Chemical Analysis of Sludge Originating from Industrial Painting Performed in Brazil

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Abstract Inadequate discard of industrial solid waste is a risk to human health and to the environment. Aiming at softening environmental damage caused by deposition on soil of an ink residue, from washing of printers used in carton box packages, it is intended to incorporate this residue into soil-cement bricks. The residue has other use potentialities such as in screeds, pavement parts, fertilizer, paints, etc. However, to explore these potentialities it is fundamental to assess the risks that the several forms of use of this residue can cause. For such, in this work the chemical analysis of the residue was performed in order to know its main chemical compounds, in addition to its characteristics of leaching and solubilization. The chemical composition assay showed traces of some heavy metals such as Pb, Cd, Cr, Zn, Al and Cu, although the residue-generating company uses ink labeled as heavy metals free. Among the elements analyzed in leaching and solubilization, some had concentration above the limit allowed by The Brazilian Codes. This code is based on *CFR—Title 40—Protection of Environment—Part 260–265—Harzardous waste management*. Therefore, it is suggested that the residue has a limited use to avoid contamination of ground water.

Keywords Waste · Paint · Soil-cement

Introduction

Economic activities have usually been generating sources of waste. Treatment and final discard of waste is more and more subject of great concern. According to Collatto and Bergmann [1], the main fear is that these residues eventually cause harm to human and environment, through soils and water contamination. The use of

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stabilization/solidification technique as pre-treatment of heavy metals residues and other toxic contaminants is common, aiming at discard on soil, as stated by Castro [2] and Lin [3].

The aim is to use a specific residue generated from effluent treatment, as aggregated in soil-cement bricks manufacturing. To determine the use potentialities of this residue, risks to human and environment should be assessed [4]. For such, it is necessary to know the main compounds of the residue, as well as its characteristics of leaching and solubilization.

Several industries generate solid waste in water treatment stations, industrial sewages or effluents, after going through flotation, decantation or filtration processes. This procedure type originates a sludge that has varied chemical composition due to the products used in the process and is constituted mostly of water, as stated by Sousa and Cordeiro [5]. Reuse of iodine is target of study by several researchers that seek to find an environmentally correct destination for such waste.

The residue under study has great use potential, especially in the construction industry. One of these applications concerns the possibility of incorporation of sludge into soil-cement bricks. There is also the possibility of use of this residue for other ends in constructions, such as in pavement parts and screeds. In this case, although there is direct contact with water, leaching will occur in lesser extent, due to the stabilization with cement and to the fact that the residue is encased in concrete. For being in direct contact with soil, the possibility of carrying of heavy metals is greater. Therefore, analysis of the possibility of leaching and solubilization of toxic agents in the parts with sludge incorporation is recommended.

For such, Dutch norm NEN 7345 (Determination of Leaching from Monolithic Construction Materials and Waste Materials by Means of a Diffusion Test), which uses monolithic samples with the end of assessing the potential and speed of compounds leaching throughout time, can be used. Other verification possibility is the use of Brazilian norms ABNT NBR 10006 [6] and ABNT NBR 10005 [7].

Other possibilities have been tested by some researchers for similar residues. Moreira et al. [8] studied sludge generated by the sewage treatment station of a textile industry in adding to clays for construction material manufacturing. Pietrobon et al. [9] studied sludge from textile laundry treatment for reuse as construction mortar. Silva [10] studied the potential of using sludge from textile industry sewage as agricultural fertilizer.

In the present work, chemical analysis of sludge resulting from washing treatment of machines that use pains was performed, assessing the following parameters: chemical composition, leaching and solubilization of sludge generated by the company Guarany Embalagens. The process of packages production includes printing of carton box surface in different colors, where a water based flexographic ink is used, which is free from heavy metals, according to the manufacturer. To change the ink color, printers are washed with water, which is directed to a processing machine. There, it goes through a flocculation process. From this process, sludge is obtained, which is removed in bags and dumped in an open external yard, where it waits for final discard while naturally dries. Wet sludge is shown in Fig. 1. In Fig. 2, sludge after dry is presented.

Fig. 1 Wet residue

Fig. 2 Dry residue

ABNT NBR 10004 [11] classifies the most common residues, which have known origin and can be identified in attachments A and B. Ink sludges from industrial painting are found in attachment A and are classified as toxic and identified by code F018. The following toxic agents are highlighted as dangerous constituents: cadmium, chromium, lead, cyanide, toluene and tetrachlorethylene. Despite this classification, that standard applies in statement that the generator of residues listed in attachments A and B can demonstrate by classification report that its residue specifically has none of the characteristics of hazardous specified in this norm. Relying on this statement and considering that company Guarany Embalagens uses an ink labeled as heavy metals free, analyses of chemical composition, leaching and solubilization became interesting, in order to study the possibilities of proper residue discard.

Concerning environmental problems, this research will provide a proper discard for industrial waste, thus avoiding the construction of industrial landfills and the indefinite accumulation in unfit areas.

It will also allow for obtaining new materials, by residues incorporation into soil-cement bricks, showing new alternatives that can contribute for decreasing the housing deficit in Brazil. Since the soil-cement is an adequate technique for construction on mutual aid, the disclosure of obtained results is expected to promote the aid of residue generator industries to organizations and families that seek solutions for their housing or community constructing needs.

Methodology

Chemical Analysis

Chemical analysis of the residue was performed in the Mineralogy Laboratory, of the Solid Department of Universidade Federal de Viçosa (UFV). This was performed by residue digestion in nitro-perchloric acid. From 0.5 g of the residue, which was transferred to an Erlenmeyer, 10 mL of nitric-perchloric solution 3:1 was added, in room temperature.

Following, the sample was transferred into a digester block at 180 °C where it was kept until total digestion (2:30 h). After cooling, hydrochloric acid was added to clean the Erlenmeyer walls and remove the elements attached. The sample was filtered in an assay tube that was completed with deionized water.

The reading of elements was performed by Plasma Emission Spectroscopy (ICP), which identified the concentrations of the following elements: magnesium (Mg), calcium (Ca), potassium (K), sodium (Na), phosphorus (P), manganese (Mn), chromium (Cr), lead (Pb), nickel (Ni), cadmium (Cd), copper (Cu), aluminum (Al), and iron (Fe).

Leaching

Leaching assay was performed according to the procedure of ABNT NBR 10004 [11]. Ink residue was dried in stove and milled before obtaining the leached extract, in order to obtain particles smaller than or equal to 9.5 mm.

A pre-test was performed, using 5 g of the sample that was transferred into a beaker where 96.5 mL of deionized water was added. The mix was vigorously stirred for 5 min. Next, pH was measured, finding 4.49. Since pH was inferior to 5, the following solution was used: 5.7 mL of glacial acetic acid and 64.3 mL of NaOH 1.0 N and adding distilled, deionized water, organic-free until the volume of 1L. The solution pH was measured, finding the value of 4.88. This value should be within 4.93 ± 0.05.

The leaching procedure for residues with solids assay equal to 100% was followed. For such, 2 g of the sample was weighed, which was transferred into leaching flasks and 40 mL of the previous solution was added, so that the solution quantity was 20 times the used mass. The flask was closed and kept under stirring for 20 h to complete (18 ± 2) h, at 20 °C of temperature with a rotation of (30 ± 2) rpm in the rotatory stirrer, as seen in Fig. 3.

Fig. 3 Rotatory stirrer

After this period, the sample was filtered, obtaining the leached extract. The reading of elements was performed by ICP, which identified the concentrations of the searched elements (Mg, Ca, K, Na, P, Mn, Cr, Pb, Ni, Cd, Cu, Al, Fe).

Solubilization

Solubilization assay was performed according to the procedure of ABNT NBR 10006 [6]. To obtain the solubilized extract of ink residue, the sample was dried at temperature 42 °C, using a stove.

A dried sample of 250 g was placed in a 1500 mL flask and 1000 mL of distilled and deionized water was added. The flask was stirred in low speed for 5 min and, next, covered with plastic wrap (PVC) and left resting for 7 days at temperature up to 25 °C. The solution was filtered, obtaining the solubilized extract. The reading of elements was performed again by ICP.

Results and Discussion

Chemical Analysis

Chemical composition of the residue is presented in Table 1. It is important to stress that the assay method used verified only the existence of searched elements, not excluding the possibility of presence of other elements.

Table 1 Chemical composition of the residue

Elements	Mn	Cr	Zn	Pb	Ni	Cd	Cu
Concentration mg/L	118.08	10.75	771.19	6.90	0.00	2.05	817.29
Elements	Al	Fe	Mg	Ca	K	Na	P
Concentration mg/L	3849.99	62,483.04	2636.43	5531.39	61.87	378.12	0.00

Table 2 Leached elements of the residue

Elements	Mn	Cr	Zn	Pb	Ni	Cd	Cu
concentration mg/L	10.65	0.00	50.94	0.00	0.00	0.01	0.00
Maximum limit mg/L	–	5	–	1	–	0.5	–
Elements	Al	Fe	Mg	Ca	K	Na	P
Concentration mg/L	13.54	1.77	548.57	6088.36	23.46	0.00	4.73
Maximum limit mg/L	–	–	–	–	–	–	–

A high concentration of iron, calcium, aluminum and manganese was observed. The high concentration of iron can have its origin in the effluents treatment, in which a flocculant is used, whose chemical composition is unknown.

The ink used by the generator company of the residue is heavy metals free, according to the manufacturer. Still, traces of some heavy metals like Pb, Cd, Cr, Zn, Al and Cu were found.

Leaching

Leaching assay shows the elements that can be leached and contaminate ground water. It is important to be aware of the presence of heavy metals because they can cause adverse effects to human health.

Results shown in Table 2 are compared to the maximum limit allowed by attachment F of ABNT NBR 10004 [11]. Among the analyzed elements, none was superior to the limit. Therefore, concerning leaching, the residue can be used without restrictions.

Solubilization

Solubilization assay shows the elements that can be solubilized and contaminate ground water. Results shown in Table 3 are compared to the maximum limit allowed by attachment G of ABNT NBR 10004 [11].

Among the analyzed elements, concentrations of elements Mn, Zn and Fe can be noticed to be above maximum limit. Manganese must be stressed for having

Table 3 Solubilized elements of the residue

Elements	Mn	Cr	Zn	Pb	Ni	Cd	Cu
Concentration mg/L	6.60	0.00	15.59	0.00	0.00	0.00	0.00
Maximum limit mg/L	0.10	0.05	5.00	0.01	–	0.005	2.00
Elements	Al	Fe	Mg	Ca	K	Na	P
Concentration mg/L	0.00	1.94	352.33	2816.94	4.50	2.58	0.64
Maximum limit mg/L	0.20	0.3	–	–	–	200.0	–

concentration 66 times superior to the maximum limit allowed by the norm. Therefore, precautions must be taken for residue discard not to cause problems of water contamination and, consequently, harms to human health and to the environment.

Discussion

For the leaching extract, a residue is characterized as toxic when it has values superior to those of attachment F of ABNT NBR 10004 [11]. Since no element had values higher than the limit, the residue under analysis cannot be classified as toxic based on the leached extract.

Other possibility of the residue being classified as toxic is the presence of one or more substances present in attachment C and also presenting toxicity. Since lead and cadmium were detected in the sample, and they are listed in attachment C, some factors present in the same attachment should be checked to see the presence of toxicity.

Although the norm mentions factors that should be considered to verify the presence of toxicity, there is no information on how to proceed to verification. Therefore, it is hard to state that the residue is not toxic.

Considering that the residue is not toxic, the analysis of solubilized extract is useful for classification as inert or not inert. Since some concentrations superior to standards of drinking water present in attachment G were found, for some elements the residue has not inert characteristics.

Therefore, considering that the residue has no toxicity due to the presence of Lead and Cadmium, it should be classified as not harmful: Class II A—Not inert. If considered presence of toxicity, it should be classified as class I harmful residue.

Conclusions

By analyzing the leaching results, there are no restrictions concerning residue use according to recommendations of the ABNT NBR 10004 [11] and Wiemes [4]. However, by analyzing solubilized values, some of them are above the standard for drinking water. Therefore, it is interesting to take special measures concerning final discard of the residue, because it cannot be directly put on soil, due to the possibility of contamination of water that can eventually be ingested. It is valid to notice that performed classification is based on water for human consumption. Thus, detected contamination does not prohibit direct contact with the residue and, accordingly, the use of this residue as construction material causes no harm to human health. In this way, care to be taken concerning the use of residue are solely about water contamination and ingestion.

In this way, some sludge reuse technologies, such as fertilization, for the sludge in concern, demand higher attention because there are possibilities of ground water contamination. However, according to Santos [12] for the purpose intended for the residue, which is its use as alternative material for construction, there is no problem, as long as the possibility of leaching is avoided.

In case of incorporation of the studied residue into soil-cement bricks, these by principle should be protected from action of direct water. In this way, the end intended for this sludge has good potential from the environmental perspective.

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