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Distribution of Heavy Metals and Relationship of Heavy Metals from Land Used in Bangkok, Thailand

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The structure of soil particles, which serves as the fundamental unit of soil, is crucial for plant growth. Human activities on land use have significantly impacted soil structure and led to the contamination of heavy metals in the soil. This research aimed to investigate the heavy metal contamination in soil across six different land use categories: agricultural zone, rural zone, commercial zone, and three classifications of urban areas based on their density—high-density residential zone, medium-density residential zone, and low-density residential zone. Soil samples were collected from 50 districts in Bangkok, resulting in a total of 150 samples obtained at a depth of 0-5 cm between October-November, 2020. These samples were analysed for six heavy metals—Cadmium (Cd), Chromium (Cr), Copper (Cu), Nickel (Ni), Lead (Pb), and Zinc (Zn)—using an Atomic Absorption Spectrometer (AAs). The findings revealed that the average levels of heavy metal contamination were as follows: Pb > Cr > Zn > Cu > Ni > Cd with concentrations of 47.10±23.20, 20.66±7.53, 11.58±6.06, 8.63±6.92, 6.50±7.91, and 0.56±0.36 mg/kg. Pb and Cr exhibited the highest levels of contamination in commercial zone, urban zone, and rural zone, while Cr and Cu were most prominent in agricultural zone. The concentrations of heavy metals in Bangkok soil did not exceed the standard limits for heavy metal contamination in residential and agricultural soils, as outlined by the National Environment Board Notification.

1. Introduction

Heavy metals are found in the natural environment, including soil, water, air, and living organisms' bodies. When present in excessive amounts, heavy metals can be toxic to humans and animals, causing symptoms such as headaches, nausea, muscle weakness, and nerve-related issues. Heavy metals have the ability to combine with organic compounds and transfer into living organisms through the food chain. This accumulation can occur in the tissues of living organisms, as well as in riverine sediments and soil layers.

The main sources of heavy metals encountered in everyday life are derived from both natural processes and human activities. As indicated by previous research, the level of heavy metal contamination is significantly influenced by land use. Different land use areas exhibit distinct characteristics of heavy metal contamination. For instance, in agricultural areas, the predominant heavy metal contaminants are Cr, Cu, Zn, Mn, and Ni, which are believed to originate from soil amendments (Deng et al., 2018). Agricultural silages often display heavy metal contamination, particularly with Mn, Cu, Zn, and Cr. Moreover, significant levels of Pb contamination have been found (Jin et al., 2019), possibly due to incomplete combustion from car engines and industrial sectors. Wind serves as a variable that transports airborne heavy metals, facilitating their spread and accumulation in rivers and soil areas. Notably, there is a statistically high level of Pb contamination (Bi et al., 2020), which aligns with the research conducted by Guangju et al. (2020) on diesel fuel and automobile combustion. During incomplete combustion of automobiles, heavy metal Pb is released into the atmosphere.

The human activities, soil physical characteristics play a role in the accumulation of heavy metals. For example, in agriculture, soil is plowed to prepare the surface for crop and vegetable cultivation. However, this process alters the size of soil particles, so increasing heavy metal contamination. Smaller soil particles tend to have higher levels of heavy metal contamination (Deng et al., 2020). The issue of studying the relationship between soil pollution caused by heavy metal accumulation and the different land use patterns in the Bangkok area remains an unanswered question to this day. There are multiple dimensions of relationships that have shaped

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the lives of people in the past and present, resulting in diverse land uses across different areas. The problem of fine dust in the Bangkok area has been worsening year after year. The studies on the level of heavy metal contamination in the soil at Bangkok are still relatively limited. It is crucial to plan and manage environmental and health safety measures for the densely populated areas of Thailand. Land use practices have implications for heavy metal contamination in the Bangkok area, the capital city of Thailand, which encompasses various dimensions of human relationships spanning from the past to the present. Different areas in Bangkok have diverse land uses. Understanding the relationship between land use and heavy metal contamination in soil is crucial for environmental and health safety planning in densely populated areas of Thailand. This research aims to investigate the correlation between land use and heavy metal contamination, as well as the contamination levels of specific heavy metals in soil at Bangkok area from 2020 to 2021.

2. Material & Method

2.1 Site description

In this research, soil samples were collected from various areas in Bangkok. This is located in the central plains of Thailand at the east longitude of $100^0\,25'\,27''$ - $100^0\,32'\,58''$ and north latitude of $13^0\,42'\,30''$ - $13^0\,47'\,42''$. The city covers area of 1,568.7 km^2, which is divided into a total of 50 districts. Each district is further categorized based on land use classifications provided by the Department of City Planning, Bangkok in 2013 (Figure 1). Normally, the three classifications of urban areas based on their density—high-density residential zone, medium-density residential zone, and low-density residential zone were divided by many factors such as population density, number of house and room for rent, usable area per population, etc. The land use map includes six main categories:

- High-density residential zone: These are highly populated regions with significant residential and commercial development.
- Medium-density residential zone: These areas have a moderate population density, with a mix of residential, commercial, and public spaces.
- Low-density residential zone: These regions have lower population densities compared to the previous categories, with a focus on residential areas.
- Agricultural zone: These are designated for agricultural purposes, such as farming and crop cultivation.
- Rural zone: These are residential areas located on the outskirts of the city, characterized by a lower population density and larger plots of land.
- Commercial zone: These regions are primarily dedicated to commercial and business activities, including shopping mall, office buildings, and industrial zones.

By collecting soil samples from these different land use categories, the research aims to investigate the level of heavy metal contamination and its potential relationship with land use patterns in Bangkok, Thailand.

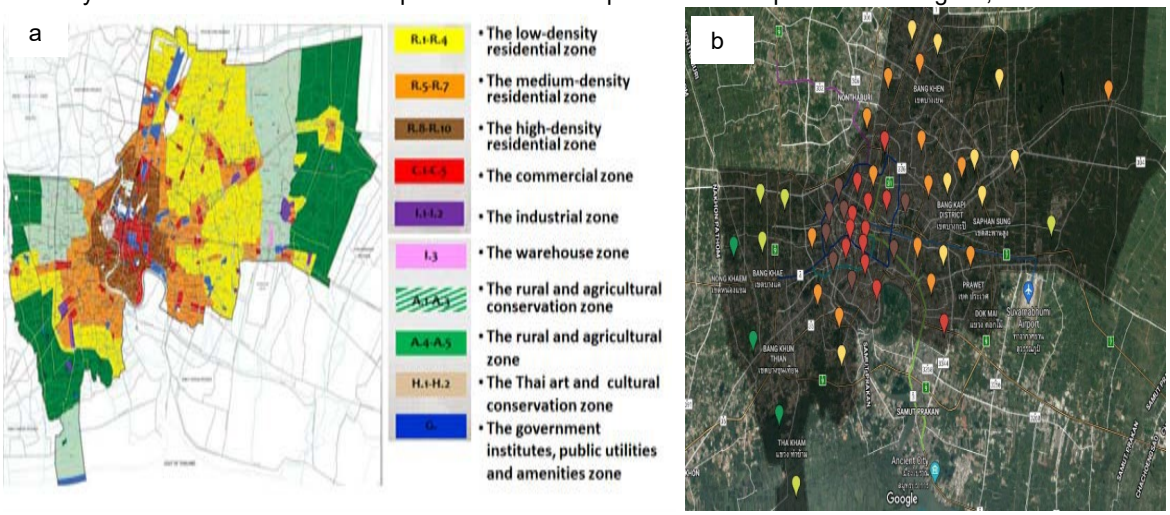

Figure 1: (a)The land use map for the Bangkok area was divided according to the Department of Land Development's classification in 2013 (B.E.2556). This map provides information on the various types of land use in Bangkok, Thailand. (b) The 50 markers of soil collection in Bangkok, Thailand (Source: google map).

2.2 Soil collection and heavy metals analysis

Soil samples were collected following soil core method (Hanpattanakit et al., 2022) cover 50 districts in Bangkok. The collection process involved selecting a particular area and gathering soil samples from three points within that area. These points were situated at a distance of 1–2 m from each other. Each of the three points, soil samples were collected from two different depths: 0-5 cm and 5-10 cm. This resulted in a total of six soil samples per area. The total soil collection was 150 samples. Then, the 6 heavy metal contents as well as Cadmium (Cd), Chromium (Cr), Copper (Cu), Nickel (Ni), Lead (Pb), and Zinc (Zn) in soil were analysed by Atomic Absorption Spectrometer (AAs). The details and procedures for the extraction and analysis process were adopted from the academic journal titled "Analysis of heavy metal in soil through atomic absorption spectroscopy for forensic considerations" by Mishra et al. (2018).

3. Result & Discussion

3.1 Level of heavy metals contamination in soil

Cr contamination in soil at Bangkok revealed that the highest recorded Cr content was 41.31 mg/kg, while the lowest recorded Cr content was 8.41 mg/kg. The districts of Bang Bon, Nong Khaem, Ratchathewi, Huai Khwang, Don Mueang, and Prawet exhibited relatively higher levels of Cr contamination in the soil (Figure 2a). The area of high Cr contaminates in soil are nearly located in commercial zone and agricultural zone. The highest of Zn contamination was highly 27.51 mg/kg, while the lowest recorded Zn content was 3.59 mg/kg. The districts of Bang Na, Khlong Toei, Bang Bon, Nong Khaem, and Chatuchak exhibited relatively higher levels of Zn contamination in the soil (Figure 2b). The area of high Zn contaminates in soil are nearly located in commercial zone and heavy traffic zone at high-density residential zone and medium-density residential zone. Cu contamination was highly 39.39 mg/kg, while the lowest was 1.84 mg/kg. The districts of Bang Bon, Bang Khun Thian, Nong Khaem, Bang Na, Huai Khwang, Lad Phrao, Don Mueang, and Nok Chok exhibited relatively higher levels of Zn contamination in the soil (Figure 2c). The area of high Cu contaminates in soil are nearly located in commercial zone and agriculture zone. The highest of Ni contamination was 30.21 mg/kg and the lowest was 0.43 mg/kg. These levels were predominantly found in the districts of Khlong Toei, Bang Na, Min Buri, and Lat Krabang. In the Saphan Sung was found in small amounts (Figure 3a). The area of high Ni contaminates in soil are nearly located in agriculture zone and heavy traffic zone at high-density residential zone and medium-density residential zone. The highest of Pb contamination was 105.44 mg/kg and the lowest was 12.50 mg/kg. These levels were predominantly found in the districts of Khlong Toei, Bang Na, Min Buri, Lat Krabang, Chatuchak, Ratchathewi, Bang Bon, Bang Khun Thian, and Chom Thong (Figure 3b). The area of high Pb contaminates in soil are nearly located in commercial zone and traffic zone at high-density residential zone and medium-density residential zone. The highest of Cd contamination was 2.08 mg/kg and the lowest was 0.09 mg/kg. These levels were predominantly found in the districts of Bang na, Pom Prap Sattru Phai, and Bang Rak. (Figure 3c). From the experimental results, the concentrations of heavy metals in the soil were as follows: Pb > Cr > Zn > Cu > Ni > Cd, with mean values of 47.10±23.20, 20.66±7.53, 11.58±6.06, 8.63±6.92, 6.50±7.91, and 0.56±0.36 mg/kg. It was found that the soil in the Bangkok area does not exceed the standards for heavy metal contamination of soil in Thailand. The standards for heavy metals contamination in soil as Cr, Ni, Pb, and Cd were 300, 1600, 400 and 37 mg/kg, respectively. When compared to China's standard, it was found that the heavy metal Cd in the Bangkok area exceeded China's soil heavy metal contamination standard. The average value was 0.56 mg/kg, but the standard value in China was 0.3 mg/kg. This is caused by human activities that promote heavy metal contamination to the soil. There will be a statistically significant increase in heavy metal contamination of Cr, Zn, and Cu due to the use of soil quality amendments and pesticides containing heavy metals. This is in line with the research of Sangthong (1996) who stated that farmers in the country use compost, manure, and other chemical fertilizers where Cr, Zn, and Cu heavy metal contaminants are present. There will also be significant Pb heavy metal contamination, which is expected to come from industrial combustion and incomplete combustion of engines. This causes the release of Pb to float into the air and fall, accumulating in the soil. Consistent with the research of Bi et al. (2020) and Jin et al. (2019), it was found that the surrounding soils of areas with high traffic or commercial land use have very high contamination of Pb, which is statistically significant.

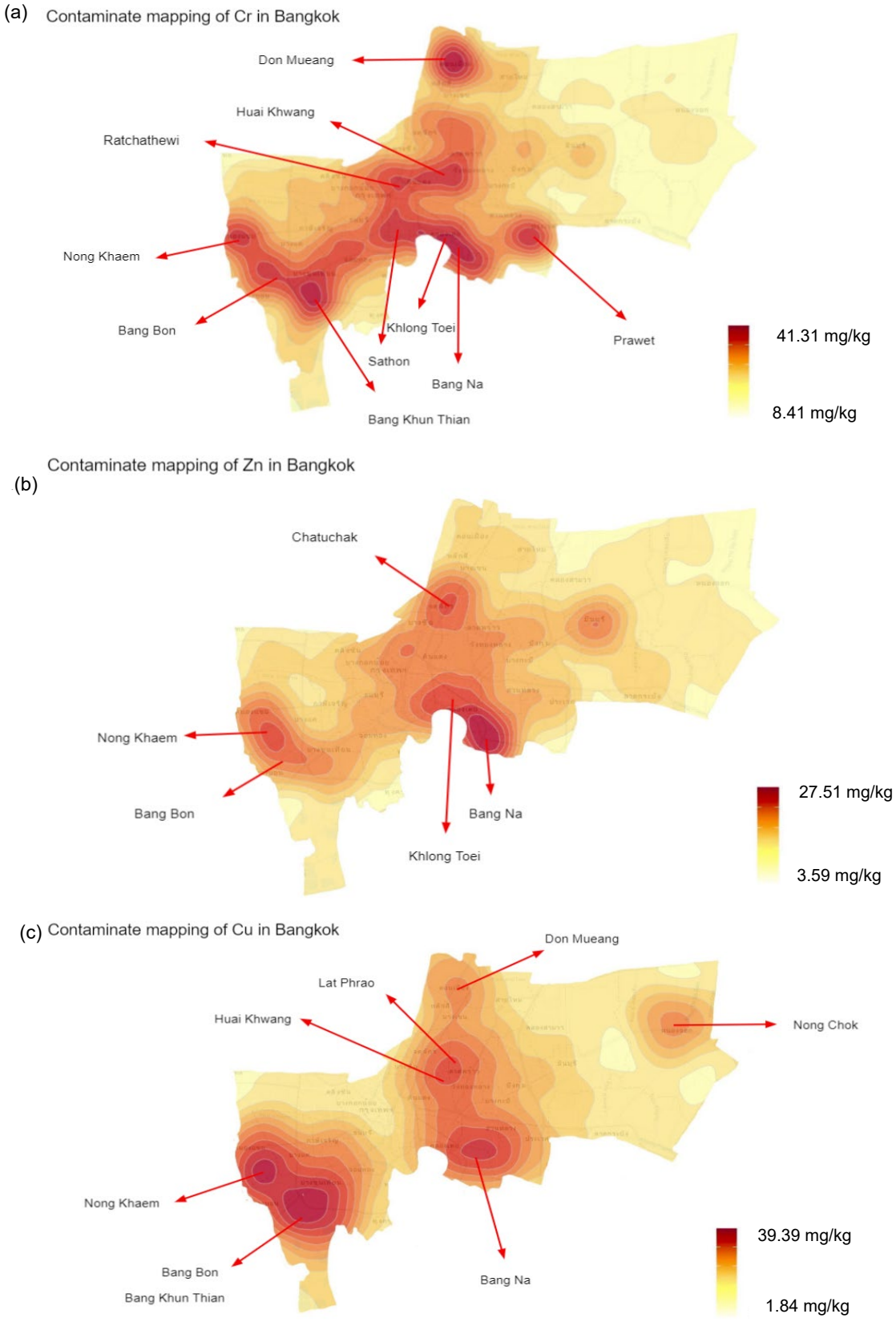

Figure 2: Heavy metals contamination in soil at Bangkok, Thailand: (a) Level of Cr contamination in soil, (b) Level of Zn contamination in soil, (c) Level of Cu contamination in soil

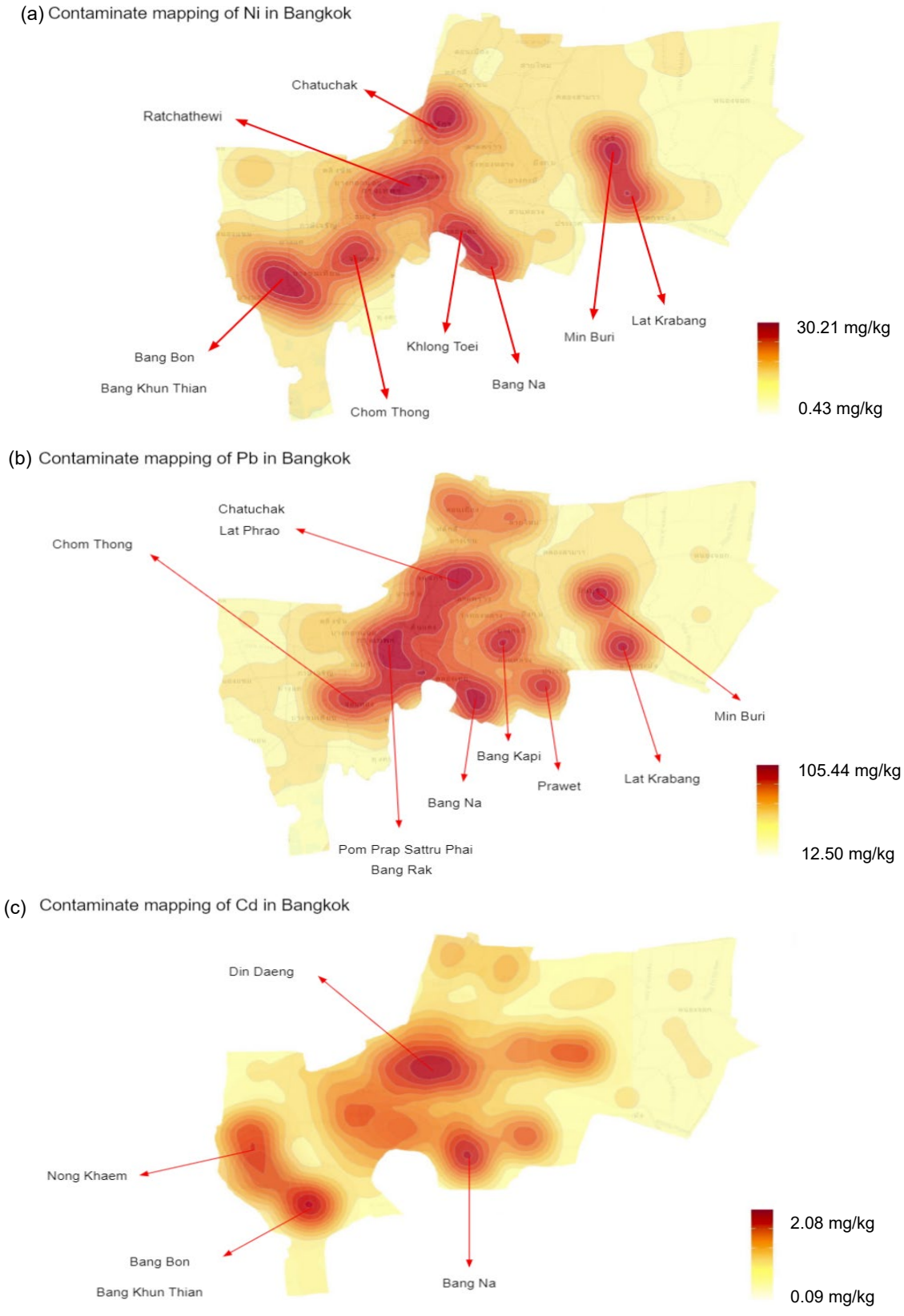

Figure 3: Heavy metals contamination in soil at Bangkok, Thailand: (a) Level of Ni contamination in soil, (b) Level of Pb contamination in soil, (c) Level of Cd contamination in soil

3.2 Relationship between heavy metal content and land used

From the results, it was found that areas with urban areas based on their density—high-density residential zone, medium-density residential zone, and low-density residential zone exhibited similar patterns of heavy metal contamination. In high-density residential zone, the contamination percent for Pb, Cu, Ni, Cr, Zn, and Cd were 52.9, 5.9, 6.0, 23, 11.6, and 0.6. In medium-residential zone, the contamination percent for Cr, Zn, and Cd were 54.8, 7.7, and 4, while low-residential zone, the contamination percent for Pb, Cu, Ni, Cr, Zn, and Cd were 52.4, 9.3, 4.4, 22.7, 10.6, and 0.6. The contamination pattern of heavy metals in the soil remained the same across different types of land use: Pb > Cr > Zn > Cu > Ni > Cd. In contrast, agricultural areas showed contamination with all six heavy metals: Pb, Cu, Ni, Cr, Zn, and Cd, the contamination percent for 16.3, 24.9, 12.9, 27.9, 16.7, and 1.3. The contamination sequence in agricultural areas was Cr > Cu > Zn > Pb > Ni > Cd. It can be observed that agricultural areas experience a significant increase in Cr, Cu, and Zn contamination. Land used is associated with the nature of heavy metal contamination due to varying patterns of human activities in different areas. For instance, residential areas experience high levels of car traffic but may have less horticulture activities. Conversely, areas located far from the city may have less traffic but are characterized by vegetable cultivation, farming, and gardening. These human activities act as catalysts for heavy metal contamination, leading to variations in contamination levels for each type of heavy metal. According to the research conducted by Deng et al. (2018), which explored the relationship between land use and heavy metal accumulation, the study investigated three different areas: agricultural areas, forest areas, and wastelands. The findings indicated that agricultural areas exhibited significant contamination of heavy metals such as Cd, Ni, Zn, Mn, and Cu. This contamination in the soil is attributed to the long-term use of soil conditioners by farmers in those areas. These soil conditioners contain all five heavy metals, resulting in higher levels of Cd, Ni, Zn, Mn, and Cu contamination compared to wasteland and forest areas.

4. Conclusions

The average values of Pb, Cr, Zn, Cu, Ni, and Cd were 47.10±23.20, 20.66±7.53, 11.58±6.06, 8.63±6.92, 6.50±7.91, and 0.56±0.36 mg/kg. Among these heavy metals, Pb and Cr were found to be the most prevalent in commercial, urban, and rural areas. Conversely, Cr and Cu heavy metals were predominantly found in agricultural areas. These findings indicate that the contamination of different heavy metals in the soil is related to the land use influenced by human activities. It is worth noting that the heavy metal content in the soil in the Bangkok area did not exceed the standards for heavy metal contamination in Thailand.

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