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Accumulation of copper metal (Cu) on the plant *Ipomoea carnea*, Jacq in around the Limboto lake

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Abstract. Limboto Lake is one of the main lakes in the north part of Sulawesi island, Indonesia. This lake is categorized as a tectonic lake, which currently undergoing a serious degradation, due to many residences built in the area. Thus, the depth of the lake is quickly shrinking. A large quantity of poisonous kale (*Ipomoea carnea* L) grows in the around of the lake. This study aims at finding out the accumulation of copper (Cu) in the poisonous kale that grows in the around of the Limboto Lake. This study is a descriptive quantitative study using survey method with purposive sampling method in three observation sites, the estuary of the *Alopohu* river, the estuary of the *Biyonga* river, and the estuary of the *Talubongo* river. The variable being measured in this study is the level of Cu in the root, stem, and leaves, as well as the rhizosphere of the poisonous kale. The calculation of the Cu is carried out through *Atomic Absorption Spectrophotometry* (AAS). This research shows that the range of Cu accumulation in the root is (3.61-36.00 mg/L), stem (0-15.00 mg/L), leaves (0-42.94 mg/L) and in the rhizosphere of the plant is (0.12-26.00 mg/L). The poisonous kale plant can be utilized as the Cu accumulator.

1. Introduction

Limboto lake is one of the prominent natural resources as well as a source of livelihood for Gorontalo people, especially those who reside near the lake. The Limboto lake stretches between two areas, Gorontalo regency and Gorontalo city with the coordinate of 122^{o} 56'-123^{o}01' EL and 0^{o} 34'-0^{o} 36' NL. Administratively, Limboto lake is bordered with several subdistricts such as Limboto, Batudaa in Gorontalo regency, and Telaga subdistrict in Gorontalo city.

People in the lake surrounding area work as fishermen, who usually catches fish, cultivate fish floating net in the middle of the lake, do some farming activities and construction activities that often have a destructive impact on the ecosystem of the lake. Through the establishment of people's residence in the area, an increased amount of domestic waste dumped into the lake is inevitable. These undegradable waste will be settled into the bottom of the lake, polluting the lake environment. One of the pollutants in the Limboto lake ecosystem is the Copper metal (Cu).

The intrusion of the Cu metal into the environment of the Limboto lake is due to the household waste like corrosive things, such as an unused battery, unused iron, and residue from farming activities surrounding the lake where farmers often use a fertilizer which contains Cu. In addition, there are also fish farming activities in the lake which uses drums as sinkers. The farming activities by using fertilizers and pesticide, which contains Cu can influence the concentration of Cu in the environment to become higher [1].

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The Cu is classified as essential heavy metal in the smallest concentrate. However, a large concentration of Cu is toxic to the environment. Contamination of Cu into the water environment can badly influence the biota by obstructing the metabolism due to the destruction and the lessening of the enzyme ability to perform their tasks. Whereas on plants, Cu can cause the roots of the plant to become shorter than normal and the leaves to become chlorosis, due to the weakening of enzyme that serves in the chlorophyll synthesis.

The sediment in the Limboto Lake contains nutrients needed for the growth of plants. One of these essential nutrients is the Cu. Yusuf (2013) revealed that the concentration of Cu in the bank area of the lake was 16 ppm and the concentration in the middle of the lake was 15 ppm [2]. The level of Cu within the plant network is about 5-25 ppm. When the concentration of Cu is high, it can be toxic for plants and human [3]

The Cu metal in the lake or river can enter the human body through the food chain. When the concentration of Cu is large, then it can be toxic for the human body. The effect of the toxin can be manifested in the form of vomiting, the burning sensation in the esophagus and gastric region, diarrhea, followed by hypotension, liver necrosis, and comatose [4]. Considering the potential of the Cu danger, alternative steps that can be applied to reduce the concentration of the Cu metal as a pollutant in the environment is needed. The alternative step that can be taken is through easy and efficient remediation steps to revert the environment back to its clean state. One of the remediation methods is phytoremediation. The phytoremediation is one of the remediation methods which lays on the role of the plants to absorb, degrade, transform, and immobilize the heavy metal pollutants. There are several plants with the ability to accumulate the heavy metals that are essential to the growth and development [5].

Limboto Lake is surrounded by various types of plants, one of them is poisonous kale. The utilization of this plant is currently limited due to the lack of knowledge of the plant. *Ipomoea carnea* L or the poisonous kale can be commonly found in the vast area and can tolerate almost any types of environment. The *I. carnea*, L has been traditionally used as medicine, but only a few have known that this plant can be used to heal wounds, as antipyretic, to normalize the menstruation cycle, and treat the skin diseases [6].

Research reports that the water hyacinth can absorb Cu by 0.0642 %. Similarly [7], also reports that water kale can effectively absorb Cu on the 14th day by accumulating 28.25 ppm or 70.62 % of the Cu [8]. The *I. carnea* L. plant is able to absorb the heavy metals like Cr, Pb, and Cd [9]. In addition, that *I. carnea* L. has active carbon which able to erase the Cu from the sea [10]. The objective of this study is to find out the ability of *I. carnea* L. plant in accumulating the Cu metal in the arround of Limboto lake.

2. Materials and Methods

This study was conducted on May to June 2017 in the around of the Limboto lake. The cleaning and drying stage of the plant sample was conducted in the Botany Laboratory of the Biology Department in the Faculty of Mathematics and Natural Science, University of Negeri Gorontalo. The level of Cu was measured in the laboratory of the PT. PG Tolangohula, Gorontalo.

Research method used in this study is survey method on the existence of the poisonous kale in the around of the Limboto Lake, the data collection method used in this study is the purposive sampling technique in three sites, Station 1 is located in the estuary of the *Alopohu* river, station 2 is located in the estuary of *Biyonga* river, and station 3 is located in the estuary of *Talubongo* river. For each station, there are three observation spots, the estuary of the *Alopohu* river 1 is in the coordinate N 00034’96.3’’-E 122’57’72.0’’, *Alopohu* river 2 is N 00034’96.5’’-E 122’57’70.1’’, and *Alopohu* river 3 is N 00034’96.9’’- E 122’57’69.9’’. Meanwhile, the coordinate for the *Biyonga* river 1 is N 00036’04.3’’-E 122’58’41.3’’, *Biyonga* river 2 is N 00036’00.8’’-E 122’58’41.0’, and *Biyonga* river 3 is N 00036’02.9’’-E 122’58’40.3’. Further, the coordinate for the *Talubongo* river 1 is N 00036’24.6’’-E 123’00’18.6’, *Talubongo* river 2 is N 00036’24.4’’-E 123’00’24.1’, and *Talubongo* river 3 is N 00036'24.9''-E 123'00'18.0'. The samples were taken in the morning from 08.00-11.00 am.

The measurement of the Cu metal in the leaves, stem, roots, and rhizosphere area of the poisonous kale plant was carried through *Atomic Absorption Spectrophotometry* method, and the data analysis was carried out in a descriptive quantitative manner.
To find out the ratio of Cu concentration in plant shoots with plant roots [11], it is calculated as the translocation factor (Translocation Factor = TF) as follows:

$$TF = \frac{\text{The Concentration of metal Cu in plants (mg L}^{-1}\text{)}}{\text{The Concentration metal Cu in the roots (mg L}^{-1}\text{)}} \quad (1)$$

To find out the percentage Cu metal accumulation, it is calculated :

$$\frac{\text{Total concentration of metal Cu in plants}}{\text{Dry weight plants}} \times 100\,\% \quad (2)$$

To find out the percentage absorption of metal Cu on the soil, it is calculated :

$$\frac{\text{Total concentration of metal Cu on plants}}{\text{Total concentration of metal Cu on the rhizosfer}} \times 100\,\% \quad (3)$$

3. Results and Discussion

3.1. Results
The poisonous kale *(I. carnea* L.*)* plant in the around of the Limboto Lake contains different level of Cu in three different sites, with nine observation stations in *Alopohu*, *Biyonga*, and *Talubongo* rivers that meet the Limboto Lake.

The measurement of the level of Cu in the rhizosphere, root, stem, and leaves of the poisonous kale resulted in a different level of concentration in each observation stations as revealed in Table 1.

Table 1. The concentration of Cu metal in poisonous kale plants around Limboto Lake.

Station	pH soil	Dry weight (g/plant)	Concentration Cu on plant				
			Rhizosphere (mg/L)	Leaf (mg/L)	Stem (mg/L)	Root (mg/L)	Total Cu on plant (mg/L)
Estuary the *Alopohu* river 1	7	36.60	0.62	42.94	7.9	18.6	69.44
Estuary the *Alopohu* river 2	7	37.60	1.26	12.26	2.15	14.29	28.70
Estuary the *Alopohu* river 3	7	28.20	0.12	1.74	0	14.00	15.74
Estuary the *Biyonga* river 1	6	46.70	26.00	40.00	15.00	36.00	91.00
Estuary the *Biyonga* river 2	6	82.80	2.78	4.46	5.55	19.37	29.38
Estuary the *Biyonga* river 3	5	100.80	3.51	3.4	7.26	10.44	21.10
Estuary the *Talubongo* river 1	5	112.30	2.3	3.18	4.18	9.18	16.54
Estuary the *Talubongo* river 2	6	57.90	3.21	2.49	1.10	10.18	13.77
Estuary the *Talubongo* river 3	6	61.10	3.74	0	0	3.61	3.61

The result of the measurement in Table 1 shows a different level of Cu level in the rhizosphere, roots, stem, and leaves of the poisonous kale in different observation sites. This study reveals that *I. carnea* L has the ability to properly absorb the Cu in the area polluted with heavy metal. Parts of the plant that absorb the largest concentration of the Cu is the roots part in the around of the *Alopohu* river 1 by 18.6 mg/L, the around of the *Alopohu* river 2 by 14.29 mg/L, the around of the *Alopohu* river 3 by 14 mg/L, the around of the *Biyonga* river 1 by 25.66 mg/L, the around of the *Biyonga* river

2 by 19.37 mg/L, the delta of the *Biyonga* river 3 by 10.44 mg/L, the around of the *Talubongo* river 1 by 9.18 mg/L, the around of the *Talubongo* river 2 by 10.18 mg/L and the delta of the *Talubongo* river 3 by 3.61 mg/L.

Further, the level of Cu in the rhizosphere and stem are higher in the around of the *Biyonga* river 1 by 5.76 mg/L and 11 mg/L, and the level of Cu found in the leaves is higher in the around of *Alopohu* river 2 by 12.26 mg/L. The average level of Cu in the rhizosphere of the around of the *Alopohu* river is 0.66 mg/L, the delta of the *Biyonga* river is 4.01 mg/L, and the delta of the *Talubongo* river is 3.08 mg/L. The average Cu level in the roots and stem of the poisonous kale in the delta of Alupohu river is 15.63 mg/L, and 3.35 mg/L, the delta of the *Biyonga* river is 18.49 mg/L and 7.93 mg/L, the delta of the *Talubongo* river is 7.65 mg/L and 1.76 mg/L. The average level of Cu accumulated in the leaves of the poisonous kale in the delta of the *Alopohu* river is 6.23 mg/L, the delta of the *Biyonga* river is 5.35 mg/L and in the delta of the *Talubongo* river is 1.89 mg/L. In addition, the average level of Cu in three different sites are as follow, the delta of *Alopohu* river is 25.21 mg/L, the delta of the *Biyonga* river is 31.78 mg/l and in the delta of the *Talubongo* river is 11.3 mg/L.

The highest Cu concentration in plants is found in the *Biyonga* estuary, while Cu concentrations in the lowest plants are found in the estuary of the *Talubongo* river. Furthermore, the part of the plant that absorbs the most Cu metals shows interesting symptoms. For plants found in the *Alopohu* river estuary, the concentration of Cu in the leaves is higher than the concentration of Cu in the plant roots. In contrast, in plants found in the *Biyonga* and *Talubongo* estuaries, Cu concentrations on plant roots were higher than those in leaf organs, and it turned out that Cu concentrations were low in all plant stems compared to other Cu concentrations in all plant locations (Table 1)

The ability of *I. carnea* plants to absorb Cu was thought to be influence by the amount of Cu concentration in the root area and soil pH. At the observation site at the *Biyonga* estuary, the average concentration of Cu in the rhizosphere was higher than that found in the estuaries of the *Alupohu* and *Talubongo* rivers. It was suspected that the Cu concentration in plants found in the *Biyonga* estuary was higher than in other observation locations.

Distribution of Cu in plant organs was thought to be influence by soil pH. At the mouth of the *Alopohu* rivers, which has a neutral pH (pH 7), Cu concentration in leaf organs is higher than the Cu concentration found at the root. Conversely, in the condition of acid soil pH (pH 5-6), it turns out that the concentration of Cu metal found in plant roots is higher than that found in leaves (Table 1).

Table 2. Data on translocation factor and percentage of Cu metal accumulation in plants and absorption of Cu metal on the soil around the Limboto Lake.

Station	TF	Percentage of Cu metal accumulation (%)	Percentage absorption of metal Cu on the soil (%)
Estuary the *Alopohu* river 1	2.73	1.90	112.00
Estuary the *Alopohu* river 2	1.01	0.76	22.78
Estuary the *Alopohu* river 3	0.12	0.56	131.17
Estuary the *Biyonga* river 1	1.53	1.95	3.50
Estuary the *Biyonga* river 2	0.52	0.35	10.57
Estuary the *Biyonga* river 3	1.02	0.21	6.01
Estuary the *Talubongo* river 1	0.80	0.15	7.19
Estuary the *Talubongo* river 2	0.35	0.24	4.29
Estuary the *Talubongo* river 3	0.00	0.06	0.97

Furthermore, in Table 2, the *I. carnea* plants found in the *Alopuhu* rivers mouth had the highest and lowest TF values found in plants found in the estuary of the *Talubongo* river 3. The translocation factor value was the ratio between the metals in the cracks, and metal on the roots, showing the metal transporting the plants. TF value > 1 is considered a good sign, as metal hyper accumulation [12]. The *I. carnea* plants found in the *Alopohu* 1 and 2 estuaries, and those found in the *Biyonga* 1 and 3 estuaries, can be categorized as Cu hyper accumulation (Table 2).

Interestingly, it turns out that the TF value is not directly proportional to the percentage of Cu accumulation in the plant body and the percentage value of Cu metal from the soil. For example, at the *I. carnea* plant at the *Biyonga* 1 estuary, it has a value of TF 1.53 (Cu hyper accumulation), the percentage of Cu accumulation is 1.95%, but the presentation of Cu absorption from the soil is only 3.5%. This is thought to influence also by the age of the plant.

The results of this study are different, research result [12], plant species that grow on substrates with high metal content contain metals that are significantly higher, when compared to plant species that live in areas with substrate with low metal content. The metals collected by plants are mostly distributed in the root tissue. The translocation factor, which is an unclear ratio of metals concentration to plant parts, shows the tolerance mechanism of internal detoxification metal, which has the potential for phyto extraction. Several factors that influence metal accumulation by plant species are metal concentration, pH, electrical conductivity, and nutritional status on the substrate.

3.2 Discussion

Cu metal is one of the micro nutrient needed by the plant in the small concentrate which serves as protein for the chloroplast and as part of the electron transport system. Therefore, its existence is critical for the plants, regardless of a small amount. In Table 3, the concentration of Cu metal can be accumulated by several plants.

Table 3. The concentration of Cu metal in several types of plants.

Plant species	The concentration of Cu metal in plant	Reference
Jatropha curcas L	30.73 ppm (without fertilizer); 18.74 ppm (treatment with biofertilizers)	Sudaryono (2010) [13]
Avicennia marina	root (2.336-7.997 mg/Kg), young leaves (2.367-6.604 mg/Kg) and old leaves (1.08-6.748 mg/Kg) Avicennia marina. Bio Concentration Factor (BCF) root and sediment 0.090-211, and Translocation Factors (TF) for young leaves (0.83-1.54), old leaves (0,46-0,94).	Nana Kariada TM, Dewi Liesnoor, Nur Kusuma Dewi (2013) [14]
Lamun (*Enhalusaccoroides)*	Cu metal content in Seagrasses is in the range 0.63-46.1 mg/kg. Leaves 10.81 mg/kg Cu.	Ismarti Ismarti, Ramses Ramses, Fitrah Amelia, Suheryanto (2017). [15]

This study shows that the level of Cu in three different sites, in the delta of *Alopohu*, *Biyonga* and *Talubong* river is different. This is based on the data of the level of Cu in the delta of *Biyonga* river with the average of 47.16 mg/L in the plants, and in the rhizosphere is 10.76 mg/L. This is suggested due to the existence of residence in the delta of this *Biyonga* river, where farmers near the delta of the *Biyonga* river are using the fertilizer, which complemented with Cu and the household waste is also dumped into the river. People’s activities such as, farming activities that use fertilizer or pesticide that contains Cu can increase the concentration of the Cu in the environment [16].

The average level of Cu in the delta of the *Alopohu* river is 37.96 mg/L on the plant and on rhizosphere is 0.67 mg/L as metal absorption by the plant is also due to the environmental factor such as soil pH. In addition, in the delta of the *Alopohu* river, the pH of the soil is 7; whereas the pH of the soil in the delta of the Biyonga and *Talubongo* rivers ranges between 5-6.

The average of Cu level in the delta of the *Talubongo* river is 11.32 mg/L on plant and 3.08 mg/L on the rhizosphere. This is because the delta of the *Talubongo* river has been made as a road for the heavy trucks carrying excavator to open up new roads and there is also environmental pollution due to the waste dumping into the delta of the *Talubongo* river. The concentration of Cu can be due to the activity of the public transport line and the fisheries activity [17].

This study shows that the poisonous kale can absorb the Cu. This is based on the data that parts of this plant can absorb the Cu in its roots, stems, and leaves. From these three parts of the plant, the part that absorbs the Cu the most is the roots part. In principle, the roots can absorb the pollutant from the environment simultaneously with the absorption of nutrient and water from the soil. The pollutant is not changed but rather settled in the stems and leaves part of the plant. This process is phyto accumulation, where the absorbed heavy metal is accumulated in the organ of the plant such as in the roots, trunks, and leaves. Fitter and Hay (1991) reported that plant has an ability to absorb ions from the environment through cell membranes. There are two characteristics of ion absorption by the plants, first concentration factor, where the plant’s ability to absorb ion to certain concentration extent, even to several extents higher than the concentration of the ion within the medium, and second, the different quantity of nutrient uptake in each type of the plant [18].

This study shows that the level of Cu in *I. carnea* L is different in three different observation sites. This is related to the ability of the plant to overcome the Cu polluted environment. Cu is the micronutrient needed for the living; however, in a large concentration above the allowed level, it can be toxic for the living things itself. The Cu is classified as the heavy metal that is essential for the living things in small concentrate, whoever, in large concentrate, this Cu can be toxic for the living organism [19].

From three observation in each site which divided into three sample collection sites for the *I. carnea* L, the *Biyonga* river 1 station reveals the concentration of Cu in the around of Limboto Lake has reached above the allowed level that is 44.87 mg/L. Chaney (1989) reported that 1-5 mg/L level of Cu in a plant in the plant as low, 3-30 mg/L as normal and 20-100 mg/L as toxic for the plant [19]. The high concentrate level of Cu in several deltas is due to people’s activities in those rivers area. Cu toxicity will only be detected when it enters the body of the organism in the large quantity [20].

4. Conclusion
The Poisonous kale plant has the ability to accumulate the Cu metal. Accumulation of Cu in poisonous kale in the around of the *Alopohu* river ranges between 0.56-1.90%, in the around of the *Biyonga* river ranges between 0.21-1.95%, whereas in the around of the *Talubongo* river ranges between 0.06-0.15%.

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