Evaluation of the Electro-removal Technique of the Treated Wood Using the Accelerated Decaying Fungus Test

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Short Report

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Abstract

Waste from treated wood can be hazardous to the environment and human health. Therefore, research is needed to investigate what to do with this waste. The electro-removal technique is a viable technique to remove the copper, chromium and arsenic metals contained in the CCA-treated wood. But is the CCA really removed? the present study investigated this cause, using the living organism *Trametes versicolor* to verify this hypothesis.

1. Introdution

Because the natural degradation process that occurs in wood by the action of xylophagous organisms, treatments on the material are necessary, mostly chemical, in order to increase the useful life and exposure in different places of application. The so-called chemical preservatives most used worldwide take in their composition the salts of boron and arsenic metals, being popularly known as Chromated Copper Arsenate (CCA) and Chromated Copper Borate (CCB) [1].

These substances present an excellent performance in terms of wood preservation, where Chromium acts as a fixative, and Copper and Arsenic as a fungicide and insecticide, however, because they have metals in their composition, they can be highly toxic to human health and the environment [2; 3]. Thus, the volume of material installed throughout the world, even after the reduction of its application due to the legislation of the countries of Europe and USA, still worries, because the material used, in the most varied sectors, has a useful life of up to 50 years [4].

The amount of products in use and that have these condoms in its composition, the search for the environmentally correct destination of the residues of this treated material still generates uncertainties. The major concern is the wood being replaced by other materials due to the end of its useful life, because both incineration and accumulation in sanitary landfills, commonly used practices, are not presented as ideal. In general, the burning of preserved wood causes serious risks to the environment due to the release of toxic gases and the deposit of this material containing metals in the same place may increase the leaching rates of inappropriate components, such as arsenic [3] for instance, to the soil [5; 4].

On the other hand, since wood is a renewable natural resource, it should be widely used in the most varied segments and not simply replaced by elements such as concrete and steel, for instance. Thus, investigations aiming at solutions for the final destination or reuse of correctly treated wood waste are of fundamental importance for the sector and should be encouraged [4].

Some procedures that extract the metals present in the material preserved with CCA have already been studied for some time [6; 7], but results are still scarce and should be better elucidated. An innovative alternative to verify their effectiveness would be the use of xylophagous organisms after the extraction of the chemical species Cu, Cr and As from preserved wood in order to assure the non toxicity of the compound.

The use of the white rot fungus *Trametes versicolor* in the process of evaluation of the efficacy of the technique consisted in the fact that the species and fungal strains differ in their sensitivity to metals and in the protection mechanisms involved and, in general, brown rot fungi may be more tolerant to certain wood preservatives, such as CCA, since they produce oxalic acid in the degradation process on a larger scale than white rot fungi, such acid is involved in the detoxification process promoted [8; 9; 10]. In view of this, the choice of the white rot fungus, *Trametes versicolor*, allowed more security in the evaluation of the viability of the technique.

In this context, this study evaluated the feasibility of using the eletrorremotion technique, for the extraction of chemical species from wood treated with CCA, associated with the technique of accelerated decaying with fungi.

2. Material And Methods

2.1 Preparation of the material

To conduct the study we used 3 *Eucalyptus grandis* stones from which four baguettes were removed, with dimensions of 2.5 x 2.5 x 20 cm in thickness, width and length, respectively, as shown in Fig. 1. After the confection the material was submitted to chemical treatment, with CCA type condom, by the vacuum and pressure method in an industrial autoclave, with retention of 9.5 kg/m3, used commercially.

2.2 X-ray spectrometry analysis

The concentration of metallic ions, copper, chromium and arsenic, present in the treated baguettes were analyzed by X-ray dispersive energy spectrometry using a spectrometer. The simultaneous collection of data in the wood samples was performed by the Fundamental Parameters Method [11]. This same process was repeated after the application of the electrorem treatment, to verify the ion concentration difference before and after the procedure.

2.3 Electroremoval

The electro-removal technique occurred in bench scale (Fig. 2), where the treated wood was submerged in a solution composed of oxalic acid and phosphoric acid, diluted in 5% concentration in ultra-pure water.

The mass balance is the according of the molarity chemical components, this, 0,6 mol/l for the oxalic acid and 0,4 mol/l for the phosporic acid.

This electrolytic conductive solution was conducted by a 25-volt voltage source at 1.5A, making the transmission of positive and negative charges through graphite electrodes. The samples remained in the solution, in constant agitation, for 4 hours under constant dilution with the aid of a magnetic stirrer. Afterwards, the material was washed with distilled water and dried in air and later in an oven for new measurements of X-ray fluorescence spectrometry in order to obtain the concentrations of the metals.

2.4 Accelerated decay test

From the baguettes with and without electrorremotion were made the specimens for the accelerated decay test following the recommendations of the modified ASTM D 2017-05 standards was carried out at the Forest Products Laboratory of the Brazilian Forest Service. The substrate used was vermiculite, duly sterilized at 121°C for 40 minutes and naturally cooled. The substrate was packed in a 250 ml bottle and permeable cap, up to half of the total volume of the container and then hydrated, with deionized water, until reaching 130% water retention capacity. In each flask was added a support plate made with *Cecropia* sp. wood for the initial development of the white rot fungus *Trametes versicolor*. Three milliliters of malt extract solution dissolved in deionized water with fungus inoculum were poured over each plate. The containers were then taken to an incubator at 25°C and 65% relative humidity, where they remained for two weeks so that the fungus could develop properly. The flasks were removed from the incubator and, in a laminar flow chamber, they received the non-translated specimens, those impregnated with CCA, and those that were submitted to the process of electro-removal. The flasks returned to the incubator where they remained for 16 weeks. The material was evaluated for loss of mass and the results obtained made it possible to classify according to the resistance to the attack of these deteriorating agents. The data were statistically analyzed in a 2x2 factorial scheme, verifying the influence of the electrorremotion treatment in the concentrations of the metals before and after the application of the technique, and a medical test was applied in order to verify the difference between the materials in the accelerated decay test.

3. Results

The results obtained regarding the electroremotion of heavy metals from the treated material showed that the chemical extraction process was effective, since there was the detachment of chromium linked to lignin and, in the sequence, of arsenic and copper from the preserved wood (Fig. 3).

The highest concentration of metals in the treated material, both for the condition with removal and in the samples where the technique was not applied, was observed for arsenic, followed by chromium and copper. However, when applied the technique, the extraction of the chemical elements was more successful for Copper, presenting a reduction equal to 34.6%, very similar to arsenic, which decreased 34.5% after the electro-removal. The chromium, which acts as a fixator of the preservative treatment in the wood, showed a smaller proportion, decreasing in 24.0% its concentration.

The extraction obtained in the experimentation reflected on the results measured in the biological test, which can be observed in Fig. 4, where although the electrode was satisfactory, the biological organism still did not have its ideal development, indicating that, the metal rates that were extracted from wood, are still not enough, interrupting the development of living organisms and being harmful to the environment in cases of accumulation or burning of this material.

4. Discussion

Other authors found reduction values of these compounds in higher proportions than the one obtained in the present study, varying between 87, 81 and 95% for copper, chromium and arsenic, respectively [12; 13; 14; 15]. The extraction of metals in this process of electro-removal is linked to several factors, according to the research of [6], where they reported that the size adopted in the particle, during the process, is a determining indicator in the removal. Thus, the result obtained in this study, when compared to the authors cited above, can be better understood, since they used fractional material for electrochemical extraction, while in this research the samples were in solid condition and of considerable volume.

Also observed stronger metal reduction values than those obtained in the present study, being above 80% for copper, chromium and arsenic, however, they used a differentiated electrolysis system, combining different acids from those applied in this research and introduced the application of temperature during the process [16].

In a similar experiment [13], obtained a removal of 57, 66 and 85% for copper, chromium and arsenic, respectively, also using fractionated material, and affirmed that they reached even more satisfactory values of removal in the treatment in which they increased the voltage used. Also, they tested greater distances between the electrodes and greater volume of mass in the electrorremoval, making these conditions reduce the efficiency of the extraction of metals from wood.

The fungal development and, consequently, the loss of mass, although they do not show statistical differences, occurred in greater proportion in the material with electroremotion, indicating that the fungus had a greater progress in the material with the extraction of the metals, although it was not 100% or close to that.

Even so, the percentage of removal obtained was not enough for the biological organism development to occur properly, which in the case of totally decontaminated material would be close to 60% of mass loss, according to the result obtained for the witness, being *Eucalyptus grandis* wood without chemical treatment.

Such results, when compared to each other, can be explained by the mild removal rate of Chromium, which acts as a fixer of the chemical treatment of Chromated Copper Arsenate in the wood, and consequently, due to its smaller scale extraction, the removal of the other metals (Copper and Arsenic). In the electro-removal technique, with the application of electricity, the process of chromium release from the lignin is accelerated, and with this, the exit of other metals is possible.

It is also worth mentioning that the present study was based on recently treated wood, which received the condom treatment with CCA especially for the experiments. The investigation of the electroremotion technique in treated wood taken out of service could present a greater removal of the metals, due to the leaching of the same that occurs over time, along with natural weathering. Also, the electro-removal applied to this type of material may be a solution to the accumulated waste of CCA-treated wood that has been removed from use all over the world, expanding its reuse applications.

5. Conclusion

The proliferation of microorganisms under the decontaminated material occurs more expressively in the witnesses in natura when comparing the treated wood without the application of the electro-removal. The Electroremotion associated to the test of accelerated decaying with fungus are presented as promising techniques for the recovery of CCA from wood treated with CCA aiming its final destination as solid residue, allowing the extraction of Cu, Cr and As present in the material.

Declarations

Ethical approval: Not applicable

Consent to participate: All authors agree to participate in the present work.

Consent to publication: All authors agree with the publication of the present work in the present journal.

Author contribuitions: All authors contributed in one way or another to the execution of this research. Since, FNG and RT acted as guiding the work, ADW and PRSB assisted in the analysis of x-ray spectrometry, ASS, MF and JRP assisted in the stages of biological testing. LC developed together with the others cited, all stages of the work.

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Competing interests: Not applicable.

Availability of data and materials: Not disponible.

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Figures

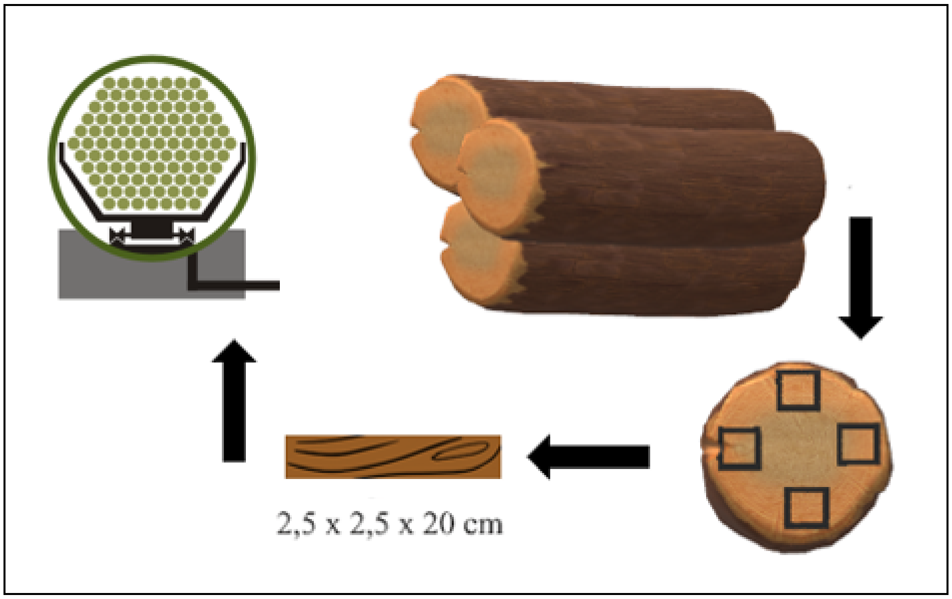

Figure 1

Representative diagram of the obtaining of the specimens and treatment in autoclave.

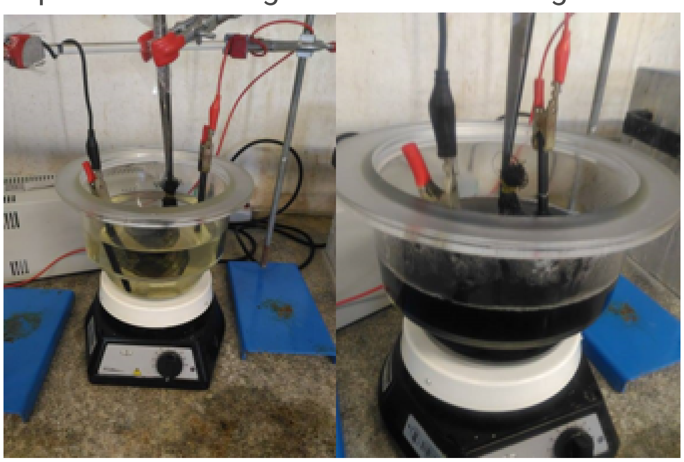

Figure 2

Equipment used in the bench scale electro-removal process. Highlight the figure on the right where the solution liquid appears in a darker color after the application of the electroremotion.

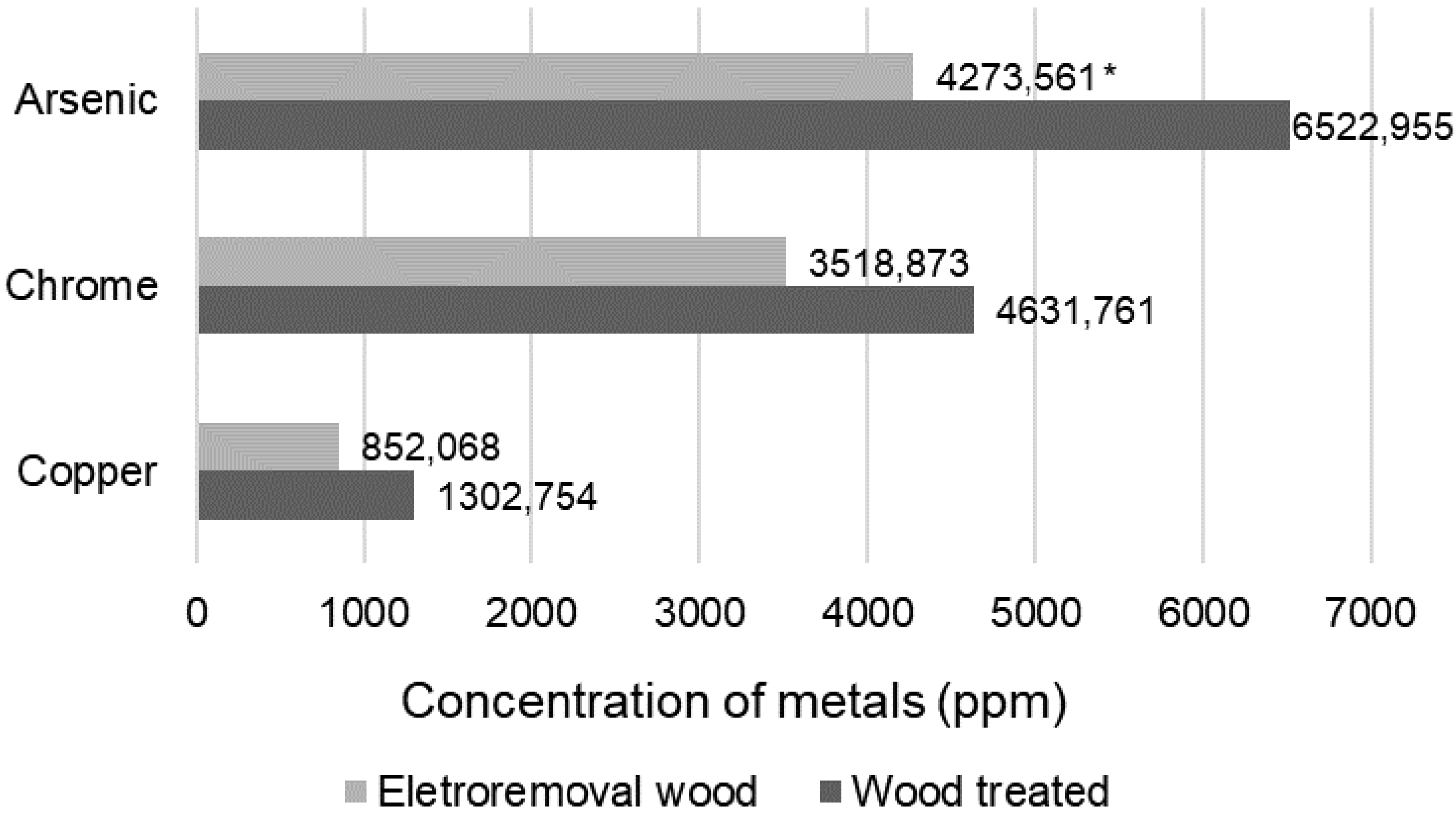

Figure 3

Arsenic, chromium and copper concentrations verified in the material before and after the electro-removal process. * Statistically significant difference between pre and post electroremotion concentration, for all metals.

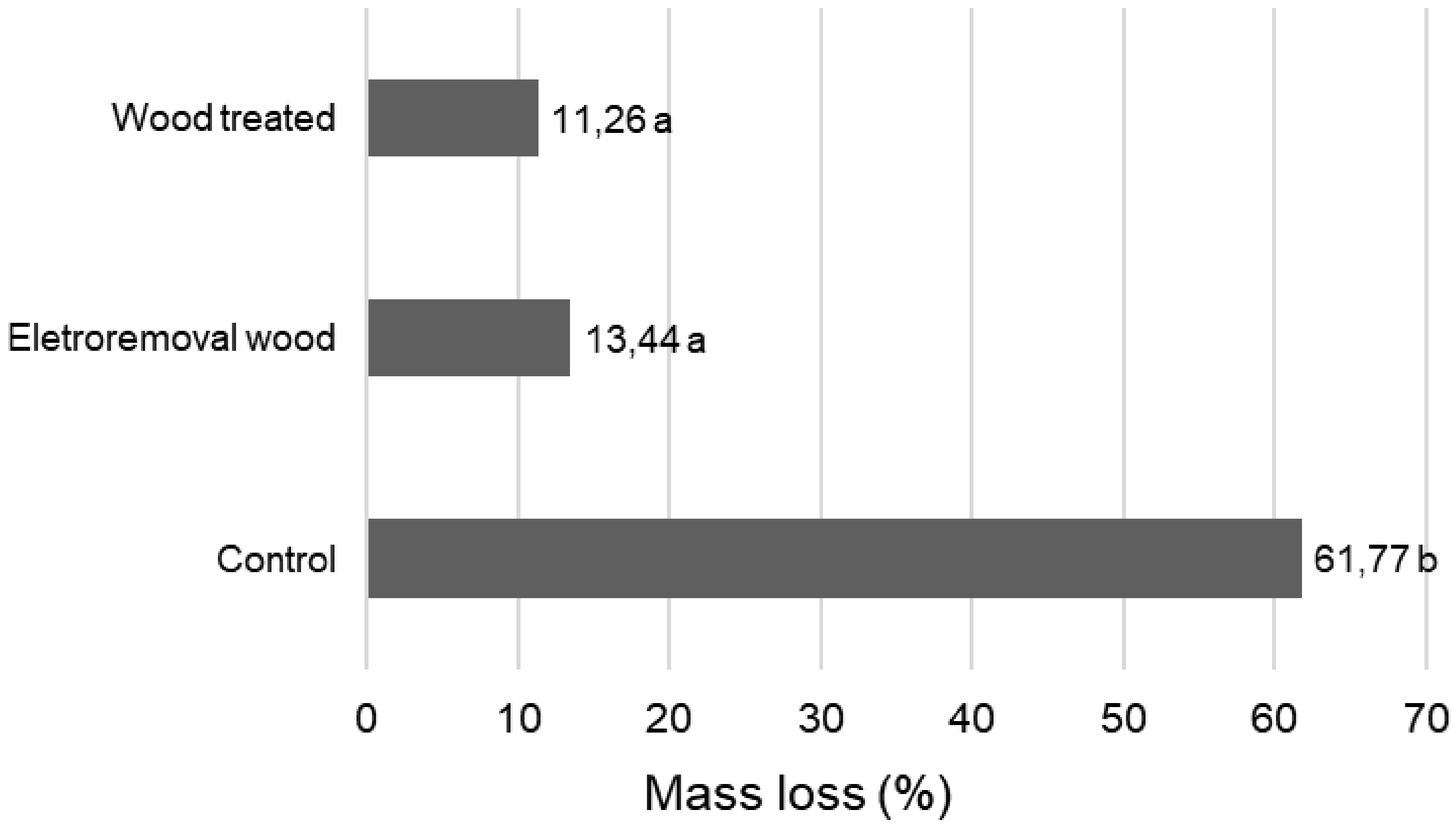

Figure 4

Mass loss averages obtained from the accelerated decaying test in the laboratory with Trametes versicolor fungus. Lower case letters next to the averages indicate Tukey's Test result at 5% error probability. Where equal letters= statistically equal; different letters= statistically different.

Supplementary Files

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