Impacts of Landfill Disposal of Construction and Demolition Waste (CDW)

Agbenyeku E. Emmanuel[1], Aigbavboa O. Clinton[1], Kukoyi T. Oladayo[1]
1 Faculty of Engineering and the Built Environment, University of Johannesburg, Johannesburg, South Africa, 17011
(E-mail:emmaa@uj.ac.za, caigbavboa@uj.ac.za, 201494957@uj.ac.za)

Abstract Growing population, industrialization and infrastructure development have resulted in enormous waste generation over the past decades. The disposal of vast amounts of waste remains a major challenge. However, in the globalized world recycling has become a main option for managing wastes while in other parts of the globe, landfilling is resorted to because of waste handling difficulties. South Africa is one of many countries where landfilling activities is high, as roughly 75 % of daily generated solid waste is disposed in landfills. This includes massive amounts of construction and demolition wastes (CDW) from reconstruction and development activities. South Africa depends on landfilling as a system of waste management which in the foreseeable future would linger on till feasible recycling options are initiated. Consequentially, the generation and seepage of leachate into soil, ground and surface water reserves is probable in such dump sites due to exposure of the waste bodies to rain and run-off water. A bespoke device was used in the study to investigate the impacts of disposing CDW in open dumps with mind for an unlined site relying on the geology of the area as worst case scenario. To generate leachate, the device was coupled with CDW in a bottom chamber and de-ionized water seeped through from a reservoir. Arsenic, Copper and Chromium from the generated leachate were analyzed by full spectral method on the effluent and were compared to South African standard of drinking water. Although, concentration levels of the targeted ions decreased through the test, it was clear that if CDW is not properly disposed, could contribute to consequential impacts on human and environmental health over time.
Keywords Leachate, Landfill, Construction and Demolition Waste, Bespoke device

1 Introduction

Treated wood of Chromated Copper Arsenate (CCA) have functioned as in and outdoor structural components for many years in the construction industry. CCA treated members are utilized aesthetically on arches and pillars, playground equipment, garden-bed borders, picnic tables, docks and decks. Currently, CCA treated materials form significant portions of Construction and Demolition Waste (CDW) disposed in landfills for lack of feasible recycling alternatives. CCA is a water-soluble inorganic pesticide normally used as wood preservative to create resistance to termite attacks and fungi decay. As recorded by [1] the material is soaked in a solution of CCA and pressurized in vacuum forcing the chemical into the wood. As a growing stream of waste, attention is insistently drawn to the impacts of using and disposing CDW containing CCA treated materials. This is pertinent because of its effects on the state of health of humans and the environment. A visible effect on humans is seen whereby freshly CCA treated material retains pesticide residues on its surface after the treatment process; as a water-soluble substance, water seeps in and leach CCA onto the surfaces of the material. This makes it easy for CCA residue to be tapped from the material’s surface smearing on hands or clothing and posing health risks from ingestion [2]. With respect to the environment, CCA weathers or in contact with rainwater leaches from the treated material into the soil beneath and on the sides of the treated components. Soil around such spot has been reported to be contaminated by arsenic, chromium and copper but using waterproofing sealants on structural components showed the soil around such spots to have lower heavy metal concentrations [3]. Increasing disposal amounts of CCA treated materials is probable considering its impact on users and the environment as well as the quantity of CDW constantly disposed in landfills. Furthermore, major concerns over children’s health have gained attention in recent years as young children are mostly at risk of exposure to CCA since they spend more time playing outdoors and have regular hand-to-mouth contacts. As recorded by [3] children using playground equipment or decks constructed with CCA treated materials are exposed to CCA from contact with the leachate on surfaces with their hands as such, inadvertently ingesting the chemical by actions of hand-to-mouth. This exposure can also occur when children play on contaminated soil thereby, unconsciously swallowing the chemical deposited in and around structures treated with CCA. 180 million m^3 of CCA treated material was estimated to be used in the United States in the last decade. Currently however, it is expected that CCA treated materials in the United States have phased out as targeted in early 2004 recorded by [4]. The driving force to bans and discontinued use of CCA treated materials may have been reports on increased cancer risks to children in contact with materials treated with CCA [5]. Nevertheless, it is noted that on removal of members treated with CCA as CDW, it becomes a fresh issue requiring proper disposal hence, preventing leaching of toxic substances from the formed leachate. Also, considering that in South Africa and most developing African countries, alternatives of recycling and reuse are still lacking and uneconomical as such, CDW containing CCA treated materials will continually be disposed in landfills. It has long been established as recorded by [6] that landfills have been and will remain for a long time to come the main system of waste management for different waste materials which includes materials treated with CCA. Similar works have reported that CDW containing CCA treated material leached concentrations of arsenic above groundwater standards [7]; this has given the study the impetus to contribute to containment and leachate control from CDW. Thus, the paper through laboratory exercise investigates the leachate quality and subsequent impacts of CDW containing materials treated with CCA on environment and human health in a case where toxic substances escapes containment most especially when the natural geology is the last line of defense.

2 Experimental Method

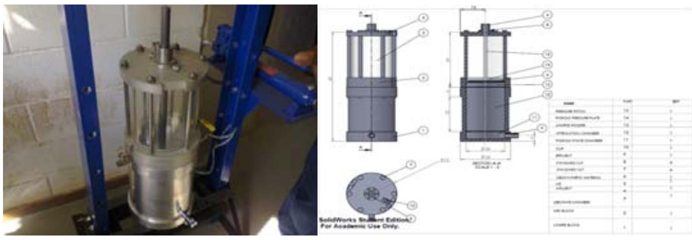
2.1 Setup and Testing Approach

The CDW containing fragments of wooden materials treated with CCA was collected in Johannesburg, South Africa from a domestic solid waste dump site somewhat far from the leachate pool as shown in Figure 1. The sampled CDW simulated the waste body used in generating leachate through laboratory experimentations in a fabricated device. The cylindrical small scale device used for the study is about 600 mm long having internal diameter of about 160 mm.

Figure 1 Sampling area for the CDW containing CCA treated materials used in the study

Figure 2a and b respectively shows the pictorial and schematic view of the device used in the study. Considering the nature of the study, the device was assembled combining two components working as a unit as described:

i. the bottom component called the bucket section; has a height of 230 mm holding the CDW and fragments of CCA-treated materials as a simulation of a landfill scenario. The sampled CDW with fragmented CCA treated materials was selected in smaller sizes to fit into the small scale testing device. Gravel was put as drainage path in the bucket section with moist geotextile overlying it to serve as filter bed in the system thereby, preventing blockage of the outlet by displaced fines.



(a) Pictorial view **(b) Schematic view**

Figure 2 (a) and (b) The small scale fabricated device used in the study

The sizeable CDW with fragmented CCA treated material was fit into the bucket underlying a 20 mm thin layer of lightly rammered clayey soil. The layer of soil prevented a rapid flush out of the influent during the testing process and allowed lasting interaction between the CDW and seeping water to form leachate. The experimental arrangement for the bucket holding the CDW containing fragments of CCA treated materials overlain by the thin layer of soil is shown in Figure 3.

Figure 3 Thin soil layer overlying the CDW fitted in the bucket section as used in the study

ii. the upper component joined to the bucket section called the reservoir; held de-ionized water as influent slowing draining into the waste body (in the bucket section) till leachate was generated, collected as effluent and the concentration of the collected effluent was tested periodically to examine the changes in the targeted toxic contents. The upper component of the assembled device as used in the study is seen in Figure 4.

Figure 4 Upper component of the device with de-ionized water in the reservior as used in the study

Considering that CDW would continually be dumped in landfills, studying this scenario will contribute to the interest in waste management by offering a closer understanding of the impacts of disposing these waste types on the environment and the implication on human health. To that effect, two main tests were conducted and recorded herein. Test-X represented the experimental scenario simulating CDW with fragmented CCA treated materials in a landfill whereas Test-Y represented the control scenario with selected CDW with no CCA content. Figure 5 shows the complete assemblage studied herein in room temperature with the testing duration lasting up to 10 days. On the formation and flow-out of leachate, a 50 ml cylinder was used to constantly collect the effluent. Only the pH from the general water quality parameters i.e., dissolved oxygen (DO), conductivity, temperature and oxidation-reduction potential (ORP) was reported in the study since other parameters require more standardized measurements and validation. The measurements in the study were done using a Portable Multi-flex Beckman Century pH/mV/FT/DO-915A-1202-TM SS-1 Meter Model. The laboratory formed leachate were collected as effluents and stored in plastic containers at a temperature of 2ºC to prevent microbial and chemical activities. Samples of the effluents were analyzed by full spectral method according [8] and then compared to the South African standard of drinking water.

Figure 5 Assemblage testing on CDW using de-ionized water as permeant to generate leachate tested in the study

3 Results and Discussion

3.2 Testing on CDW using De-ionized Water for Leachate Formation

Test-X and Test-Y displayed scenarios of leachate formation from the disposal of CDW with and without CCA treated materials respectively as indicative of an actual landfill. Each test setup lasted 10 days with de-ionized water as permeant for suitable interaction with the waste body and adequate leachate generation. Both Test-X and Test-Y had very early stages of flow-out. The leachate analysis and measurement of general water quality parameters for toxic ions (i.e., in this study, arsenic, copper and chromium) were done for both tests till a steady concentration point was reached at 10 days. The analysis and measurement for general water quality parameters offers further understanding into characterization of the generated leachate. Hence, the results and analysis revealed the pH of tests X and Y respectively decrease across the test period. Conversely, Test-X had a pH of 6.25 while Test-Y had a pH of 6.89 as seen in Figure 6. The pH values gotten from the tests herein were similar to those recorded by [7] as such, are considered to be typical for general CDW.

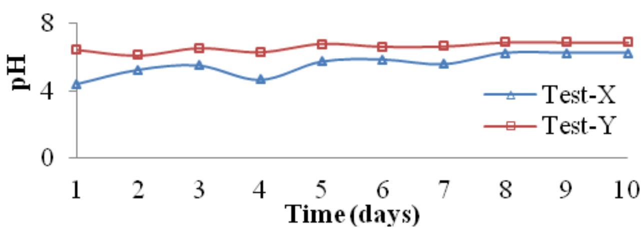


Figure 6 Measured pH for tests on CDW with and without materials treated with CCA

Figure 7a-c shows the concentrations of the measured arsenic, copper and chromium ions from the generated leachate in both tests. Test-X of CDW with fragmented CCA treated materials showed higher concentration levels as compared to Test-Y of CDW without CCA content.

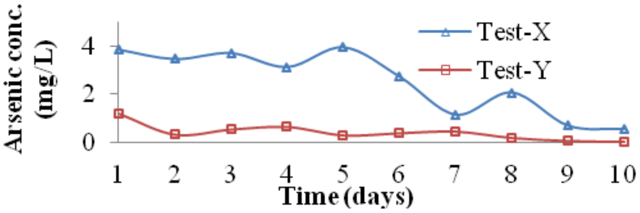


Figure 7(a) Measured arsenic for tests on CDW with and without materials treated with CCA

The arsenic and chromium concentrations found in the leachate in Test-X were higher than that of the leachate from Test-Y respectively. The outcomes from the study revealed reasonable similarities with studies by [4]. Nevertheless, it is noted that since the study herein was a fast tracked investigation contrary to studies by other authors conducted in fields over long periods, the represented values may not be likened to real life outcomes.

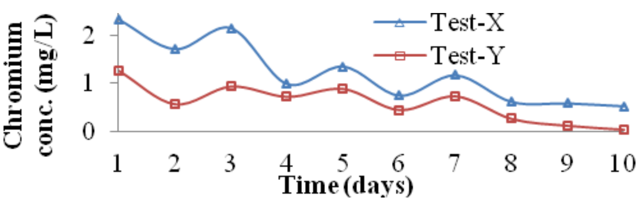


Figure 7(b) Measured chromium for tests on CDW with and without materials treated with CCA

The copper concentration was detected to be different as compared to the arsenic and chromium concentrations such that; the concentration of copper was initially only detected and measured from Test-X with Test-Y showing no results in concentration. However, towards the end of the testing period for Test-Y, slight concentrations of copper were then detected. Generally, the copper concentration were relatively low and this may be accounted for by the formation of complexes having various organic and inorganic ligands, considering the suitable pH values for the CDW recorded in the study as similarly observed by [4].

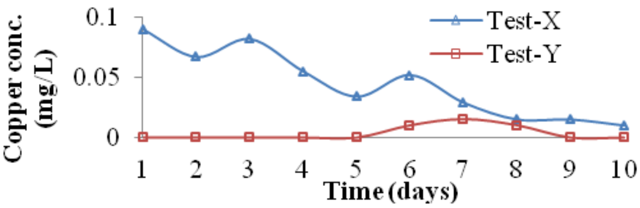


Figure 7(c) Measured copper for tests on CDW with and without materials treated with CCA

Some degree of microbial activity in both Test-X and Y is suspected to have occurred through the testing period however, such a short-term investigation will require validation to ensure heightened certainty. Nevertheless, [9] have reported certain bacteria to thrive on materials treated with CCA as such, extracting the metal ions present. Again, [4] reported that some fungi create dicarboxylic acid; other organic acids making chromium and arsenic remain in water soluble forms. This can trigger precipitation of copper as copper-oxalate having low water solubility. Hence, this may probably account for the relatively low concentration levels of copper recorded in both tests on CDW with and without CCA treated material contents as against arsenic and chromium respectively.

4 Conclusions

It is now a known fact that CDW will continually be disposed in landfills as the primary form of waste management in South Africa and other countries probably till feasible recycling and reuse alternatives are adopted. The study has therefore shown that chemical contaminants can form as found in Test-X from the landfill disposal of CDW containing materials treated with CCA. From results and analysis, the following conclusions were drawn:

I. That the arsenic, chromium and copper concentrations were found to slightly increase while the pH decreased.

II. Based on the amount of leachate produced in a short-term investigation, there could be an advantage to separately disposing CDW containing CCA treated materials if proper management can be ensured.
III. The concentration levels of arsenic chromium and copper in the generated leachate from the disposal of CDW for Test-Y will not constitute any environmental risk as recorded by EPA (2003a). However, it is clear that the disposal of CDW containing CCA treated materials influenced the concentration levels recorded for arsenic, chromium and copper.
IV. The concentration levels recorded over such a short time frame for CDW containing CCA treated materials; it may appear that with increased quantity of disposed CCA treated material the generated leachate could reach concentrations that can negatively impact human and environmental health.

In summary, leachate from CDW co-disposed with CCA treated materials contains arsenic, chromium and copper. Similar studies have shown that exposure to arsenic poses the greatest potential health risk. Nonetheless, it is unsure what exposure level threatens health from contact with materials treated with CCA. Notwithstanding, since materials treated with CCA cannot suddenly come out of service particularly in developing countries, a few measures are suggested to minimize exposure to CCA contamination:

- when working with materials treated with CCA dust masks, gloves and protective clothing must be worn to reduce chances of exposure to sawdust.
- sealants should be applied to materials treated with CCA at intervals of 1-2years to prevent direct contact with treatment chemicals.
- children should be guided from playing in CCA contaminated areas as well as reminded to wash up after contact with CCA treated material components or playground equipments.
- clients and firms are advised to consider greener optional and eco-friendly building materials i.e., hardwood and plastics as outdoor structural members.
- retail CCA treated material stores should have consumer information sheets describing safe handling recommendations. More to this, materials treated with CCA may be disposed as ordinary household trash but should not be burnt as advised by [10] because toxic chemicals would be released into the air or remain in the ashes. Finally, materials treated with CCA must not be mulched and sawdust from CCA treated materials must not be added in composting piles as suggested by [4].

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