1}{\left(\frac{x}{m}\right)} = \frac{1}{b} + \frac{1}{ab(Pb^{2+})} \qquad (1)$$

Freunldich´s isotherm: The straight lines in Fig. 5 shows that lead adsorption by vermicompost also obeyed the Freundlich´s model, in which the adsorbent is considered as an heterogeneous surface, with adsorption sites of different energies, which is consistent with the evidences of the presence of sites with variable and permanent charge. The effect of temperature was observed in the values for the terms of Freunlich's equation (Table 6). For example, at 30 °C and 50 °C the slopes were similar and close to the unity, making the adsorption equivalent to a distribution law (Glasstone, 1960). The requirements of energy for the retention Pb^{2+} by the active sites on vermicompost surface were evidenced by the less adsorption found at 11 °C, which is another evidence for the endothermic character of the reaction.

During the experiments the pH was kept below the PZC in a condition where the adsorbent surface was positively charged and as a consequence of the electrostatic repulsion of equal charged particles, the adsorption of positive ions is not favored.

Therefore, non electrostatic forces should be the responsible for the attraction of lead ions by the surface (Serkar *et al.*, 2004). These forces would be associated with the affinity of divalent lead ions for oxygen atoms of carboxylic acids to form stable monodentante or bidentante complexes, which would requires the ionization of organic acids as a previous step.

Adsorption of lead in a vermicompost column

As shown in Fig. 6, the vermicompost column removed a maximum of 25.22 mg of the lead initially present in 700 mL of the solution, representing a reduction of about 75 %, showing the potentialities of this material for the treatment of polluted waters. Although value represented scarcely the 1 % of the maximum obtained by adsorption isotherms, it is important to consider that the time of contact between adsorbent and the solution was of ten minutes for each 100 mL aliquots in a constant movement through the column while in batch experiments the equilibrium time was as long as two hours.

Once the solution flowed through the column a progressively increase in its pH was detected from 4.0 to 7.5, showing the ability of the vermicompost for neutralizing H_3O^+ ions as was indicated by the adsorption of determining ions experiments.

FTIR spectra of vermicompost

The infrared spectra of vermicompost at pH 3.8 exhibited the signals of $\upsilon_{(C=O)}$ stretching of non ionized carboxylic acid at 1711 and 1730 cm^{-1} (Fig. 7a). These bands disappeared when the pH was increased to the neutrality (Fig. 7b) as a consequence of the conversion to the carboxylate anion, which produced a peak at 1580 cm^{-1} by the coupling of antisymmetrical vibrational modes of the oxygen atoms (Carrasquero and Flores, 2004). The changes in the zone of C-OH stretch were masked by a broad band around 1250 cm^{-1} of carbohydrates and Si-O tensions. It was also observed a slight broadening of the peak at 1390.8 cm^{-1}associated with the symmetric stretch of the C-O bonding in the carboxylate. There are several FTIR signals which remained unaltered at the two pH conditions; for example, C=C stretching of aromatic ring at 1695, 1668 and 1517 cm^{-1}, including a peak at 1645 cm^{-1} probably due to a vibration $\upsilon_{(C=N)}$ (Bellamy, 1966). The signal of methyl (υ_{CH3}) is unaffected by the alkalinity of acidity of the solution, therefore, the pH only affects the bands of those groups that participate in the acid-base equilibrium. The treatment with the acid lead solution (Fig. 7c) modified the same absorption peaks as it was describe for the neutral pH. For instance, there is a significant reduction in the band around 1700 cm^{-1} of COOH, with a simultaneous broad and intense signal between 1536 and 1557 cm^{-1} produced by the group

Table 6: Equations of Freundlich's model for the adsorption isotherms of lead

Temperature (K)	Equation	R^2	k	n
11	$Log_{10}(x/m) = 0{,}754\ Log_{10}(Pb^{2+}) + 0{,}588$	0,965	3.88	1.33
30	$Log_{10}(x/m) = 1{,}088\ Log_{10}(Pb^{2+}) + 0{,}782$	0,974	6.05	0.92
50	$Log_{10}(x/m) = 1{,}087\ Log_{10}(Pb^{2+}) + 0{,}871$	0,981	7.43	0.92

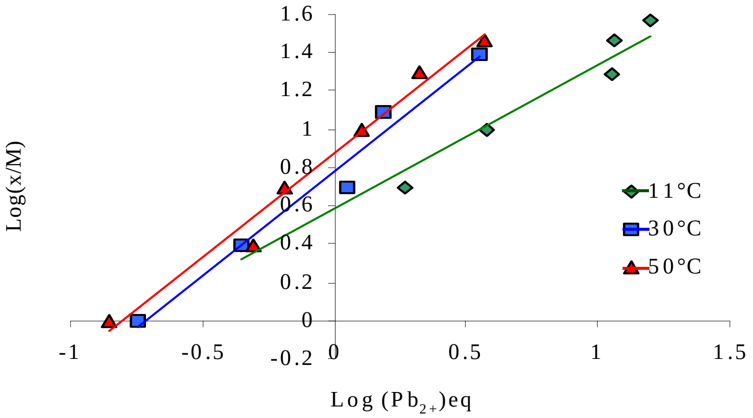


Fig. 5: Freunldich adsorption isotherms for removal of lead on vermicompost

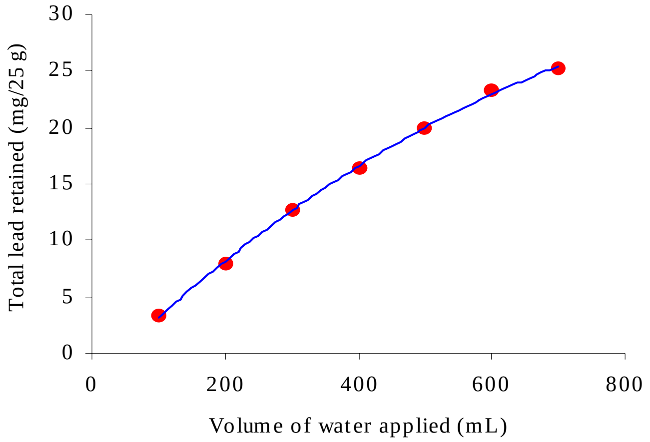


Fig. 6: Amount of lead retained (mg) by a vermicompost column of 25 g

COO^-. The complexation between the heavy metal and the organic ligand produced a strong and wide peak between 1361 and 1388 cm^{-1} (Nakamoto, 1978). In other words, Pb^{2+} induced changes at a molecular level characterized by the ionization of carboxylic acids to produce carboxylate anions which act as ligands to form a coordinate bond throughout unpaired electrons of oxygen atoms.

Plant growth and lead uptake

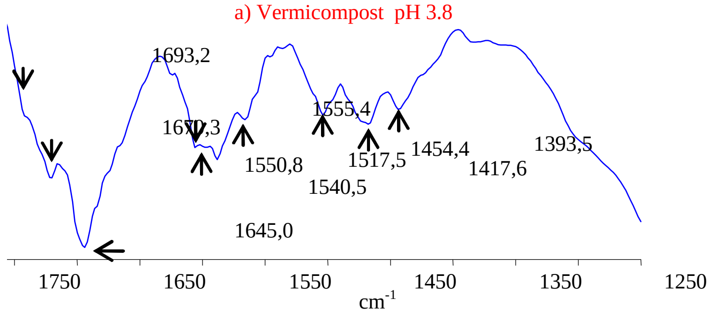
After 50 days of irrigation with $Pb(NO_3)_2$ solutions, plants did not show unfavorable changes in their appearance such as browning, chlorosis or necrosis that would be attributed to metal toxicity. This tolerance may be due either by a low level of Pb accumulated in the tissues or by the instrumentation of any mechanism of avoidance or inactivation (Piechalak *et al.* 2002).

Also, not significant differences in shoots dry weight yield among treatments were found (Table 7), although the plants growing in the vermicompost treated soil had a slight increase in biomass production in the roots if compared with the control plants, however, it is necessary to consider that the low soil fertility would be the most important factor that influenced the development of the plants. On the other hand, the lead concentrations in shoots and roots of control plants were significantly higher than in those plants that grown in the soil amended with the vermicompost.

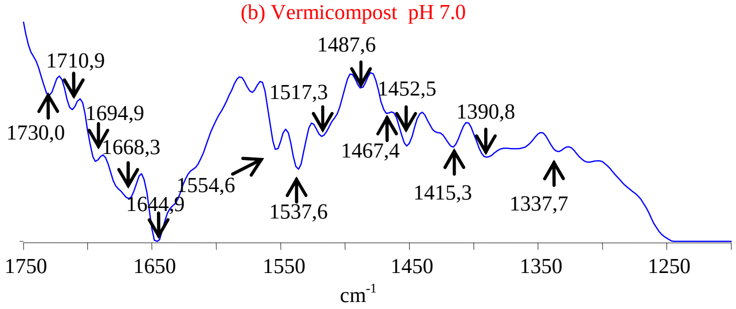
Table 7: Effects of the application of vermicompost to soil on dry matter yield and accumulation of lead in bean plants

Treatment	Dry matter yield (%)		Lead concentration (µg/g)	
	leaves + stem	Roots	leaves + stem	leaves + stem
Control	18.7 ± 1.5^{a}	28.5 ± 2.7^{b}	42.7 ± 2.8	53.2 ± 3.3
T_1	16.6 ± 1.0^{a}	34.0 ± 0.4^{a}	12.2 ± 1.5	27.2 ± 4.2
T_2	16.9 ± 0.7^{a}	35.4 ± 0.8^{a}	8.1 ± 1.5	27.0 ± 0.9

a) Vermicompost pH 3.8



(b) Vermicompost pH 7.0



(c) Vermicompost + 500 µg/mL Pb^{2+} pH 3.8

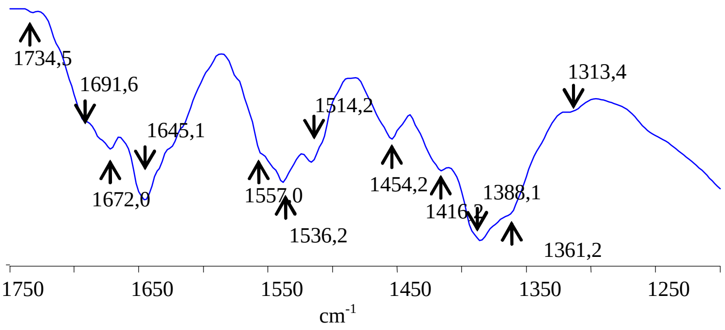


Fig. 7: FTIR spectra of vermicompost at two pH conditions and in the presence of aqueous Pb^{2+}

DISCUSSION AND CONCLUSION

Addition of the amendment produced the decrease of Pb bioavailability as a consequence of the formation of complexes between the heavy metal and carboxylic groups of humic substances which are too large molecules to permeate root cells; also the increase of solution pH favors insoluble lead hydroxide. The role of humic substances for reducing the uptake of heavy metals was studied by Narancikova and Markovnikova (2003) who concluded that organic matter not only form strong complexes but also may retains heavy metals in exchangeable forms. For example, cooper ions which are bounded in an unavailable form while cadmium remains as an exchangeable ion, making the effects of the humified materials dependent on the type of heavy metal and the results of this study seems to indicate that the tendency for lead is to be immobilized.

Soil conditions as pH, cationic exchange capacity among others also influence the bioavailability of heavy metals in the presence of organic matter. Soil pH is affected due to the ability of vermicompost for reduction H_3O^+ activity in soil solution through a mechanism involve an acid-base equilibrium that, according to the Le Chatelier Principle, in the presence of an excess of hidronium ions responds favoring the formation of unionized molecules by combination of H_3O^+ ions with the conjugated bases of organic acids, resulting in a rise to pH values at which lead hydroxide precipitates, making this an important mechanism for lead immobilization.

An interesting effect is related with the soil microorganims, Ibenake and Takenaka (2005) found that the microbial activity on humic acids may produce smaller fragments which also form chelates with the heavy metal favoring the absorption by roots, which would be one of the reasons for the presence of lead in roots in all treatments with vermicompost. Although lead translocation was observed in all treatments, the presence of the compost reduced the amount accumulated in the above ground parts of the plants. For example, the lead concentrations in leaves and stems in the control represented the 80 % of the accumulated in the roots. This proportion decreased in the other plants to 44.8 % and 30.8 % with the incorporation to soil of 5 % and 15 % of composted organic material. Theories for the translocation of metals propose that chelators such as phytochelatins and exuded organic acids mobilize the heavy metals extracted by the roots but the results of this study suggest that if the lead was absorbed as chelated by fragments of humic acids the mobility into the plant tend to be limited resulting in a major accumulation in the roots.

Although the vermicompost in acid solutions (pH < PZC) had a low density of negative sorption sites for retaining cations such as Pb^{2+}, the spectroscopy analysis showed that adsorption requires the initial ionization of carboxylic acids to produce negative charges on oxygen atoms to coordinate with the heavy metal. The system has to absorb energy from the surroundings to promote the process that would be described as a cationic exchange. The high amount of lead adsorbed, calculated by using the Langmuir model, is an evidence of the potential used of this material to immobilize Pb^{2+} of contaminated waters, as a low cost adsorbent for the initial treatment of the sources of water for agricultural purposes in the developing countries, either by direct use or as a component of a more complex technology.

Although it was not possible to establish if the minor lead bioavailability resulted form an adsorption reaction or precipitation, the presence of vermicompost effectively limited the uptake and translocation of the pollutant, suggesting a very low accumulation in the beans, which is of considerable importance because beans constitute an important source of food for many Venezuelan people.

In conclusion, the vermicompost may play an important role in the agriculture, not only as an amendment for improving soil physical quality, but also as a resource for controlling the mobility of pollutants such as lead, which is of considerable importance for those countries with high levels of heavy metals in soils and water that in other circumstances can nor be used for food production. Also, vermicompost is a natural organic material that can be produced in little farms, using raw materials with uncontaminated residues. These practices have the additional advantages that do not require more expensive technologies for remediation.

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