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Heavy metal concentrations in roadside soil of cagayan de Oro City, Philippines

Jonalyn L. Olarte[1], Ronnie L. Besagas[2*]

[1]*Department of Chemistry, University of Science and Technology of Southern Philippines, Cagayan de Oro City, Philippines*

[2]*Department of Science Education, University of Science and Technology of Southern Philippines, Cagayan de Oro City, Philippines*

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Abstract

An investigation was conducted to study the heavy metal concentration and other physico-chemical parameters of the roadside soil in the 2nd Congressional District of Cagayan de Oro City. The samples were collected from seven different locations and analyzed for pH, conductivity, organic matter, and the heavy metals—Cd, Cu, and Pb. The pH of the soil is in the ranged between 7.85 to 8.54 while the conductivity and organic matter of the soil varies between locations with the highest value of 259 µS/cm and 5.54%, respectively. The average concentrations of metals in soils were 0.21 mg/kg Cd (ranged between 0.07 to 0.51 mg/kg), 87.7 mg/kg Cu (ranged between 61.0 to 169.7 mg/kg), and 97.6 mg/kg Pb (ranged between 43.2 To 264.0 mg/kg). Overall, the concentrations of heavy metals can be ordered as Pb > Cu > Cd. A higher concentration of heavy metals was observed in the soils collected from areas where there are frequent traffic congestions happen due to high traffic volume. The concentrations of heavy metals in roadside soils of District 2, Cagayan de Oro City were considered medium or low in comparison with those in other cities around the world.

* **Corresponding Author:** Ronnie L. Besagas ✉ rlbesagas@ustp.edu.ph

Introduction

Heavy metals are indisputably one of the major environmental contaminants in today's modern society. Cities and urban centers with high population density and intensive anthropogenic activities have a great number of sources of heavy metals which have enormous impact on the health of humans, other living organisms, and on different ecosystems. Although a few of the naturally occurring heavy metals, in the form of either elements or compounds, are essential micronutrients or trace elements of the human body, the majority has no known function as nutrients and are toxic to living organisms. Even those heavy metals considered essential can be toxic if present in excess. The heavy metals can impair important biochemical process posing a threat to human health, plant growth and animal life (Jarup, 2003; Silva *et al.*, 2005; Ali *et al.*, 2008; Yoshinori *et al.,* 2010; Aslam *et al.*, 2013).

Heavy metal pollution may come from domestic waste, chemical industry, transportation, and various anthropogenic activities such as urban road construction, quarrying, agriculture, waste incinerations, sewage disposal, bush burning, vehicle exhausts, industrial discharges, oil, lubricants, and automobile parts (Ho and Tai, 1988; Chen *et al.*, 2010). The pollution of soils by heavy metals from the transport sector is a crucial environmental issue in different part of the world. The metals are emitted during various transport operations such as combustion, component wear, fluid leakage, and corrosion of metals. The automobile exhaust is one of the potent contributors of heavy metals in urban area (Fergusson, 1992). A substantial amount of toxic metals from automobiles are received by the roadside soils, plants and organisms (Garcia *et al.*, 1998; Ho *et al.*, 1998; Sanchez-Martin *et al.*, 2000). Lead, cadmium, copper, and zinc are the major metal pollutants of the roadside environment (Swaileh *et al.*, 2001; Akbar *et al.*, 2006; Dolan *et al.*, 2006; Baker *et al.*, 2007; Yoshinori *et al.*, 2010). Therefore, there is really an urgent need to investigate the concentration, distribution, fate, and effects of metals in components of an ecosystem relative to the tolerable limit set by various regulating and guideline giving agencies.

Cagayan de Oro is a highly urbanized city in the southern part of the Philippines. Cagayan de Oro is the regional center and logistics and business hub of Northern Mindanao. The city's economy is largely based on industry, commerce, trade, service and tourism. Moreover, as the regional economic center of Northern Mindanao, the city houses the Cagayan de Oro Branch of the Bangko Sentral ng Pilipinas (Central Bank of the Philippines). As of December 2017, at least 100 banks are operating in the city.

The fast development has exerted a lot of pressure on its urban environment, particularly the roadside area, caused by more and more urban traffic. The objective of this study was to determine the concentrations of cadmium, lead, and copper in soils along the Iligan-Cagayan-Butuan road crossing the 2nd District of Cagayan de Oro City.

Materials and methods

Sampling and sample preparation

There was a total of seven soil samples from the seven barangays (villages) of the 2nd District of Cagayan de Oro City where the Iligan-Cagayan-Butuan road crosses. The location of the sampling sites is shown in Fig. 1. Each soil sample is a composite from 5 identified roadside sampling spots from each barangay. Soil samples were taken within a 15-meter distance from the road. In each case, surface soils were taken using a shovel and placed in a polyethylene bag. Samples were air dried, powdered using mortar and pestle, and sieved to 100 mesh.

Analysis of pH and conductivity

Twenty grams of soil were mixed with 50 mL deionized water in a beaker. The soil-water mixture was stirred for 5 minutes using a magnetic stirrer. It was then allowed to stand for 30 minutes to allow the suspended soil particles to settle. The pH was measured using a Hach sensION+ PH1 pH meter while the conductivity is measured using the Hach sensION5 meter.

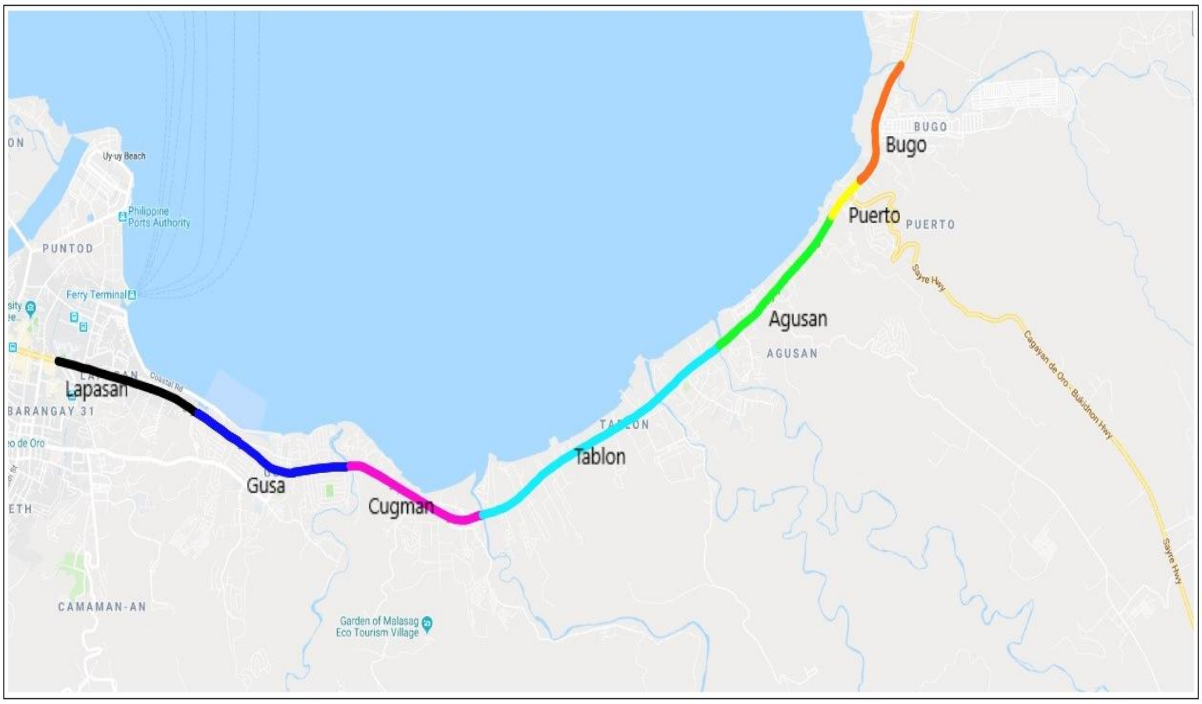

Fig. 1. A portion of the map of Cagayan de Oro City showing the 7 Barangays along the Iligan-Cagayan-Butuan road.

Analysis of organic matter

One gram of soil sample was placed in a 500 mL Erlenmeyer flask and reacted with 10 mL of 0.167 M $K_2Cr_2O_7$ and 20 mL concentrated H_2SO_4. The reaction mixture was gently mixed and placed in an insulated pad to avoid rapid heat loss for 30 minutes. Then it was diluted with 200 mL deionized water (this is to provide a clearer suspension for viewing the endpoint) and a 10 ml of 85% H_3PO_4 and 0.2 g NaF was added. The H_3PO_4 and NaF were used to complex with Fe^{3+} which would interfere with the titration endpoint. About 10 drops of ferroin indicator were then added just before the mixture was titrated with 0.5 M Fe^{2+} solution. During the titration the color flashes from yellowish green to greenish and finally brownish red or burgundy at the end point.

Analysis of heavy metals

Heavy metals in the soil samples were extracted by aqua regia digestion. About 5 g soil was digested with 30 mL of the acid for 2 hours in a hot plate. It was then filtered, when already cooled, using Whatman no. 42 filter paper and diluted to 100 mL with deionized water. The levels of cadmium, lead, and copper was analyzed using a Perkin Elmer AAnalyst200 atomic absorption spectrophotometer with acetylene gas as fuel.

Results and discussion

Analytical results of heavy metals, pH, conductivity, and organic matter in the roadside soils are summarized in Table 1. Results showed that the roadside soils in the 2nd District of the city of Cagayan de Oro are basic with a pH value that ranged from 7.85 to 8.54.

The conductivity and organic matter of the soil varies significantly between locations with the highest value 259 µS/cm and 5.54%, respectively. Concentrations of heavy metals in the roadside soils were in the ranged between 0.07 to 0.51mg/kg for cadmium, 61.0 to 169.7 mg/kg for copper, and 43.2 to 264.0 mg/kg for lead. The roadside soils from Lapasan has the highest concentration of cadmium, Puerto has the highest concentration of copper, and Gusa has the highest concentration of lead.

A statistical analysis by analysis of variance revealed that all parameters investigated differ significantly among seven locations at 0.05 levels. Overall, the concentrations of heavy metals can be ordered as Pb > Cu > Cd. In this study, lead and copper were found at considerably higher concentrations. Copper is considered to be an essential trace element for plants and animals; it is a component of many metalloenzymes and respiratory pigments. However, exposure to excessive levels of copper can result in a number of adverse health effects, including liver and kidney damage, anemia, immunotoxicity, and developmental toxicity (Alberta Environmental Protection, 1996).

Table 1. Heavy Metal Concentrations and Other Physico-Chemical Characteristics of the Roadside Soils in District 2, Cagayan de Oro City.

Location	Parameters ($\bar{x} \pm sd$)					
	Cd (mg/kg)	Cu (mg/kg)	Pb (mg/kg)	pH	Conductivity (μScm^{-1})	Organic Matter (%C)
Lapasan	0.51± 0.05	78.1±8.4	86.5±6.5	8.54±0.03	151.07±7.18	5.54±0.24
Gusa	0.19±0.01	73.1±4.0	264.0±19.3	8.22±0.02	177.70±8.72	5.21±0.17
Cugman	0.19±0.06	61.0±0.9	139.7±2.1	8.34±0.01	204.30±11.2	4.52±0.10
Tablon	0.13±0.04	65.4±4.8	52.6±8.3	7.97±0.02	259.00±13.45	3.79±0.11
Agusan	0.07±0.03	61.0±3.2	43.2±6.4	8.47±0.03	83.10±8.49	2.79±0.25
Puerto	0.09±0.03	169.7±3.9	51.0±31.4	8.27±0.01	210.90±29.62	3.38±0.05
Bugo	0.30±0.01	105.5±7.9	46.7±1.8	7.85±0.02	761.67±15.95	3.94±0.09
Overall Mean	0.21	87.7	97.6	8.24	263.96	4.16
Std. Dev.	0.15	37.5	77.8	0.24	214.97	0.95

On the other hand, with regards to lead, exposure to high lead levels can severely damage the brain and kidneys and ultimately cause death. In pregnant women, high levels of exposure to lead may cause miscarriage. High level exposure in men can damage the organs responsible for sperm production (Martin and Griswold, 2009).

Table 2. Regulatory Standards of Heavy Metals in Soil.

	Cd (mg/kg)	Cu (mg/kg)	Pb (mg/kg)
US EPA[a]	0.38	46	14
Australia[b]	3	100	600
WHO	0.8	36	85

[a]USEPA RSLs MCL-based SSL THQ=1.0

[b]Ecological Investigation Levels (DEC, 2010).

Comparing the heavy metal concentrations with the regulatory standards shown in table 2 revealed that both Cu (87.7 mg/kg) and Pb (97.6 mg/kg) on the average exceeded the limits set by the USEPA and WHO. Specifically, soil samples form Lapasan and Bugo are significantly higher than the standard levels of USEPA and WHO in terms of Cu content while practically all soil samples from seven locations are beyond the limits set by USEPA in terms of Pb content. With respect to the Australian standard for lead, only soil samples from Gusa and Cugman exceeded the limits. The levels of cadmium, on the other hand, showed to be relatively lower on the average than any of the standard limits. The roadside barangays mentioned where higher concentrations of heavy metals in the soils were observed are the one with frequent traffic congestions happen due to heavy traffic. Lapasan, for example, is a barangay right at the heart of the city and it has the highest traffic volume among the seven barangays.

Table 3. Comparison of Heavy Metal Concentrations in Urban Soils.

	Cd (mg/kg)	Cu (mg/kg)	Pb (mg/kg)
London[a]	1.0	73	94
Glasgow[b]	0.53	97	216
Hongkong *(urban parks)*[c]	2.18	24.8	93.4
Beijing[d]	0.215	29.7	35.4
Dubai *(maximum concentrations)*[e]	0.93	5.81	113.26
West Bank, Palestine[f]	0.45	23.85	149.88
Dar es Salaam, Tanzania[g]	not analyzed	178	2, 274
Quezon City, Philippines[h]	not analyzed	445	594
This Study	0.21 ± 0.15	87.7±37.5	97.6±77.8

[a]Thornton (1991)
[b]Gibson and Farmer (1986)
[c]Li *et al* (2001)
[d]Chen *et al* (2010)
[e]Aslam, Khan, & Khan (2013)
[f]Swaileh, Rabay'a, Salim, Ezzughayyar, & Rabbo (2001)
[g]Kacholi& Sahu (2018)
[h]Navarrete *et al.* (2017)

There is a positive correlation between the levels of heavy metal and traffic volume (Chen *et al.*, 2010). Heavy metals are in most cases high in areas where anthropogenic activities are prevalent like industrial and residential areas, roadside, and crowded commercial districts (Cicchella *et al.*, 2005; Lee *et al.*, 2006; Chen *et al.*,2010; Navarrete *et al.*, 2017).

Comparing the heavy metal concentrations of the roadside soil in the Iligan-Cgayan-Butuan road that crosses the District 2 of Cagayan de Oro City with those of roadside soil and urban soil studies reported in the literature (Table 3) reveals that average concentrations of heavy metals from this study were relatively lower than those of other places.

The level of Cd (0.21 mg/kg) in this study is the lowest if we compare with the Cd level in the soil of Glasgow, Hongkong, Beijing, Dubai, and West Bank, Palestine (Gibson and Farmer, 1986; Li *et al.*, 2001; Swaileh *et al.*, 2001; Chen *et al.*, 2010; Aslam *et al.*, 2013). On the other hand, the concentration of Pb (97.6 mg/kg) is closer or comparable to the Pb concentration in Hongkong and London (Thornton, 1991; Li *et al.*, 2001). In the last decades, considerable attention has been directed towards lead in the roadside environments as a result of its widespread use as an anti-knocking agent in gasoline (Davies and Hololmes, 1972; Wheeler and Rolfe, 1979; Hafen and Brinkmann, 1996; Turer and Maynard, 2003).

Conclusion

The concentrations of heavy metals collected from the roadside soil along the Iligan-Cagayan-Butuan road crossing the 2nd District of Cagayan de Oro City were in the order of Pb > Cu > Cd. On the average, the Pb and Cu concentrations in the soil exceeded the standard limits of USEPA and WHO. With regards to the level of Cd, the concentrations in the soil were within the limits of the USEPA, Australia, and WHO.

The highest concentrations of metals were detected from soil samples of areas with high traffic volume and frequent incident of traffic congestion.

The concentrations of heavy metals in this study are considered low or medium compared with those in other urban places around the world.

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