Measurements of Mg in the ecosystem of Hiroshima Regional Urban Area

Yumiko Nitta*, Hiroyuki Katsuoka*,
Toshihide Harada** and Fumiko Ishizaki***

(Received on September 17, 2022)

ABSTRACT

To investigate the distribution of Mg in the Hiroshima Regional Urban Area, concentrations of Mg in the elements were examined. Concentrations of Mg in the seaweeds (n = 3) and plants (n = 4), which were representative of aquatic and terrestrial elements, respectively, were determined by the inductively coupled plasma atomic emission spectrometry. *Ulva pertusa* contained Mg the highest among the organisms examined. Concentrations of Mg as well as Ca in the extracts of soils (n = 9), sediments (n = 4), seaweeds (n = 3), and plants (n = 12) were measured and determined by spectrophotometry and colorimetric method. Concentrations of Mg in the sediment extracts were as high as those of seaweeds in aquatic area, whereas, the concentrations of Mg in the extracts of plants were higher than those of soils in terrestrial area. These two ways of measurement could make a part of the environment, in which humans live, visible and contribute for the evaluation of ecosystem in the Area.

key words: ecosystem, Hiroshima Regional Urban Area, Lamiaceae, Mg, *Perilla citriodora*

INTRODUCTION

Mg as an essential element for humans:

Organisms are made up of raw elements. The main elements are C, O, H N, Ca, P, and K with the composition ratios of 50, 20, 10, 8.5, 4. 2.5, and 1%, respectively, for humans.

Ca, P, K, and Mg are the light metals among the elements, whose concentrations in the human body, are the highest in this order. Mg^{2+} is one of the electrolytes playing important roles to prevent or treat for many diseases[1]. Low levels of serum Mg associated with chronic or inflammatory diseases, while, high levels of serum Mg were reported

* Hiroshima Shudo University
** Hiroshima Prefectural University, Graduate School of Comprehensive Scientific Research
*** Hiroshima Prefectural University, Emeritus

in the chronic renal failure patients when prescribed laxatives.

Mg in marine organisms:

O, Si, Al, Ca, Na, K, and Mg are the elements composing earth's crust, those concentrations are the highest in this order (http://www.spring8.or.jp/ja/news_publications/research_highlights/no_93/). Mg has dissolved in seawater or deposited as sediments on seabed, from which marine organisms have taken the Mg in their bodies. Mg and other metals in aquatic environments were found in organisms, seaweeds, bivalve mollusks, fishes, and whales, of collected or captured as foodstuffs or research samples[2).

Mg in terrestrial organisms:

Plants require the following 17 elements, C, H, O, N, P, K, Ca, Mg, S, Fe, Mn, B, Zn, Mo, Cu, and Cl for their growth. Terrestrial plants absorb the metals from soil and water[3). The decomposed granite soil is one source of Mg for naturally growing plants. Fertilizers are the other sources of Mg for agricultural farm plants.

Through consumption of grasses in farm pasture, Mg are accumulated in the bodies of fielded ruminants[4, 5). The Mg is transferred to the human body through food chain.

Mg in bedrocks and waters:

Granites are the main bedrocks in the western part of Japan. The composition ratio of Mg in the granite at Mihara City in the Hiroshima Regional Urban Area is 0.04~0.23%[6). The Mg contained in public drinking well waters is 1.06~5.11mg/L all over Japan[7).

Questions to be clarified in this study:

The objective of this paper is to screen current concentrations of Mg in drinking waters and foodstuffs available in a local area as a case study. Mg concentrations in sediments, seaweeds, soils, and terrestrial plants were measured based on the food chain hypothesis of metal flow in ecosystem (**Fig. 1**)[8). The dynamics of Mg from geological environment to terrestrial organisms was challenged to be shown numerically. Geological maps of Yamaguchi[9) and Hiroshima (https://www.gsj.jp/Map/EN/geology2-5.html#Hiroshima) prefectures will be helpful to obtain the bedrock information. Concentrations of Mg, a light metal, in granitoids of the Sanyo Belt[6) will provide additional information on the local natural environment.

This study is the beginning of a cross examination of the Mg flow at a local area of the Hiroshima Regional Urban Area in 2020s. The data will contribute for the evaluation of present biological environment and for the promotion of human health in the Area.

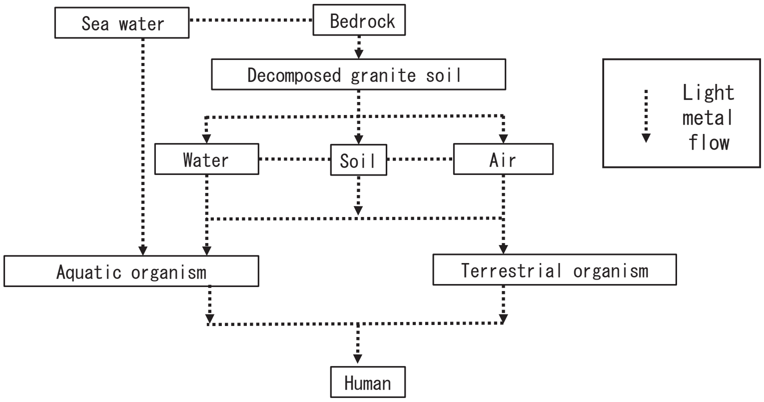

Fig. 1. A hypothesis of Mg flow in local area.
Both aquatic and terrestrial areas were examined. The examined elements in the ecosystem were sediments and seaweeds for the sea area and soils, naturally growing plants, and agricultural farm plants for the land area.

MATERIALS AND METHODS

Study area:

The Hiroshima Regional Urban Area is an economic unit comprising of 23 cities and towns of Hiroshima and Yamaguchi prefectures, the population of which is 2 million (The total number of municipalities is 24 in April, 2022, since another city, Miyoshi, has attended) (**Fig. 2**).

Sample collection:

Samples used in the present experiment were collected between 2019 and 2022. Sediments and soils were collected in April and stored at −20°C until use. A specific sampler was used for collection (Ekuman-Birge, RIGO Co. Ltd., Tokyo, Japan)[10]. The sediments at the mouth of rivers were collected when the tide was low. The sediments under the oyster rafts around the iles of Kakuma-jima were collected at a depth of 20 m from the surface, with wet weight of more than 0.3 kg each scoop. Depth was measured using a water depth detector.

Seaweeds at the mouth of the Otagawa river were collected from the surface of stones, when the tide was low in June. They were stored at −20°C until use.

Two kinds of Brassicaceae plants, *B. rapa x B. oleracea* and *Raphanus sativus var. hrtensis*, and four kinds of Lamiaceae plants, *Salvia hispanica*, *P. furutescens*, *P. frutescens var. crispa*, *P. citriodora*, were collected from an experimental farm (N34°09' 39.77, E132°

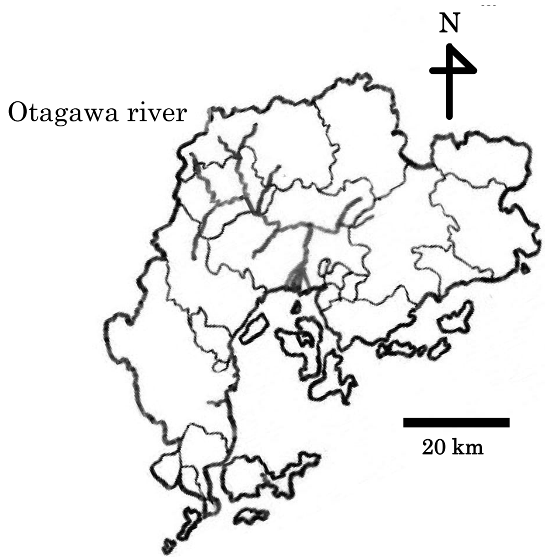

Fig. 2. Hiroshima Regional Urban Area and Hiroshima Bay.
A rough map of the Hiroshima Regional Urban Area (6302.8 km^2). The iles of Kakuma-jima (N34°31' 33.21, E132°40' 17.83) face the mouth of Otagawa river.

19' 06.01) in spring and autumn for the plants of Brassicaceae and Lamiaceae, respectively. All the collected samples were stored at −20°C until use.

Hot water extraction method:

One gram of each sample was put into 50 mL plastic tube. Fifty mL of boiling deionized water was poured into the tube. The tube was left for 5 min at room temperature. Then aqueous solution was extracted through a qualified filter paper using funnel. The extracts were used for further experiments.

Measurements of Mg and Ca:

Concentrations of Mg in seaweeds and plants were determined via ICP-AES (Inductively Coupled Plasma Atomic Emission Spectrometry)[8] and calculated on a wet weight basis.

Concentrations of Mg and Ca in the extracts of samples were measured by a colorimetric method. Commercial water quality test kits (Kyoritsu Chemical Check Lab. Co. Ltd, Tokyo, Japan) were used. Concentrations of Mg and Ca were shown on a dry weight basis.

Statistical analysis:

Student's *t*-test was performed to compare the concentrations of Mg and Ca for the farm plants. Pearson's coefficient of correlation was used to compare the Mg and Ca values. KaleidaGraph software version 3.6 (HULINKS, Tokyo, Japan) was used.

RESULTS

A comparison of Mg concentrations as a component of organisms to those as an extract of organisms:

Ulva pertusa contained the highest Mg among the organisms examined when determined by ICP-AES (**Table 1**). The Mg in *Ulva pertusa* was found successfully to be extracted into water by the method with high doses when determined by the colorimetrical method.

Concentrations of Mg in Brassicaceae plants were not so high when compared to those of the other organisms, whereas, their extract concentrations were high.

Mg concentrations in the extract of soil, sediment, and organisms:

Concentrations of Mg were shown for most of the commercially available natural mineral waters (14/15 cases of examined) with those of Ca simultaneously (**Fig. 3-A**). The exceptional water was made in a local town within the Hiroshima Regional Urban Area. The correlation co-efficiency of the concentrations between Mg and Ca was high (R = 0.67, $p < 0.01$).

Average concentrations of Mg were 37.3 ± 22.5 mg/L for the sediment extracts (n = 4) and 54.6 ± 23.7 mg/L for the seaweed extracts (n = 3) (**Fig. 3-B**). Average concentrations of Ca in extracts were 32.5 ± 20.6 mg/L and 16.7 ± 5.8 mg/L for the sediments and

Table 1. Concentrations of Mg in seaweeds and farm plants.

No.	Order	Family	Species	Mg (mg/g)	Extracted Mg/g (mg/L)
1	Algae	Seaweed	*Undaria pimmatifida*	2.70	41.0
2			*Ecklonia kurome*	4.03	41.0
3			*Ulva pertusa*	14.40	82.0
4	Spermatophyta	Brassicaceae	*Brassica rapa* × *Brassica oleracea*	0.17	82.0
5			*Raphanus sativus* var. *hortensis*	0.31	68.3
6		Lamiaceae	*Perilla frutescens* var. *crispa*	2.24	20.5
7			*Perilla citriorora*	2.04	8.2

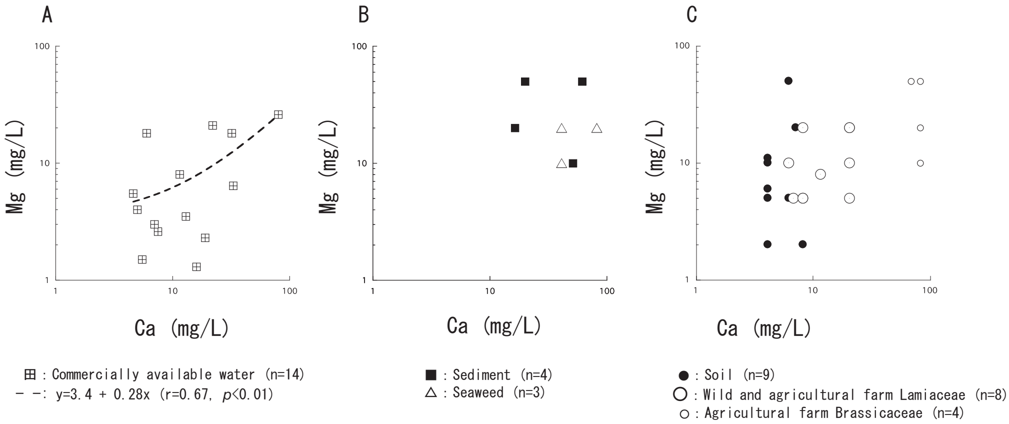

Fig. 3. Mg concentrations in extracts of soil, sediment, and organism.

seaweeds, respectively. The concentrations of Mg and Ca in the sediment extracts were as high as those of the seaweed extracts.

Average concentrations of Mg in extracts were 5.4 ± 1.6 mg/L for soil (n = 9), 13.2 ± 6.5 mg/L for the Lamiaceae plants (n = 8), and 78.6 ± 6.9 mg/L for the Brassicaceae plants (n = 3) (**Fig. 3-C**). Average concentrations of Ca in extracts were 12.1 ± 15.3 mg/L for soils, 10.0 ± 8.7 mg/L for Lamiaceae plants, and 16.0 ± 23.0 mg/L for Brassicaceae plants.

DISCUSSION

Information on natural as well as anthropogenic metals in the local area is essential to ensure the health of residents. In this study, Mg, a light element essential for humans, in the environment has been measured. The established measurement method of Mg via ICP-AES was used[11]. Simultaneously, a commercially available test kit for water quality was used, since just one step was enough to prepare the sample for measurement.

Concentration of Mg in *Ulva pertusa*, a kind of seaweed commonly observed in the Seto Inland Sea, was the highest among the samples examined. The doses were as high as those shown in the Food Composition Database by the ministry of Education, Culture, Sports, Science and Technology (https://fooddb.mext.go.jp). However, seasonal effects on the Mg concentration in seaweeds are to be examined, since the best season for the measurement of Mg for each seaweed has not been grasped, yet.

Concentrations of Mg in Brassicaceae plants were as high as those shown in the Food Composition Database. The concentration of Mg in *P. citriodora* was as high as those of seaweed, however, no standard data were available from the Food Composition Database. Monitoring the Mg concentration with growth are to be examined for each species of plants.

When compared the amount of Mg in the extracts, the Brassicaceae plants showed the highest. Any relationship between the extraction method and chlorophyll destruction might influence on data. Commercially available teas do not present the concentrations of Mg, no matter how they show the way of tea extraction individually on their package.

In conclusion, devising better ways to obtain extracts are the first to force the measurement of Mg in the ecosystem including humans.

ACKNOWLEDGEMENTS

The authors thank Prof. K. Katoh, the Open University of Japan, for advising us concerning to the perilla cultivation. The author thanks Mr. K. Sasabe, a member of the Yamaguchi Prefectural Hunting Association, for growing agricultural farm plants.

NOTE

Element symbols used are boron: B, carbon: C; calcium: Ca; cadmium: Cd; chloride: Cl; copper: Cu, iron: Fe; hydrogen: H; potassium: K; magnesium: Mg; manganese: Mn; molybdenum: Mo; nitrogen: N; oxygen: O; phosphorus: P; sulfur: S and zinc: Zn.

REFERENCES

1. Fiorentini, D.; Cappadone, C.; Farruggia, G.; Prata, C. Magnesium: Biochemistry, Nutrition, Detection, and Social Impact of Diseases Linked to Its Deficiency. *Nutrients* 2021, *13*, 1136. https://doi.org/10.3390/nu13041136
2. Wise Jr, J. P.; Tayler J Croom-Perez, T. J.; Meaza, I.; Aboueissa, A-M.; Montalvo, C. A. L.; Martin-Bras, M.; Speer, R. M.; Bonilla-Garzón, A.; Urbán R, J.; Perkins, C.; Sr, J. P. W.: A whale of a tale: A One Environmental Health approach to study metal pollution in the Sea of Cortez. *Toxicol Appl Pharmacol* 2019, *376*, 58–69.
3. Alengebawy, A.; Abdelkhalek, S. T.; Qureshi, S. R.; Wang, M. Q.: Heavy Metals and Pesticides Toxicity in Agricultural Soil and Plants: Ecological Risks and Human Health Implications. *Toxics* 2021, *9*, 42. doi: 10.3390/toxics9030042.

4. Lane, E. A.; Canty, M. J.; More, S. J.: Cadmium exposure and consequence for the health and productivity of farmed ruminants. *Res Vet Sci* 2015, *101*, 132–139.
5. López-Alonso, M.; Miranda, M.; Benedito, J. L.; Pereira, V.; García-Vaquero, M.: Essential and toxic trace element concentrations in different commercial veal cuts in Spain. *Meat Sci* 2016, *121*, 47–52.
6. Ishihara, S.; Murakami, H.: Characteristics of REE distribution in granitoids of SW Japan. *Bull Geol Surv Japan* 2006, *57*, 89–103. (in Japanese)
7. Nahar, S.; Zhang, J.: Impact of natural water chemistry on public drinking water in Japan. *Environmental Earth Sciences* 2013, *69*, 127–140.
8. Nitta, Y.; Katoh, K.: Wildlife as a biomonitoring model of terrestrial cadmium (Cd): Kidneys of female wildlife reflecting the environmental Cd. *J Environ Inf Sci* 2020, *1*, 45–55.
9. Nishimura, Y.; Imaoka, T.; Kanaori, Y.; Kameya, A.: Geological map of Yamaguchi Prefecture (1,150000) and its explanatory text 3rd Ed. *Geological Society of Yamaguchi* 2012, 167. (in Japanese)
10. Fukuhara, H.; Sakamoto, M.: An improved Ekman-Birge Grab for sampling an undisturbed bottom sediment core sample. *Jpn J Limnol* 1987, *48*, 127–132. (in Japanese)
11. Yamaki, A.: A simple simultaneous analytical method for multi-components including heavy metals in agricultural products using 1M nitric acid extraction-ICP-AES (ICP-OES 730-ES, Agilent, Tokyo, Japan). *Annual research bulletin of the Chiba Prefectural Agriculture and Forestry Research Center* 2011, *3*, 56–60.

広島広域都市圏の生態系における
マグネシウム（Mg）の測定法

新田由美子*・勝岡　宏之*・原田　俊英**・石崎　文子***

（受付　2022 年 9 月 17 日）

要　　　約

広島広域都市圏における Mg の分布と濃度を明らかにするため，陸域と海域の要素について，Mg 含有量を測定した。海藻（n＝3）と植物（n＝4）の Mg 含有量を誘導結合プラズマ発光分析法により測定した。アナアオサ（*Ulva pertusa*）の含有量が最も高かった。底質（n＝4），海藻（n＝3），土壌（n＝9），植物（n＝12）の Mg 含有量をカルシウム（Ca）含有量とともに測定した。検体の熱湯抽出液を調整し，市販の水質検査キットを用いて可視光分光光度法と比色法により測定した。海域生態系では，底質抽出液の Mg 濃度は海藻抽出液のそれと同程度であった。一方，陸域生態系では，植物抽出液の Mg 濃度は土壌抽出液のそれより高かった。これらの２つの測定方法とデータは，ヒトを含む環境を見える化し，広島広域都市圏の生態系を評価することに用いることができる。

key words: 生態系，広島広域都市圏，レモンエゴマ，Mg，シソ科植物

* 広島修道大学健康科学部健康栄養学科
** 県立広島大学大学院総合学術研究科保健福祉学専攻
*** 県立広島大学名誉教授