Cu, Cr and As Distribution in Soils Adjacent to CCA-Treated Utility Poles

E.D. Gezer, T. Yüksek and A. Temiz

Abstract—In this study, the main objective was to assess the distribution of Cu, Cr, and As in soils adjacent to CCA-treated utility poles in four different study areas in city of Artvin where is northern east part of Turkey and determine the influence of soil composition. Surface (0–5 cm) and subsurface soil samples (30–40 cm) were collected near CCA-treated utility poles and control soil samples away from CCA-treated utility poles were also collected. Water holding capacity, pH and mechanical properties of soil samples were determined for both depth levels. The results showed that Cu, Cr and As concentration in soil samples taken from all four study areas in 0–5 cm depth was higher than soil samples taken from 30–50 cm depth.

Keywords—Utility poles; Soil properties; Leaching, CCA.

I. INTRODUCTION

CHROMATED COPPER ARSENATE (CCA) has been one of the most widely used wood preservatives since the 1933’s to protect wood products against decay and insects for exterior applications such as decks, housing, utility poles, play equipment and fences. CCA wood preservatives are formulated from chromium trioxide, copper oxide, and arsenic pentoxide [1]. Copper and arsenic are excellent broad-spectrum fungicides against decay fungi, insects, and marine borers. Chromium acts as a “fixing” agent for these components. During the fixation process, chromium is reduced from the hexavalent state (Cr+6) to the trivalent state (Cr+3) and in the process reacts with wood and the other CCA components to form low solubility reaction products. The arsenic is fixed primarily as chromium arsenates (pentavalent) while the divalent copper is stabilized primarily by ion exchange to wood components. Retention levels in CCA treated wood range between 4.0 kg/m3 for above ground contact uses to 40 kg/m3 for marine piling. The average retention for all products treated in the USA was estimated to be 5.6 kg/m3 in 1990 [1]. On February 12, 2002, the US Environmental Protection Agency (EPA) announced a voluntary decision by the pressure-treated wood industry to phase out use of common arsenic-based wood preservative CCA in products destined for consumer markets. Since January 2004, the EPA has no longer allowed pressure treated wood containing CCA to be used for residential applications such as children’s play structures, decks, picnic tables, landscaping timbers, residential fencing or walkways [2, 3]. However, CCA has still been allowed to treat utility poles and railroad sleepers. The environmental risks that CCA elements represent has been under investigation for the last decade, and information has accumulated for both aquatic environments and soils [4–9].

Since soils are more complex and inhomogeneous than bodies of water, exposure effects are much more difficult to predict. In addition, the soil compartment is extremely difficult to distinguish from other compartments such as the soil atmosphere or soil pore water. The chemical reactions in soil depend on the soil types and physical and chemical characteristics [10]. Toxicity and mobility of arsenic (As), copper (Cu) and chromium (Cr) in soil depend on different soil characteristics such as content of clay, sand and silt (texture), organic matter, soil pH, Al, Mn, Fe oxides, soil redox potential, etc. Soil constitutes chemically react with As, Cu and Cr by reactions of specific and non-specific adsorption, precipitation, cation exchange, organic complexation, etc. Therefore, these elements are transformed in the soil medium and the type of reaction can increase or depress element toxicity [10].

Numerous studies have been done dealing with environmental risks that CCA elements represent for both aquatic environments and soils (e.g. [11, 12, 13-16]). However, there are only two studies that have done in Turkey by Erdin et al.[17] and Gezer et al. [18]. Gezer et al [18] studied CCA element concentrations in soils near the utility poles and observed higher concentrations adjacent to them, compared to control soils. Erdin et al. [17] studied the content and mobility of copper (Cu), chromium (Cr) and arsenic (As) in the soil of a wood-preserving plant using CCA. They found concentrations as high as 513, 1945 and 2400 mg kg-1 for arsenic, copper and chromium, respectively.

Toxicity and mobility of As, Cu and Cr in soil depend on different soil characteristics, such as contents of clay, sand and silt (texture), organic matter, soil pH, Al, Mn, Fe oxides, soil redox potential, etc [13, 18]. Soil constitutes chemically react with As, Cu and Cr by reactions of specific and non-specific adsorption, precipitation, cation exchange, organic complexation, etc. Balasoiu et al. [13] reported that retentions...
of Cr and Cu in soils increased with increasing organic matter content, while As retention did not change with organic matter. Chromium exhibits a typical anionic sorption behavior, its adsorption decreasing with increasing pH and when competing dissolved anions are present [19]. These elements are transformed in the soil medium and the type of reaction can increase or depress element toxicity [10].

In this study, the main objective was to assess the distribution of Cu, Cr, and As in soils adjacent to CCA-treated utility poles in four different study areas in city of Artvin and its surrounding.

II. MATERIALS AND METHODS

Four different study areas in city of Artvin were selected according to their climatic conditions (Fig. 1). A soil auger was used to sample the soil around each pole, with soil samples collected based on both horizontal distance away from the utility poles and vertical depth at that horizontal locations. Surface (0–5 cm) and subsurface soil samples (30–40 cm) were collected near CCA-treated utility poles, and control soil samples were collected away from CCA-treated utility poles. The tree samples from the same depth and distance from post were collected and combined for a given pole. A total of 120 (30 samples for each study area) soil samples adjacent to the CCA-treated utility poles were collected for study area. Water holding capacity, pH and mechanical properties of soil samples were determined for both depth levels. The soil samples were air-dried in the laboratory and sieved to remove coarse fragments larger than 2 mm. Organic matters was determined by a wet combustion procedure. Soil pH was measured in water. Each dried soil sample was digested with nitric acid/hydrogen peroxide and analyzed for Cr, Cu and As content by ICP according to AWPA A9-99 test method [20].

Fig 1. Study areas chosen in city of Artvin, Turkey

III. RESULTS AND DISCUSSION

Soil properties for each study area in Artvin were determined and are given in Table 1. It was found that pH of soil samples taken from study area I was lower than that of the other three study areas studied in this research. Percentage of sand in samples taken from study area I and III were higher than that of the other two study areas. Percentage of clay was the highest in soil samples taken from study area IV. Percentage of dust in soil samples taken from study area II and IV was higher than that of study area I and III. Water holding capacity was found to be higher in samples taken from study area I than that of the other three study areas.

The distribution of Cu, Cr, and As in soils adjacent to CCA-treated utility poles in four study areas was determined and is given in Figs. 2–5. Results showed that Cu, Cr and As concentration in soil samples taken from all 4 different study areas in 0–5 cm depth was higher than soil samples taken from 10-30 and 30–40 cm depth. However, there is not much difference in the Cu, Cr, and As concentrations between control and samples taken from 30–40 cm depth. Erdin et. al. [17] and other researchers [10, 15, and 21] reported similar findings that Cu, Cr and As concentrations were higher in the soil samples taken from soil surface than that from subsurface (30–40 cm depth).

Fig. 2: Cu, Cr and As concentrations in the soil samples taken from study area I.

Table 1: Soil properties for each study area located in Artvin

<table>
<thead>
<tr>
<th>Study Area</th>
<th>Depth</th>
<th>pH Mean</th>
<th>Std</th>
<th>Sand (%) Mean</th>
<th>Std</th>
<th>Clay (%) Mean</th>
<th>Std</th>
<th>Dust (%) Mean</th>
<th>Std</th>
<th>WHC (%) Mean</th>
<th>Std</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>0-5 cm</td>
<td>4.76</td>
<td>0.70</td>
<td>65.81</td>
<td>10.05</td>
<td>16.67</td>
<td>9.21</td>
<td>17.52</td>
<td>4.57</td>
<td>63.07</td>
<td>12.81</td>
</tr>
<tr>
<td></td>
<td>30-40 cm</td>
<td>4.59</td>
<td>0.68</td>
<td>62.03</td>
<td>9.00</td>
<td>23.80</td>
<td>5.43</td>
<td>14.17</td>
<td>1.88</td>
<td>49.32</td>
<td>14.91</td>
</tr>
<tr>
<td>II</td>
<td>0-5 cm</td>
<td>6.55</td>
<td>0.18</td>
<td>52.61</td>
<td>6.86</td>
<td>22.63</td>
<td>1.40</td>
<td>24.76</td>
<td>1.18</td>
<td>35.18</td>
<td>2.70</td>
</tr>
<tr>
<td></td>
<td>30-40 cm</td>
<td>6.62</td>
<td>0.18</td>
<td>50.18</td>
<td>7.15</td>
<td>23.07</td>
<td>1.37</td>
<td>26.75</td>
<td>1.75</td>
<td>33.38</td>
<td>2.68</td>
</tr>
<tr>
<td>III</td>
<td>0-5 cm</td>
<td>6.50</td>
<td>0.40</td>
<td>66.10</td>
<td>5.80</td>
<td>17.25</td>
<td>1.66</td>
<td>16.65</td>
<td>1.80</td>
<td>45.07</td>
<td>8.67</td>
</tr>
<tr>
<td></td>
<td>30-40 cm</td>
<td>6.21</td>
<td>0.15</td>
<td>63.59</td>
<td>5.20</td>
<td>18.94</td>
<td>1.98</td>
<td>17.47</td>
<td>0.93</td>
<td>40.53</td>
<td>9.34</td>
</tr>
<tr>
<td>IV</td>
<td>0-5 cm</td>
<td>7.55</td>
<td>0.22</td>
<td>43.18</td>
<td>4.87</td>
<td>32.37</td>
<td>3.21</td>
<td>24.45</td>
<td>1.13</td>
<td>29.37</td>
<td>7.81</td>
</tr>
<tr>
<td></td>
<td>30-40 cm</td>
<td>7.62</td>
<td>0.32</td>
<td>46.47</td>
<td>4.69</td>
<td>28.74</td>
<td>3.19</td>
<td>24.79</td>
<td>1.26</td>
<td>33.60</td>
<td>8.07</td>
</tr>
</tbody>
</table>

WHC, water holding capacity; Std, standard deviation.
While Cu concentrations were found to be higher in soil samples taken from 0–5 cm depth in all cities, Cr concentrations were found to be higher than As concentrations. In other words, the leaching order in soil samples from CCA-treated utility poles was found to be Cu > Cr > As.

The results showed that soil properties and climatic factors affected the Cu, Cr and As concentrations in soil samples taken from four different study areas. The highest Cu and Cr concentrations were found in soil samples taken from Study Area I while the highest As concentration was found in soil samples taken from Study Area IV. The reasons for higher concentrations of Cu and Cr As in soil samples taken from Study Area I could be explained by several factors. First, soil pH in Study Area I was lower than that of the other three study areas and this might cause these metals to leach from CCA-treated utility poles into soil. Several researchers already stated that acidic and alkaline conditions cause CCA components from CCA-treated wood materials [10,18]. The other reason is that sand percentage in soil samples taken from city of Study Area I is fairly high, and it is already reported by several other researchers that leaching rate is much higher in sandy soils [15]. In addition, the soil samples in this study were taken from tea plantation areas where CCA-treated utility poles are used in service for only 10–15 years. In these tea plantation areas, fertilizers are heavily used and cause Cu, Cr and As leaching from CCA-treated utility poles into soil.

ACKNOWLEDGMENT

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REFERENCES

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