Effect of industrial and residential sewage sludge and burnt garbage on cadmium content in soil and kangkong plants (Ipomoea reptans L Poir)

L Victor, Sarifuddin* and Jamilah
Faculty of Agriculture, Universitas Sumatera Utara, Medan, Sumatera Utara, Indonesia.

E-mail: *sarifuddin@usu.ac.id

Abstract. This research aimed to determine the effect of sewage sludge from industry and residential and burnt garbage that applied to Inceptisol as media for kangkong (Ipomoea reptans L Poir). This study was using a randomized block design consisted of 2 factors. Factor 1 was the type of sewage sludge with 3 treatments, namely L1 = sludge in urban settlements, L2 = sludge from Mabar Industrial Area (KIM), and L3 = Burnt garbage from Medan, Sumatera Utara. Factor 2 was the dosage of sewage sludge with 3 treatments, namely D1 = 50%, D2 = 75% and D3 = 100% applied with 3 replications. The result showed that the application of sewage sludge taken from the industry, municipal, and burnt garbage increased the level of cadmium (Cd) in soil and kangkong plant. Moreover, the Cd content in soil with all types of sludge with a dosage level of 75% and 100% exceeded the critical limit of Cd in soil, which was 0.5 ppm. The concentration of Cd in plants was higher than in the soil, but under critical level for the plant, which was 5-10 ppm.

1. Introduction
Hazardous and toxic material waste is the residue of business activity that contains hazardous and toxic materials, both directly and indirectly, can pollute, damage and endanger the environment, health, survival of human and other living things [1]. Based on the form of waste produced, waste is divided into three types, namely solid, liquid, and gas waste. In the treatment process, the industry produces by-products of the wastewater treatment process in the form of sludge [2]. Sludge wastewater treatment plant in industry contains organic matter, with a high content of nitrogen (N) and phosphorus (P). However, the content of potassium (K) in the sludge wastewater treatment plant is low and also contains Ca, Mg, and metallic metals such as Pb and Cd [3].

Cd is a vital metal and has many benefits, especially for electroplating and galvanization, because it has non-corrosive properties. Cd is widely used in alloy metal manufacturing, as colour pigments in paints, ceramics, plastics, and plastic stabilizers, as cathodes for Ni-Cd in batteries, as photographic materials, in TV tubes, rubber, soap, fireworks and textile printing manufacturing, and also as pigments for glass and dental email [4].

Cd in various forms can enter the environment, especially from human activities. All industries that involve cd in their industrial operational processes are the source of Cd pollution. Also, Cd comes from
household waste and fossil fuel burning, because naturally, the fuel contains Cd [5]. Cd will undergo biotransformation and bioaccumulation in living organisms (plants, animals, and humans). In the body of aquatic biota, the amount of metal accumulated will continue to increase along with the process of biomagnification in the bodies. Besides, the level of biota in the food chain system also determines the amount of accumulated Cd. Where in the higher strata biota, more accumulated Cd will be found, whereas in the top-level biota, it is the place of highest accumulation. If the amount of Cd that enters has exceeded the quality standard, then the biota will experience death and even extinction [5].

Sewage sludges from municipalities are frequently applied to soils in disposal operations, as soil conditioners or as a source of plant nutrients. The concentrations of Cd in sewage sludge always exceed those typically found in soils. Municipal sewage sludge contains in the range of approximately 2 to 3500 mg Cd/kg sludge, with medians in the order of 5 to 20 mg/kg [6]. It is customary for several people in the residential areas to use the residue from burning waste and sludge from the trenches to fertilize the soil and plants without realizing the presence of toxic metals in the waste, but the sewage sludge can reduce the toxicity effect of cadmium [7]. This study aimed to determine the impact of the application of sludge and residual burnt waste in the Cd metal content in soil and kangkong plants (*Ipomoea reptans* L Poir.).

2. Materials and methods

The materials used in this study were sludge from the industrial area in KIM Mabar, urban settlements and burnt garbage in Medan, which were taken in a composite manner, incetsisol soil from Kwala Bekala (3028 '19 "LU and 98038 '22 BT) as planting medium and kangkong seeds plants as indicator plants.

This study was using a factorial randomized block design method with 2 factors. The first factor was the type of waste, L1 = residential sewage sludge, L2 = Industrial sewage sludge from Mabar Industrial Area (KIM) and L3 = burnt garbage, while the second factor was the dosage of soil-waste (w/w) which was D1 = 50%, D2 = 75% and D3 = 100% with 3 replications.

The preparation of planting media was conducted according to the specified treatment as much as 5 kg, then placed in a polybag. After that, the planting media was incubated for 2 weeks in a field capacity condition. Furthermore, the mixture of Inceptisol and sludge waste was analysed by pH-H2O (2.5: 1) and C-Organic (Walkley and Black) and soil Cadmium (Acid Extraction). Moreover, the kangkong seeds that have been aged 4 days then transplanted into polybag with each treatment. Kangkong harvesting was done 30 days after planting by separating the plant and the root parts. The plant was analysed to determine the Cd content of plants.

3. Results and discussion

The result of soil pH analysis after mixing the soil and waste for 2 weeks incubation is presented in Table 1. Application of residential and industrial sewage sludge and burnt waste increased the pH of the soil to somewhat alkaline but not significant for each type and dosage of waste given. This may cause the release of Cd ions to be lower in the neutral soil than in the acidic soils. The degree of soil acidity was a major factor in the availability of metals in plants. Acidic soil will increase the release of metals in the soil, including toxic metals [8]. If other soil conditions remain unchanged, the cadmium concentration of plant tissue will decrease as the pH of the soil increased [6].

| Types of Waste                  | Dosage | Average |
|--------------------------------|--------|---------|
| Residential Sewage Sludge      | 50%    | 7.37    | 7.46 |
|                                | 75%    | 7.47    |       |
|                                | 100%   | 7.54    |       |
| Industrial Sewage Sludge       |        | 7.90    | 7.54 |
| Burnt Garbage                  |        | 7.38    | 7.39 |
| Average                        |        | 7.41    | 7.57 |

Table 1. pH of soil due the application of waste at 2 weeks after incubation
Likewise, the application of sludge waste and burnt garbage, which were mostly organic materials in varying amounts, were able to increase soil carbon content almost equivalent to the amount of waste given because \( \% \text{ organic matter} = 2.54 \times \% \text{ C} \). Higher dosage of sludge increased organic carbon in soil but not significant for all treatments as shown in Table 2.

Application of waste either in the form of industrial or municipal sludge waste and combustion waste originating from urban residential solid waste has significantly increased soil Cd content, where the residual combustion waste contributed the most exceptional value compared to other wastes, and the higher the dosage of the waste given turns out to be more increase soil Cd levels. The interaction between types and dosages of waste increased significantly as shown in Table 3. At 75 % dosage of waste, it turns out that the Cd content of the soil is above the permissible critical limit of 0.5 ppm [9].

### Table 2. Soil Carbon due to the application of waste at 2 weeks after incubation

| Types of Waste            | Dosage 50% | Dosage 75% | Dosage 100% | Average |
|---------------------------|------------|------------|-------------|---------|
| Municipal Sewage Sludge   | 24.81      | 17.65      | 28.78       | 23.75   |
| Industrial Sewage Sludge  | 19.61      | 22.21      | 25.59       | 22.47   |
| Burnt Garbage             | 19.07      | 26.64      | 25.72       | 23.81   |
| Average                   | 21.16      | 22.17      | 26.70       |         |

### Table 3. Soil Cadmium due to the application of waste at 2 weeks after incubation

| Types of Waste            | Dosage 50% | Dosage 75% | Dosage 100% | Average |
|---------------------------|------------|------------|-------------|---------|
| Municipal Sewage Sludge   | 0.47gh     | 0.86fg     | 1.03cd      | 0.79c   |
| Industrial Sewage Sludge  | 0.03i      | 0.76g      | 2.08b       | 0.96b   |
| Burnt Garbage             | 0.41h      | 1.02d      | 2.74a       | 1.39a   |
| Average                   | 0.30c      | 0.88b      | 1.95a       |         |

The numbers in the row and column followed by the same letter are not significantly different at \( \alpha = 5\% \).

The increment of Cd content in the soil was also in line with the increase of Cd levels in plants, where the higher of the amount waste given resulted in a higher Cd level absorbed by plants. The type of waste did not show any differences, although it showed varying levels. Metal accumulation in plants not only depended on the content in the soil but also depended on the chemical elements in the soil, the type of metal, and plant species [7]. Cadmium absorption increased when there was a deficiency of calcium (Ca), iron (Fe), and low protein in food [4]. In detail, the Cd content in plants is listed in Table 4.

### Table 4. Plant Cadmium due to the application of waste at 4 weeks after planting

| Types of Waste            | Dosage 50% | Dosage 75% | Dosage 100% | Average |
|---------------------------|------------|------------|-------------|---------|
| Municipal Sewage Sludge   | 1.02       | 1.84       | 2.73        | 1.86    |
| Industrial Sewage Sludge  | 0.65       | 1.26       | 3.56        | 1.82    |
| Burnt Garbage             | 0.92       | 1.63b      | 2.82        | 1.79    |
| Average                   | 0.86c      | 1.59b      | 3.03a       |         |

The amount of Cd in plants was still below the threshold of 5 -10 ppm [10]. This may occur because the pH of the soil contained a slight alkaline, but in more acidic soil, the possibility of absorption could be
higher. The concentration of metals in plant tissue decreased when soil pH raised, and the higher the concentration of metals in the soil made, the higher the concentration of metals in plant tissue [8]. The impact of Cd contamination on agricultural soils depended on soil physical, chemical, and biological properties, which influenced the plant uptake and availability of cadmium [7]. Soil pH, Cd content of the soil, and redox potential influenced the absorption of Cd by agricultural crops. Crops grown on the soil naturally elevated in Cd show higher concentrations of Cd than those grown on similar soils whose Cd concentrations were low [6]. Plants grown on Cd-enriched soils in containers in the greenhouse tended to absorb more Cd than the same plants grown on the same soil amended with identical amounts of Cd in the field [6]. The correlation between Cd content in soil and plants showed a fairly close relationship that was \( r = 0.633 \), as shown in Figure 1.

![Figure 1. Correlation of Cd in soil and plant](image)

4. Conclusion
Type and dosage and waste had no significant effect on soil pH and C-Organic of soil. Burnt garbage increased the highest Cd levels in soil, and the higher the level of dosage would affect the content of Cd, which made them higher as well. All types of sludge increased the Cd level in plants, and the higher the level of dosage of the sludge would increase the content of Cd as well.

References
[1] Undang-Undang Republik Indonesia Nomor 23 Tahun 1997 Tentang Pengelolaan Lingkungan Hidup [Republic of Indonesia Law No 23/1997 concerning Environmental Management]
[2] Ristyawan A, Syafrudin and Samudro G 2012 *Studi Pemanfaatan Aktivator Lumpur Aktif Dan EM4 Dalam Proses Pengomposan Lumpur Organik, Sampah Organik Domestik, Limbah Bawang Merah Goreng Dan Limbah Kulit Bawang* [Study of Utilization of Activated Sludge Activator and EM4 in the Process of Composting Organic Sludge, Domestic Organic Waste, Shallot skin fried Waste and Onion Skin Waste] (Indonesia: Universitas Diponegoro)
[3] Yazid M M, Supriyatni K E and Budiono M E 2005 *Kajian Pemanfaatan Sludge Ipal Kota Jogyakarta Sebagai Pupuk Organik Yang Ramah Lingkungan* [Study of Utilization of Sludge in Waste Processing Installation in Yogyakarta City as Environmentally Friendly Organic Fertilizer] *J. Puslitbang Teknologi Baru – Bantan GANENDRA* 8 1
[4] Widowati, Sastiono A and Usuf R 2008 Efek Toksik Logam, Pencegahan dan Penanggulangan Pencemaran [Metal Toxic Effects of Pollution, Prevention and Management] (Yogyakarta: Penerbit C V Andi Offset)

[5] Palar H 2008 Pencemaran dan Toksikologi Logam Berat [Pollution and Toxicology of Heavy Metals] (Jakarta: Rineka Cipta)

[6] Page A L, Chang A C and el-Amamy M 1987 Cadmium Levels in Soils and Crops in the United States The Lead, Mercury, Cadmium, and Arsenic in the Environment Edited by T C Hutchinson and K M Meema (New York: John Wiley & Sons Ltd.)

[7] Gupta A, Maurya B R and Latare A M 2017 Effect of Sewage Sludge and Cadmium on Growth and Quality Features of Marigold (Tagetes erecta L) Grown in Three Soils Int. J. Curr. Microbiol. App. Sci. 2017 6 9

[8] Darmono 2001 Lingkungan Hidup dan Pencemaran: Hubungannya dengan Toksikologi Senyawa Logam. [Environment and Pollution: Relationship with toxicology of Metal Compounds] (Jakarta: UI Press)

[9] Ministry of State for Population and the Environment Republic of Indonesia and Dalhousie University Canada 1992 Environmental Management in Indonesia, Report on Soil Quality Standards for Indonesia (interim report)

[10] Mengel K and Kirby A 1987 Principles of Plant Nutrition 4th Ed (Wortblauf-Bern: Int. Potash Inst.)