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Research Article

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A study on the application of phytoremediation ecological technology of heavy metals in water using *E. fluctuans*: A medicinal plant adapting to climate change

An The Huynh*, **Trung Minh Dao**

ABSTRACT

Phytoremediation can be used as a different approach to absorb heavy metals because of environmentally friendly and potential cost-effective. *E. fluctuans* is one species of herbaceous, semi-aquatic, widely distributed in Vietnam, South and Southeast Asia, and tropical Africa. Its leaves are used as edible vegetables in daily meals, and it is also used to treat some diseases in traditional medicine. This paper aims to test the effectiveness of *E. fluctuans* in removing heavy metals from the aquatic environment. The experiments were performed using healthy, young, and acclimatized *E. fluctuans*. Water containing 0.5 mg/L cadmium, 0.5 mg/L arsenic, 2 mg/L lead, 5 mg/L zinc, and 5 mg/L copper concentrations were experimented with 100 g of *E. fluctuans* in 30-liter foam containers. The experiments were repeated three times. Throughout the course of the trial, water samples were tracked and their heavy metal concentrations were examined every 10, 20, and 30 days. Through the use of inductively coupled plasma-mass spectrometry, the heavy metals were identified. After 30 days, *E. fluctuans* could remove Cd at 83.4%, As at 60.8%, Pb at 60.4%, Zn at 40.5%, and Cu at 58.7%. Thus, the *E. fluctuans* show a high potential for effectively extracting heavy metals from industrial effluent.

Key words: phytoremediation, E. fluctuans, cadmium, arsenic, lead, zinc, copper, climate change, medicinal plant

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INTRODUCTION

One of the most important resources for human survival and daily activities is water[1]. When the global population continuously increases, it is also increasing the food demand and intensive activities of industry and urbanization leading to the requirement of water owing steadily increasing. However, the quantities of water are gradually degraded in many areas due to the expanded volume of huge amounts of dangerous chemicals from intensive agriculture and industries as well as human activities that of contaminated waste and wastewater released directly into the natural environment[2]. Especially, ollution from heavy metals is an emergency impact to the environment and human health because of their toxic properties, tendency, and persistent in nature[3–5]. Specifically, excessive levels of heavy metals including Cd, A, Pb, Zn, and Cu in wastewater will pollute water sources and easily accumulated in the human body by drinking the water without or un-well treatment. Those heavy metals can cause deleteriously affecting human health even though at very low concentrations[6].

Among the most appealing research areas is the development of environmentally friendly and effective wastewater treatment systems. Phytoremediation is acknowledged as an ecological remediation technology that is climate change-adapted and is thought to be a viable technique for removing contaminants from wastewater[7].

Aquatic plants are essential for maintaining water resources in the phytoremediation system, as a part to absorb energy, organic matter, and heavy metals in the water, which is greatly improving the water quality[8]. Previous researches have found a number of aquatic plants improving the water environment such as *Water Lily*, *Cyperus Alternifolius*, *Phragmites Australis*, *Water Hyacinths*, *Water Spinach*, *Typha Orientalis*... Besides, *E. fluctuans* is considered as a potential aquatic plant remove heavy metals in water.

E. fluctuans commonly known as helencha or harkuch is a tropical herb. It is belonging to Asteraceae family which is importance species for therapeutic process. This herbaceous vegetable plant, which is edible and semi-aquatic, has serrated leaves and is widely grown in Vietnam. The plant is a prostrate herb with 1-3 inch long, opposing sessile, linear oblong leaves. The herb is often pubescent and glandular, with a glabrous texture. The stems have a length of 0.3–0.6 m and can either simply extend or divide at the nodes. The leaves

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have a hint of bitterness, and they are good for treating smallpox, bronchitis, leucoderma, nervous affliction, laxative, and inflammation. The nutritional worth of plants, such as β-carotene, saponins, cholesterol, glucoside, and enhydrin, among others. Moreover, *E. fluctuans*'s fuel extract contains antioxidant, hepatoprotective, CNS depressant (Central Nervous System (CNS) depressants), analgesic, and Antidiarrheal activity[9–11].

Vietnam is a tropical country with year-round high temperatures and humidity. The country has a long coastline of 3,260 km with more than 2,360 rivers and streams and thousands of lakes and ponds[12]. This water source is the habitat of animals, plants, and millions of people and is also the main source for production. However, overuse and various levels of pollution are causing these water resources to be severely damaged and destroyed. Even many rivers, river sections, ponds, and lakes are "dead" by the volume of waste, garbage and wastewater discharged into the environment without being treated.

However, there have been a few studies in Vietnam about the ability of aquatic plants to treat wastewater pollution. Furthermore, it is still no research about using *E. fluctuans* to treat heavy metal pollution in wastewater, especially in industrial wastewater. It is necessary to investigate the research on the use of *E. fluctuans* - A medicinal plant with potential in phytoremediation of water contaminated by heavy metals. The study will send the significant theory and practical results of uptake heavy metals contaminants from industrial wastewater by *E. fluctuans*.

PHARMACOLOGICAL ACTIVITY OF *E. FLUCTUANS*

Medicinal plants are a class of plants that are used for medicinal purposes and have specific active medicinal components together with certain traits or attributes that allow them to be used as drugs or therapeutic agents[13].

A small genus of marsh herb known as *E. fluctuans* (Family: Asteraceae) is found in tropical and subtropical regions. The plant is an annual herb that spreads to the prostate. This is another edible, semi-aquatic herbaceous vegetable plant that grows throughout Vietnam and has serrated leaves[14] Between november and january, the wet roadside canals and marshy waste areas are the primary habitats for *E. fluctuans*[13].

It is a plant with medicinal potential in Bangladesh, Malaysia, Srilanka, Zambia, Zimbabwe, India, China, Thailand, Indonesia, Southeast Asia, Tropical Africa, and Vietnam. From ancient times, folk medicine has been used in all of *E. fluctuans* to treat a wide range of illnesses, with different countries having different indications. The pharmacological activity of *E. fluctuans* are detailed in Figure 1.

E. Fluctuans may have some anti-cancer properties. Though it has only been shown against Swiss Albino Mice with Ehrlich's Ascites Carcinoma (EAC). Therefore, more investigation is required to ascertain the anti-cancer potential of the plant extracts[15]. In addition to its antioxidant qualities, it possesses antimicrobial, cytoprotective, anti-inflammatory, analgesic, CNS depressant (Central Nervous System (CNS) depressants), and thrombolytic characteristics. The abundance of biomolecules in the database suggests that more study will advance the pharmaceutical industry.

MATERIALS- METHODS

Chemicals and instruments

Standard solutions containing 100 μg/mL of copper, zinc, lead, arsenic, and cadmium were made. All of the compounds were pure substances produced by Merck Chemical in Darmstadt, Germany. The water used to make the solutions was double-distilled.

The research employed various instruments such as an analytical balance with a precision of 0.0001 mg, a flask, a test tube, an electric stove, and a micropipette. ICP-MS (Inductively Coupled Plasma - Mass Spectrometry) equipment made by Perkin Elmer ELAN 9000 was used to analyze the samples.

Experimental Setup

100 g of *E. fluctuans* were utilized in the pot for the course of the 30-day trials. Thirty-liter foam containers were used for planting, after they had been cleaned with distilled water to remove any dust and soil (Plant with a 35-cm body length that is selected based on a set of characteristics, such as the absence of insects and the roots being three months old). According to the ational technical regulation on industrial wastewater in Vietnam (QCVN 40:2011/BTNMT), concentration selection tests were conducted based on the allowed threshold levels for Cd, As, Pb, Zn, and Cu in aquatic environments. Three to five times the permitted threshold was exceeded by the experimental concentration. *E. fluctuans* was cultivated in irrigation water that had chosen concentrations of the heavy metals Cd (II), As (III), Pb (II), Cu (II) and Zn (II). Table 1 shows the concentrations selected for performing the experiment.

Plants in distilled water were planted as a matched plant control sample.

Heavy metals (Cd, As, Pb, Zn, and Cu) in water were the analyzed parameters.

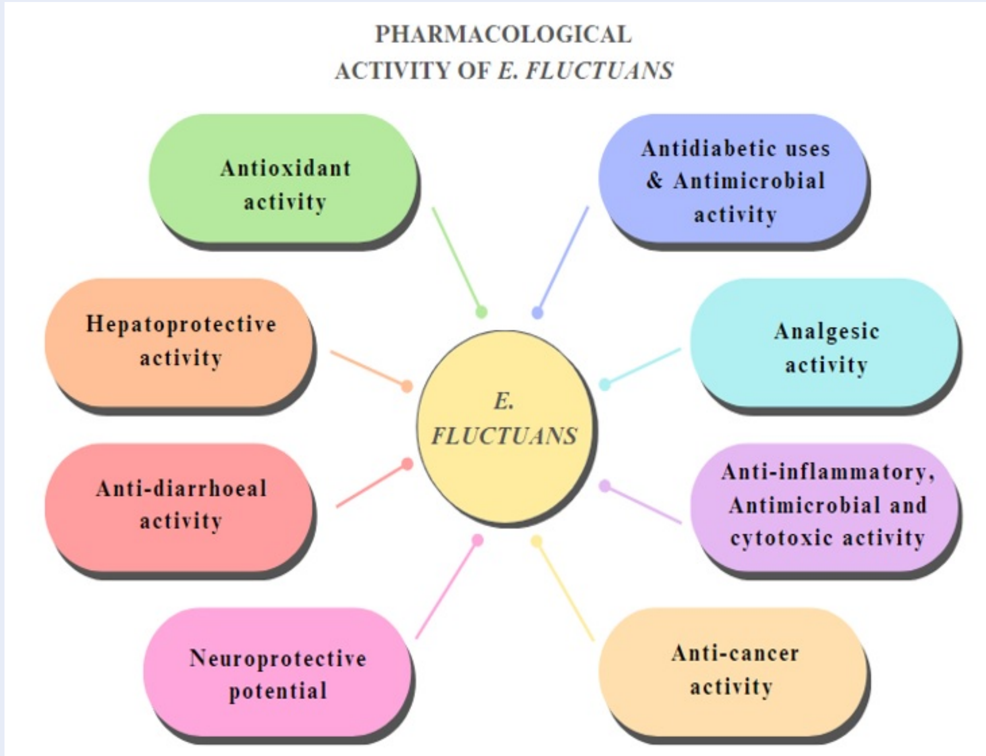

Figure 1: The pharmacological activity of *E. Fluctuans*

Table 1: Concentration selected for experiment

No.	Heavy metal	Concentration
1	Cadmium (Cd)	0.5 mg/L
2	Arsenic (As)	0.5 mg/L
3	Lead (Pb)	2 mg/L
4	Zinc (Zn)	5 mg/L
5	Copper (Cu)	5 mg/L

Analysis Sample

Following planting, three analyses of the heavy metal concentration in the water were conducted on the sample at 10, 20, and 30 day intervals in order to track the evolution of the amount of metal in the treated water with *E. fluctuans*. Through the use of inductively coupled plasma-mass spectrometry, the heavy metal content of the plants was determined to be Cd, As, Pb, Zn and Cu.

Analyzing Data

The researched data were evaluated and contrasted with the most recent tandards for Vietnam (QCVN 40:2011/BTNMT). Software from Statgraphics and Excel were used to process the data.

RESULTS AND DISCUSSIONS

Growth of *E. fluctuans* in heavy metals polluted water

Normally, when the concentration of a metal in water is not higher than the critical tolerance value of the plant, it does not affect the growth and height of the plant, so the biomass of the plant will not affect the plant growth. Because lant growth necessitates specific heavy metals and upkeep[16]. However, when the metal concentration in the water exceeds the limit value, the plant growth will be inhibited and manifest external states such as yellow leaves, which reduces its height and biomass [17]. Depending on the specific heavy metal involved in the process, different heavy metals have different effects on plant growth. Table 2 displays the impact of water contaminated with heavy metals on *E. fluctuans* plant growth. The changes in plant growth in these samples could plausibly be explained by significant differences in height growth rates. ($p < 0.05$).

Table 2 presents the results, which indicate that one of the key indicators for evaluating the growth of plants containing various heavy metals in the environment (Cd, As, Pb, Zn, and Cu) is height. The plants' ability to absorb nutrients determined the *E. Fluctuans* ' height growth rate. The heavy metals in the water, in the following order: Cd > As, Cu > Pb > Zn, were correlated with the decreasing height. The following is a description of the growth condition:

The growth of plants in the environment with 0.5 mg/L Cd and As content. *E. fluctuans* showed good Cd and As absorption capacity, the plants were less likely to die, had good growth ability. There was an increase in height.

Growth of plants in a water environment with 2 mg/L of lead. *E. fluctuans* grew and developed well. However, after 15 days, it was observed that the plants had yellowing of leaves.

The plants in the water containing 5 mg/L of zinc showed symptoms of stunted growth; the stems and leaves had gone yellow. Ninety percent of the plants had softened leaves and stems by day 20 due to yellowing. The plants began to wilt, turn yellow, and show no signs of survival at the end of the experiment. The plants in 5 mg/L of Cu in water demonstrated that the growth of the plants was still maintained and there was growth in height. However, at the end of experimental period, many foliage had turned to yellow.

When plants are grown in water contaminated with heavy metals, their growth is reduced as a result of altered physiological and biochemical activities. This is particularly true when the heavy metal in question has no favorable effect on the growth and development of plants [18]. It is therefore clear from the height of the *E. fluctuans* in each pot that height growth was taken into consider. However, the various metals had varying effects on the *E. fluctuans*' height growth; some even wilted, perished, and failed to develop young plants. After that, the pot's biomass was drastically decreased.

Potential of *E. fluctuans* to accumulate heavy metals

Plant species with the potential to process heavy metals must meet at least two of the following conditions: (i) have the ability to accumulate large amounts of pollutants (100 times greater than normal plants); (ii) capable of generating large biomass under the simplest cultivation conditions [19,20].

Removing potentially hazardous metals from the environment through phytoremediation is thought to be an efficient, aesthetically pleasing, economical, and environmentally benign approach. Through their roots, plants in phytoremediation gather pollutants, which they then transfer to the portion of their bodies above ground [21,22]. Many terms, including agro-remediation, green remediation, vegetative remediation, green technology, and botano remediation [23,24] are used to refer to phytoremediation.

E. fluctuans was used in a phytoremediation procedure with the aim of evaluating its efficacy in treating heavy metals. In order to track the amount of metal in water that *E. fluctuans* has treated over time, the sample was planted and the heavy metal concentration in the water was tested three times, after 10, 20, and 30 days. Table 3 presents the findings.

According to the experimental procedure, the findings indicate that as the duration of treatment with *E. fluctuans* increased, the amounts of Cd, As, Pb, Zn, and Cu in the water steadily reduced. In particular, the starting levels of Cu, Zn, Pb, As, and Cd in the water were 0.5 mg/L, 0.5 mg/L, 2 mg/L, 5 mg/L, and 5 mg/L, correspondingly. The amounts of Cd, As, Pb, Zn, and Cu in the water were 0.304 mg/L, 0.392 mg/L, 1.617 mg/L, 4.087 mg/L, and 3.261 mg/L, respectively, ten days after the *E. fluctuans* was planted. The concentration of heavy metals (Cd, As, Pb, Zn, and Cu) dramatically dropped by day 30 of the experiment.

Growing *E. fluctuans* in water that contains heavy metal contamination (Cd, As, Pb, Zn, and Cu) has been shown to allow the plant to grow and flourish to a certain extent. The effects of various heavy metals on plant growth and development vary depending on the particular heavy metal involved in that process. Metals like Pb, Cd, and As have been demonstrated to negatively affect plant growth even at extremely low concentrations and to play no beneficial role in plant growth [18]. The examination of the water's content of heavy metals revealed a trend of gradually declining concentration. As a result, *E. fluctuans* is highly effective at cleaning water tainted with heavy metals.

Heavy metal remaining ercentages in water and removal efficiency ercentage

Figure 2 displays the percentage of removal efficiency for the plants' capacity to take up heavy metals (Cd, As, Pb, Zn and Cu) in the water over time.

Table 2: Effect of heavy metal polluted water on plant growth of *E. fluctuans*

Factor	Initial Height (cm)	After thirty days, Height(cm)
Cd	35	$38.0^{a} \pm 0.2$
As	35	$37.2^{b} \pm 0.8$
Pb	35	$37.0^{b} \pm 0.2$
Zn	35	$36.1^{b} \pm 0.5$
Cu	35	$37.2^{c} \pm 0.4$
P= 0.0069*		

1. The values represented by a, b, and c are statistically distinct.
2. * Significant means with p<0.05.

Table 3: Results of analysis of heavy metal concentrations in water over time.

Days	Cd (mg/L)	As (mg/L)	Pb (mg/L)	Zn (mg/L)	Cu (mg/L)
0	0.5	0.5	2	5	5
10	0.304 ± 0.001^{a}	0.392 ± 0.001^{a}	1.617 ± 0.0006^{a}	4.087 ± 0.002^{a}	3.261 ± 0.002^{a}
20	0.215 ± 0.0006^{b}	0.297 ± 0.001^{b}	1.250 ± 0.001^{b}	3.428 ± 0.002^{b}	2.782 ± 0.001^{b}
30	0.083 ± 0.002^{c}	0.196 ± 0.002^{c}	0.793 ± 0.0006^{c}	2.977 ± 0.001^{c}	2.067 ± 0.002^{c}
QCVN 40:2011/BTNMT (Column B)	0.1	0.1	0.5	3	2

** The data are presented as mean ± SD; values indicating significant differences at P < 0.05 are indicated by various superscripts in the same column.*

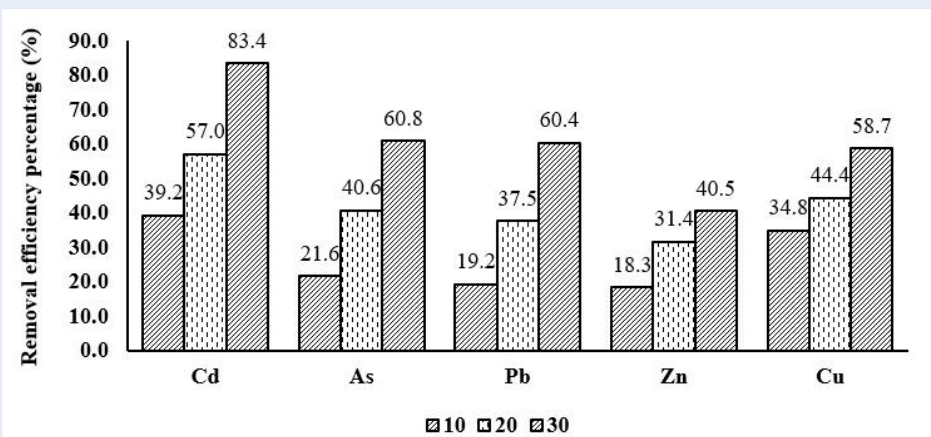

Figure 2: Heavy metal removal efficiency percentage in water

Cadmium has the best absorption performance among metals. Zinc is the metal with the worst absorption performance. Over the course of the 30-day trial, *E. fluctuans* was able to achieve treatment efficiencies for Cd, As, Pb, Zn, and Cu of 83.4%, 60.8%, 60.4%, 40.5%, and 58.7%, respectively. These results corresponded to the beginning concentrations of 0.5 mg/L, 0.5 mg/L, 2 mg/L, 5 mg/L, and 5 mg/L. All heavy metals (Cd, As, Pb, Zn, and Cu) had cleaning rates of 40.5–83.4% for *E. fluctuans* by the end of the 30-day survey period. The analysis results show that after 30 days compared with the values in column B QCVN 40:2011/BTNMT, the Cd content (reaching the treatment rate of 83.40%) is within the allowable limit.

The findings demonstrate that, in comparison to the initial concentrations, after 30 days, *E. fluctuans*' capacity to accumulate heavy metals steadily declined with the residual heavy metal contents in the water in the order Cd < As < Pb < Cu < Zn. In particular, the residual percentage of cadmium was just 16.6%, meaning that the initial concentration was 0.1 mg/L. According to the study, *E. fluctuans* has a strong capacity to absorb heavy metals in wastewater, including lead, zinc, copper, cadmium, and arsenic. The analysis's findings supported the buildup of various metals within *E. fluctuans* and the related decline in metal levels in the water. As has been noted in a number of other macrophyte species, *E. fluctuans* exhibits a high capacity for heavy metal removal from the aqueous medium. This capacity may be facilitated by their greater biomass, quick development, and capacity for metal absorption from the aqueous medium.

CONCLUSIONS

As opposed to other environmental pollutants, heavy metals are now the main cause for concern. because heavy metals can't be destroyed by degradation. So, choosing a low-cost, environmentally friendly technology is a top priority. An additional option as a green method to treat areas affected by heavy metals is phytoremediation. Choice of the appropriate plant is the most significant feature in phytoremediation.

E. fluctuans was evaluated as a possible plant for the removal of Cd, As, Pb, Zn, and Cu based on the amounts of heavy metals in water using phytoremediation technology. *E. fluctuans* was able to lower the concentrations of Cd by 83.4%, As by 60.8%, Pb by 60.4%, Zn by 40.5%, and Cu by 58.7%, per the experiment results. Sixty-eight percent less heavy metal was present overall. Furthermore, *E. fluctuans* is a medicinal plant that has been useful in the treatment of a wide range of illnesses. These characteristics, along with its capacity for fragmentation-based asexual propagation, make it a plant that is worthwhile investigating for its potential use in both safe and environmentally friendly wastewater treatment methods that integrate natural ecosystems and phytoremediation of heavy metal-contaminated water.

CONFLICT OF INTEREST

There is no conflict of interest declared by the authors.

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AUTHOR CONTRIBUTIONS

(A.T.H) Original draft writing, writing reviews, editing, conceptualization, methodology, research, and experimentation. The conceptualization, review, and supervision were completed by (TMD).

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Bài nghiên cứu

Nghiên cứu ứng dụng công nghệ sinh thái xử lý ô nhiễm kim loại nặng trong nước sử dụng cây Ngổ trâu: Cây thuốc thích ứng với biến đổi khí hậu

Huỳnh Thế An*, Đào Minh Trung

TÓM TẮT

Phương pháp xử lý ô nhiễm môi trường bằng thực vật có thể được sử dụng như một giải pháp thay thế để hấp thụ kim loại nặng vì thân thiện với môi trường và có khả năng tiết kiệm chi phí. Cây Ngổ trâu là loài cây thân thảo, bán thủy sinh, phân bố rộng rãi ở vùng nhiệt đới Châu Phi, Nam Á, Đông Nam Á và Việt Nam. Lá của nó được dùng làm thức ăn và trong y học cổ truyền ó cũng được sử dụng để điều trị một số bệnh. Bài báo này nhằm mục đích kiểm tra hiệu quả của cây Ngổ trâu trong việc loại bỏ kim loại nặng khỏi môi trường nước. Các thí nghiệm được thực hiện bằng cách sử dụng cây Ngổ trâu khỏe, trưởng thành và đã thích nghi với khí hậu. Nước chứa ồng độ 0,5 mg/L cadimi, 0,5 mg/L asen, 2 mg/L chì, 5 mg/L kẽm và 5 mg/L đồng đã được thử nghiệm với 100 g Ngổ trâu trong thùng xốp 30 lít. Các thí nghiệm được lặp lại ba lần. Các mẫu nước được theo dõi và phân tích hàm lượng kim loại nặng tại các thời điểm 10, 20 và 30 ngày của quá trình thí nghiệm. Các kim loại nặng được xác định bằng phương pháp hổ khối-plasma kết hợp cảm ứng. Sau 30 ngày thí nghiệm, cây Ngổ trâu có khả năng loại bỏ Cd là 83,4%, As là 60,8%, Pb là 60,4%, Zn là 40,5% và Cu là 58,7%. Do đó, cây Ngổ trâu tiềm năng cao trong việc loại bỏ kim loại nặng khỏi nước thải công nghiệp một cách hiệu quả.

Từ khoá: xử lý môi trường bằng thực vật, cây Ngổ trâu, cadimi, asen, chì, kẽm, đồng, biến đổi khí hậu, cây thuốc

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