

1  
MINISTRY OF NATURAL RESOURCES AND ENVIRONMENT  
**VIETNAM INSTITUTE OF  
METEOROLOGY, HYDROLOGY AND CLIMATE CHANGE**

**VU THI PHUONG THAO**

**EXPERIMENTAL RESEARCH ON ROLE OF SOME  
AQUATIC PLANTS AND PROPOSE SOME  
BIOLOGICAL SOLUTIONS TO IMPROVE WATER  
QUALITY OF NHUE RIVER**

Major: Environment and Resources Management

Code: 62850101

**SUMMARY OF ENVIRONMENTAL CONTROL AND  
MANAGEMENT PH.D THESIS**

**HA NOI, 2017**

The PhD dissertation was completed in:

VIETNAM INSTITUTE OF METEOROLOGY, HYDROLOGY  
AND CLIMATE CHANGE

Supervisors:

1. Assoc. Prof. PhD. Le Xuan Tuan, Hanoi University of Natural resources and environment.
2. PhD. Dinh Thai Hung, National centre for Hydro – meteorological Forecasting.

Reviewer 1: .....

Reviewer 2: .....

Reviewer 3: .....

This PhD dissertation will be defended at the Scientific Council at Institute level: Vietnam Institute of Meteorology, Hydrology and Climate Change

Time, date (dd/mm/yy): / /2017

The PhD dissertation can be found at:

- Vietnam National Library;
- Vietnam Institute of Meteorology, Hydrology and Climate Change Library

## INTRODUCTION

### 1. The urgency of PhD research

Located in highest population density and best economic growth region, Nhue River plays an important role in economic activities in the basin. Nhue River takes water from the Red River, receives waste water from Hanoi and riverside areas every day, supplies water for agricultural lands and riverside aquatic lagoons. When using this water source as an irrigation water, besides its beneficial effect, there are harmful matters to human which need to be concerned such as the toxic organic substances or pathogenic microorganisms, heavy metal elements,... (FAO,1994), (Marcussen H., 2008). Use of Nhue River water meeting irrigation water standards of Vietnamese Government is an urgent and legitimate need of people to ensure public health as well as Hanoi beauty. River ecosystems and river basin play an indispensable role, which is an integral part of river environment, which is involved in transportation, accumulation processes, to be main part in self-purification process of water. This dissertation “*Experimental research on role of some aquatic plants and some biological solutions to improve water quality of Nhue River*” has focused on studying and evaluating specific role of some aquatic macrophytes which have advantage in absorbing pollutants in water to purify water environment. This dissertation has practical significance and is scientific basis for development of biological solutions to minimize and control pollution in order to protect effectively water sources, protect environment and natural landscapes of Nhue River basin.

### 2. Scientific and practical significance

(1) *Scientific significance:*

+ This dissertation has studied and combined data sources (climate, weather data, flow rate, water quality data, etc.) to assess water and sediment quality of Nhue river section from Cau To to Cong Than and role of aquatic macrophyte species such as *Cyperus flabelliformis* Rottb, *Ipomoea aquatica* Forsk., *Enydra fluctuans* Lour in purifying Nhue River water environment.

+ In this dissertation, biological solution using aquatic macrophytes to remove main contaminants in Nhue River water - phytoremediation method with many advantages such as low cost, simple technology, high efficiency, friendly environment was also proposed.

*(2) Practical significance:*

Results of dissertation contribute to practical and theoretical basis for use of aquatic plants for purifying contaminated river water. Success of study leading to application into improvement of Nhue River water quality as well as many other rivers that are polluted on territory. This will bring tremendous economic and spiritual values, affirm correctness of economic development along with protection of living environment, improve and preserve natural resources to meet needs of present and future generations.

### **3. Objectives of research**

- To assess current status of water and sediment pollution of Nhue river section from Cau To to Cong Than.

- To identify role of some effective aquatic macrophyte species in purifying Nhue River water quality.

- To propose useful biological measures for protecting water environment, developing bio-diversity of Nhue River ecosystem.

### **4. Scope of study**

The study was carried out on Nhue River section from Cau To to

Cong Than, with 32 km long, flowing through five districts of Hanoi, including Ha Dong District, Thanh Oai District, Thuong Tin District, Phu Xuyen District. Geographic coordinates are from 20°57'06" to 20°41'56" North latitude and 105° 48'42" to 105° 53'49" East longitude.

## **5. Methodology**

Many methods have been used to conduct research, mainly 3 groups of methods including group of field research methods, group of in laboratory methods and group of synthesis methods.

## **6. List of new scientific contributions**

For the first time, a study on role of three species as *Cyperus alterfoliosus*, *Ipomoea aquatica* Forsk, *Enydra fluctuans* Lour in Nhue river water quality improvement by experimental method was implemented. Experimental results have demonstrated that three aquatic macrophyte species are capable of absorbing high concentrations of TN, TP, Fe and Zn in Nhue river water. Higher biomass, higher pollutant content in plant tissues, and tissue anatomy show large variations in cell size indicating adaptation to polluted environment. Results of water quality analysis showed that in the tanks with aquatic macrophyte, Nhue river water quality after the experiment almost met irrigation water quality standards of MONRE (QCVN 08:MT/BTNMT/2015). Experimental results are the scientific basis for development of environmentally-friendly biological solutions to improve water quality of Nhue River.

## **7. The dissertation outline**

The dissertation includes Introduction and three chapters:

Chapter 1: Overview

Chapter 2: Scope, subjects, times, content and methodology

Chapter 3: Results and discussion  
Conclusions and recommendations

## CHAPTER 1. OVERVIEW

### 1.1. Current status of river pollution in the world and in Vietnam

Development of industrialization and urbanization processes have accelerated polluted river status in everywhere of the world because of waste water from urban waste streams, residential areas, industry, ... with chemicals used more and more. All of these polluted effluents have been increasing pollutant content and wastewater volume that brings to people environmental challenges due to polluted river water amount is so big, but the pollutant concentration in river are not too high, mainly consisting of nutrient compounds, heavy metal, microorganisms,... (Ministry of Natural Resources and Environment, 2007, 2010, 2012), (Asia Development Bank, 2013), (B. Wu,2009), (Fu Kaidao, 2012)...

### 1.2. Research on use of aquatic plants to purify water pollution

#### *1.2.1. Scientific basis of use of aquatic macrophytes to purify water pollution*

- **The pollutants are inorganic substances:** The absorption of inorganic pollutants, mainly nutrients, heavy metals and radioactive nucleic in aquatic plants, takes place by roots and leaves. The role of root is to assimilate nutrients, and the main role of the leaf is inorganic carbon fixation (Bhupinder Dhir, 2013).

- **Pollutants are organic substances:** Aquatic plants absorb toxic pollutants mainly through roots and leaves (Vajpayee P., 1995). The organic matter absorption process of aquatic plants consists of two mechanisms:

+ To absorb directly the pollutants and convert these substances into macrophyte tissue.

+ To release secretions and enzymes that stimulate microbial activity and improve the results of microbial transformation in the root zone.

The organic matter amount absorbed by aquatic macrophyte species depends on the macrophyte itself, the biochemical composition of the macrophyte cell, the physicochemical properties of the contaminant such as polarity, fluctuations in molecular weights, water resistance,... (Bhupinder Dhir, 2013).

### ***1.2.2. Standards for aquatic macrophyte speices to purify water pollution***

In order to be high effect in purifying water pollution, selected species must: be resistant to high levels of pollutants; Ability to absorb quickly pollutants from the water environment; Ability to accumulate pollutants in the body; Ability to transport pollutants from the roots to the stem and leaves; Ability to tolerate poor nutritional or eutrophic environmental conditions; Capable of growing fast and get high biomass. In addition, aquatic macrophyte speices are used not to become invasive or weeds harmful to the environment and other organisms, easy to control the breed, the ability to spread, develop in the ecosystem.

### ***1.2.3. Advantages and disadvantages of using aquatic plants to purify polluted water:***

***Advantages:*** Use aquatic plants to purify polluted water with high environmental friendliness; Utilization of aquatic plants to purify polluted water is also superior to chemo-chemical methods, does not adversely affect the biological activity of water, takes place on the spot pollution and does not need more area; Reduce the degree of water disturbance; Reduce the level of pollution spread through air and water;

The technological cost of using aquatic plants to purify water pollution is much lower than for other technologies.

**Disadvantages:** However, treatment of water pollution by aquatic plants are slower than physical chemistry; The growth and development ability of the species depends heavily on the physical and chemical factors of the environment such as pH, salinity, pollutant concentration and the presence of toxins; Aquatic plants used to treat pollutants are often limited in root length. Therefore, the use of aquatic plants for purifying pollution in deep water bodies is not suitable.

***1.2.4. Studies on the purification of water pollution by aquatic plants and studies on the use of *Cyperus alterfolious*, *Ipomoea aquatica* Forsk, *Enydra fluctuans* Lour***

The water purification capacity of aquatic plants have been known since the 19th century, but until the 1970s it was mentioned as a new technology for treating contaminated environment by metals, organic compounds, gunpowder and radioactive substances (Bhupinder Dhir, 2013). By many experiments with a variety of different types of aquatic plants, the authors studied and announced viability and purification ability of many aquatic plants in different polluted environments (Raskin P. (1997), Petrucio M. M., et al (2000), Liao X et al, (2005),... In general, use of aquatic plants for water purification focused on solving two problems of surface water environment: excess of nutrient contaminants and presence of significant heavy metal content in water bodies.

Studies of Hailiang Song et al (2014), Nerella et al (1999), Truong Thi Nga và Vo Thi Kim Hang (2010), Tran Van Tua (2004)...have shown that plants such as *Cyperus flabelliformis* Rottb, *Ipomoea aquatica* Forsk, *Enydra fluctuans* Lour are both capable of removing

nutrient compounds, and capable of removing a significant heavy metal amount in water body. This indicates suitability of using these species in improving water quality of Nhue River.

#### *1.2.5. Research on treating aquatic plants after use to purify polluted water*

Biomass of aquatic macrophytes containing pollutants can be a serious source of pollution, so depending on toxicity of treated water and pollutant content inside plants, using proper treatment and management methods.

### **1.3. Natural and socio-economic characteristics of Nhue River basin and impact of socio-economic development on water resources of Nhue River basin**

Nhue River with 72 kilometer long flows through seven districts of Hanoi and two districts of Ha Nam. River basin area is over 107.500 ha, with 87.820 ha of Hanoi and 19.710 ha of Ha Nam province. Nhue River occupies an important place in socio-economic development of the basin. Nhue River water is used for irrigation and aquaculture. Nhue River is also the wastewater drainage area of the entire basin every day.

Historical statistics show that population of Hanoi has increased rapidly in the last half century. Rapidly increasing population along with rapid socio-economic development has created large waste and wastewater. These waste and wastewater are poured directly into Nhue River through Thanh Liet Dam, making water quality of Nhue River seriously degraded. Population boom and industrial, agricultural and fishery development ... have led to high need for clean water in Nhue River basin, leading to a lack of clean water and excessive polluted water. To solve this challenge, it is necessary to take measures to protect fresh water resources, to improve water source quality by

appropriate and effective methods.

## **CHAPTER 2: SCOPE, SUBJECTS, TIMES, CONTENTS AND METHODOLOGY**

### **2.1. Scope, subjects, times of study**

**2.1.1. Scope of study:** This study was carried out on Nhue River section from Cau To to Cong Than, with 32 km long, flowing through five districts of Hanoi, including Ha Dong District, Thanh Oai District, Thuong Tin District, Phu Xuyen District. Geographic coordinates are from 20°57'06" to 20°41'56" North latitude and 105° 48'42" to 105° 53'49" East longitude.

**2.1.2. Subjects of study:** Water and sediment quality of Nhue River section from Cau To to Cong Than; three aquatic macrophyte species as *Cyperus alterfolious*, *Ipomoea aquatica* Forsk, *Enydra fluctuans* Lour

**2.1.3. Study time:** From 12/2012 up to now.

### **2.2. Study content:**

- To study water and sediment quality of Nhue river section from Cau To to Cong Than;

- To study biodiversity of Nhue River, selecting a number of aquatic macrophyte species that can effectively purify water;

- To study specifically effect of *Cyperus flabelliformis* Rottb, *Ipomoea aquatica* Forsk, *Enydra fluctuans* Lour on absorbing pollutants from Nhue River water environment;

- To propose biological solution to improve Nhue River water quality to develop biodiversity to protect aquatic environment.

**2.3. Research methodology:** Many methods have been used to conduct research, mainly 3 groups of methods including group of field research methods (including field survey method, diversity assessment method

plant, sedimentation, water sampling methods, sample preservation methods, etc.), group of method in laboratory (including methods of sediment quality, water quality, nutrient content and heavy metal in plant analyzing, morphology of plant cell analyzing, etc) and group of synthesis method (Include methods of information collection, documental inheritance, expertise, measures and data processing, etc.).

## **CHAPTER 3: RESULTS AND DISCUSSION**

### **3.1. Water quality of Nhue River during study period**

Nhue river water quality in the studied river section is heavily polluted by organic substances, total nitrogen, total phosphorus and a significant amount of Fe, Zn. Water quality parameters of COD, BOD<sub>5</sub>, NH<sub>4</sub><sup>+</sup>, PO<sub>4</sub><sup>3-</sup>, Fe, Zn were high and exceeded limit B1 of QCVN 08-2008 / BTNMT in most study sites. The level of pollution varies significantly between dry and rainy seasons.

### **3.2. Quality of Nhue River sediment during study period**

Nhue River sediment is heavily polluted by organic matter and some heavy metals such as Cd, Pb, Zn. These heavy metal parameters are very high in the Nhue River sediment, exceeding the values of QCVN 43: 2012 / BTNMT for sediment quality.

### **3.3. Aquatic macrophyte diversity of Nhue river basin and possibility of utilizing Nhue River aquatic macrophyte to purify water pollution.**

According to field surveys, there are 33 species of vascular aquatic macrophyte species, including group of submerged macrophyte species (3 species), group of floating macrophyte (6 species), and group of submerged macrophyte (24 species) living in freshwater ecology of Nhue River basin.

### **3.4. Experiment for assessment role of aquatic macrophyte in improvement of water and sediment quality of Nhue River**

#### ***3.4.1. Water and sediment quality used for experiment***

Results of analyzing water and sediment samples of Nhue River on March 30, 2015 showed the typical characteristics of water and sediment quality of Nhue River in dry season with many parameters exceeding the limit value B1 of QCVN 08-MT: 2015 / BTNMT and some heavy metal parameters in sediment exceeds limit value of QCVN 43: 2012 / BTNMT. Except pH value to meet value B1 of QCVN 08-MT: 2015 / BTNMT for irrigation water standard, other physical parameters, especially total suspended solids TSS, dissolved oxygen DO, not satisfy limit value B1 of this standard; The parameters of organic pollution, microorganisms, total nitrogen, total phosphorus in water samples are very high, showing heavy pollution levels by organic substances, nutrients, microorganisms. Therefore, Nhue River water quality does not meet the standard for irrigation; Besides, iron and zinc elements in water samples are also high in content.

The analyzing results also show that in sediment samples, there were significant content of organic matter in the composition with neutral pH. Cd, Pb, Zn exceeds the value of QCVN 43: 2012 / BTNMT in most samples. Sediment samples of Nhue River were severely polluted by Cd, Pb, Zn. The purpose of the experimental use of aquatic macrophyte is to study the possibility of reducing content of Nhue River water pollutants, concentrating mainly on high concentration parameters as nitrogen and phosphorus compounds, Fe, Zn.

#### ***3.4.2. Growth and tissue composition transformation of aquatic macrophyte species***

### 3.4.2.1. Anatomical structure, cell variation, growth ability, material composition of *Cyperus alterfoliosus* after experiment

#### - Transformation of cell before and after experiment

Size of stem cells after experiment increased, especially xylem cells and epidermal cell length. However, there is no change in structure, order of cell alignment and vascular bundles. Not so much changes in morphology was observed, so that it can be still recognized what is species. Green colour leaves change, leaves before experiment was dark green, leaves after experiment was medium and light green.

- *Growth ability*: The plants were observed to develop equally in all four experiment environments. While Dong Quan sample tank gave the highest biomass, up 58% fresh biomass compared to initial time, other sample tanks from Cau Chiec, Cau To, Cong Than up in turn 44%, 54%, 55%. The productivity of *Cyperus alterfoliosus* when planted by Nhue River water and sediments in the first stage ranged from 4.6 to 6,04 gDW/m<sup>2</sup>/day, highest in Dong Quan tank and lowest in Cau Chiec tank. In the second stage, yields ranged from 0,95 to 2,04 gDW/m<sup>2</sup>/day, highest in Cau To tank and the lowest in the Cong Thien tank. The rate of fresh biomass/dry biomass after experiment has changed markedly. While this rate was 19 at initial time, this figure was 17,98 ÷ 18,4 at final time, the highest rate at Cong Than and the lowest rate at Cau Chiec.

- *Content and composition of plant tissue*: Tissue analyzing results showed that nitrogen and phosphorus content in plant tissues were significantly increased after experiment. Total nitrogen in samples before experiment was 16,2 mg/gDW, in the samples after experiment ranged from 16,6 ÷ 17,1 mg/gDW, increased from 0,4 ÷ 0,9 mg/gDW (about 2,5 ÷ 5,5%) in plant tissues. The total phosphorus in samples

before experiment was 4,23 mg/gDW, after experiment was in range of 4,42 ÷ 4,48 mg / gDW, increased from 0,19 ÷ 0,25mg/g DW (about 4,5 ÷ 5,9%).

- *Fe, Zn content in the plant leaf, stem, root and ability to transport these heavy metal from the roots to the leaf and stem:* Before experiment, there was a small amount of Fe, Zn (several ppm) in plant roots, leaves. After experiment, significant content of these heavy metals were detected. Samples after experiment contained Fe content higher than samples before experiment 35 ÷ 48 times (in leaves), 19,6 ÷ 30,7 times (in stems), 27,78 ÷ 35 times (in roots); Samples after experiment also contained Zn content higher than samples before experiment 46 to 50 times (in leaves), 28 ÷ 35 times (in stems), 23 ÷ 34.25 times (in roots). Plant samples collected at Cau To tank contained the highest levels of iron in roots, stems and leaves. Water and sediment samples collected at Cau To also have the highest iron content. The highest zinc content in the stem and leaves was detected at Cong Than tank but highest zinc content in the roots was detect at Cau To tank.

TF is the transportation coefficient representing the transformation ability of heavy metal from roots to stems and leaves of plant was high for Zn (TF = 0,63 ÷ 0,83), was mean for Fe (TF = 0,4 ÷ 0,6). So 2/3 of zinc amount absorbed by plant would be transferred to stem and leaves. This is significant because this zinc amount is readily removed from the environment simply by cutting off the leaves.

- *Nhue river pollutant adsorption ability of *Cyperus alterfoliosus**

+ TN, TP adsorption ability of *Cyperus alterfoliosus*: Results of biomass increment and TN, TP in plant tissue analysis showed that in the first stage of experiment (first 7 days of experiment), *Cyperus alterfoliosus* had absorbed 14,5 ÷ 23,4% TN, 16 ÷ 21 % TP in Nhue

River water. At the second stage (last 7 days of experiment),  $7,6 \div 12\%$  TN and  $12 \div 14\%$  TP was absorbed by this plant. Totally, after 14 days of experiment,  $26 \div 33\%$  TN and  $30 \div 34\%$  TP from water environment were absorbed by *Cyperus alterfolious*. In general, in Dong Quan and Cong Than tanks, absorption of nutrients were mainly in the first stage while in remaining tanks the absorption were stronger in the second stage.

+ Fe, Zn adsorption ability of *Cyperus alterfolious*: In early stage of experiment, *Cyperus alterfolious* absorbed  $0,3 \div 0,8\%$  Fe,  $0,6 \div 1,2\%$  Zn from water environment. At the second stage,  $0,6 \div 1,5\%$  Fe,  $0,8 \div 1,5\%$  Zn in water were absorbed by *Cyperus alterfolious*. Thus, it was different from nutrient pollutants, heavy metals such as Fe, Zn were strongly absorbed by the plant in the second stage of experiment.

#### 3.4.2.2. Anatomical structure, cell transformation, growth ability, material composition of *Ipomoea aquatica* Forsk after experiment

- Transformation of cell before and after experiment: *Ipomoea aquatica* Forsk stem cell size after experiment increased compared to before experiment, especially xylem cells (increased 2 to 3 times) and epidermal cell length (doubled). However, in structure and order of cell alignment, the vascular bundles have no change. About morphology, with no significant change, except dark green leaves before experiment and yellowish green leaves after experiment were observed.

#### - Growth ability

+ Experiment results showed that mortality rate of *Ipomoea aquatica* Forsk was different from 4 tanks, ranging from  $0 \div 30\%$ , with the highest mortality in Cau To (23%), smaller at Cau Chiec (17%) and Dong Quan (6%). No dead *Ipomoea aquatica* Forsk stem was found at Cong Than tank. At the end of experiment, biomass of Cong Than tank

was the highest, rising 206% compared to the initial, while biomass of Cau To tank was the lowest, rising 76% while in Dong Quan tank rising 191%. The yield of *Ipomoea aquatica* Forsk were recorded in range of  $2,65 \div 10,21$  gDW/m<sup>2</sup>/day in the first stage of experiment,  $1,99 \div 4,2$  gDW/m<sup>2</sup>/day in the second stage. The highest productivity was highest at Cong Than tank and lowest at Cau To tank.

+ The rate of fresh biomass / dry biomass after experiment has changed markedly. While this rate was 22.6 at initial, this number was  $21 \div 22$  at final, the highest at Cong Than and the lowest at Cau Chiec. This change indicated that a significant proportion of high-density substances such as heavy metal was absorbed by *Ipomoea aquatica* Forsk to create biomass of plant.

- *Content and composition of plant tissue*

+ Plant tissue analyzing results before experiment showed that total nitrogen content of *Ipomoea aquatica* Forsk samples was 13,4 mg/gDW. After the first stage, this content was in range of  $13,5 \div 13,6$  mg/gDW; At the end of experiment, TN content in tissues was within range of  $13,5 \div 14,3$  mg / gDW. Initial TP content in samples was 3mg/g DW. After the first stage, TP content was in range of  $3,01 \div 3,14$  mg / gDW; At the end experiment, TP content was in range  $3,1 \div 3,3$  mg / gDW.

+ Before experiment, a significant content of Fe in each gram dry root, leaves and stem was detected while Zn was not detected in plant tissue. After experiment, in each gram of dry weight, there were several times of iron content rising. The plant samples contained higher iron content compared to initial from  $5.1 \div 13$  times (in leaf),  $8.9 \div 13.4$  times (in stem),  $7 \div 8.5$  times (in roots). The highest content of iron in roots was detected at sample grown at Cau To tank while highest

content of iron in leaf was detected at sample grown at Cong Than tank and lowest content of iron in roots was detected at Dong Quan tank. TF from root to stem and leaf of *Ipomoea aquatica* Forsk for Fe was from  $0,53 \div 0,69$  and not significantly different from plant samples grown at different tanks. For zinc, after 14 day experiment, Zn content increased in leaves from 34 to 37 mg/gDW, in stem from  $383 \div 671$  mg/gDW, in roots from  $938 \div 1176$  mg/gDW. TF from root to stem and leaves of *Ipomoea aquatic* Forsk. for Zn is medium ( $0.4 \div 0.6$ ).

- *Nhue river pollutant adsorption ability of Ipomoea aquatic* Forsk

+ TN, TP adsorption ability of *Ipomoea aquatic* Forsk: Results of biomass increment and TN, TP content in plant tissue analysis showed showed that after experiment,  $21 \div 27\%$  TN and  $24 \div 30\%$  TP in Nhue River water was absorbed by *Ipomoea aquatic* Forsk.

+ Fe, Zn adsorption ability of *Ipomoea aquatic* Forsk: *Ipomoea aquatic* Forsk exhibited a greater ability to absorb of Fe, Zn from water environment. In the first 7 days of experiment,  $7,3 \div 14,6\%$  Fe,  $6,9 \div 28,8\%$  Zn was absorbed from the water environment. In remaining 7 days,  $11 \div 25,7\%$  Fe,  $8,4 \div 31\%$  Zn was absorbed.

3.4.2.3. *Anatomical structure, cell transformation, growth ability, material composition of Enydra fluctuans Lour after experiment*

- *Transformation of cell before and after experiment*: Size of epidermis and soft tissue cells were significantly increased at the time after experiment, especially, epithelial cells increased from 0,9 to 1,4  $\mu\text{m}$ /cell, soft tissue cells increased from  $0,8 \div 2,8$   $\mu\text{m}$  / cell.

- *Growth ability*: In the first stage of experiment, mortality rate of *Enydra fluctuans* Lour at Cau To tank was 40%, at Cau Chiec tank was 20%, at Dong Quan tank was 10%. In the second stage, 10% mortality rate of *Enydra fluctuans* Lour at Cau To tank. Mortality rate of *Enydra*

*fluctuans* Lour at Cong Than tank was 0% during experiment time. Growth ability of *Enydra fluctuans* Lour at Cau To and Cau chiec was very poor. Increment of branch numbers, biomass and stem length were significant different between 4 tanks. The final biomass of experiment showed the highest biomass increment was at Cong Than tank (up 90%), the lowest biomass was recorded in Cau To tank (up 1%), after that biomass at Cau Chiec tank (14%) and Dong Quan (up 50%). Thus, the productivity of *Enydra fluctuans* Lour when grown on water and sediment of Nhue river was recorded in range of  $-1,6 \div 9,1$  gDW/ m<sup>2</sup> / day in the first stage and  $1,9 \div 3$  gDW / m<sup>2</sup> / day at stage 2. The fresh biomass / dry biomass rate after experiment also changed markedly (before experiment was 21, after experiment was  $20,6 \div 20,9$ ).

- *Content and composition of plant tissue*

+ Total nitrogen and total phosphorus content in plant tissue: At initial *Enydra fluctuans* Lour samples, TN content was 12 mg /gDW, TP content was 2,8 mg / gDW. At the end of experiment, TN content in plant was in range of  $12,16 \div 12,49$ , TP content was in the range of  $2,85 \div 2,94$ .

+ Fe, Zn content in plant tissue and ability to transport these heavy metal from roots to leaf and stem: Analysis result showed that, at initial, a significant content of Fe in *Enydra fluctuans* Lour was detected. Zn was not detected in plant tissues. After experiment, in roots, stems and leaves of *Enydra fluctuans* Lour, found a significant Fe content increment. TF from roots to stem and leaves of *Enydra fluctuans* Lour for Fe were in range  $0,6 \div 0,94$ , very different between other tanks. Surviving *Enydra fluctuans* Lour after 7 days of experiment contained significant zinc content, in leaves from  $12 \div 28$  mg / gDW, in stem  $128 \div 138$  mg / gDW; in roots  $238 \div 329$  mg / gDW. At final, Zn content

increased in leaves to ten times, in stem from 6 to 7 times. TF from roots to stem and leaves to Zn are medium ( $0.4 \div 0.6$ ).

- *Nhue river pollutant adsorption ability of Enydra fluctuans Lour*

Biomass increment and TN, TP content increment in *Enydra fluctuans Lour* tissue show that, after experiment, 21  $\div$  27% TN and 24  $\div$  30% TP in Nhue River water has been absorbed by *Enydra fluctuans Lour*. Thus, *Enydra fluctuans Lour*'s capacity of absorbing pollutants in Nhue River water were poorer than *Cyperus alterfolious* and *Ipomoea aquatic Forsk*. This is due to in Cau To and Cau Chiec, there was a significant proportion of *Enydra fluctuans Lour* dead at first stage while there was not any *Cyperus alterfolious* dead at all the time of experiment.

+ *Enydra fluctuans Lour* survived poorly in Cau To, Cau Chiec, Dong Quan, lived well in Cong Than and gave higher ability to *Cyperus alterfolious* and *Ipomoea aquatic Forsk* in absorbing these pollutants from water environment at Cong Than tank.

**3.4.3. Variation of water and sediment quality parameters of Nhue River during experiment**

Water and sediment sample analysis of Nhue River before experiment showed that Nhue River water quality was not qualified for irrigation. Over time of experiment, along with growth of plant, found a marked change in these water quality parameters.

**3.4.4.1. Variation of water parameters**

- **Variation of pH:** After experiment, pH value of experimental tanks with growing aquatic macrophytes decreased sharply than tanks with non-growing aquatic macrophytes. pH variation during growing plant time, especially in *Cyperus alterfolious*, was significantly over

time, fluctuating in neutral and within limit range of QCVN 08 - MT: 2015 / BTNMT - B1, suitable for aquatic macrophyte growth.

- **Variation of TSS:** Over time, TSS in all tanks with macrophytes were significantly reduced compared to control tanks. This shows the superiority of aquatic macrophyte in removing suspended solids in water. In the first stage, in control tanks, TSS decreased from 12,4 ÷ 13,5%, much less than in tanks with *Cyperus alterfoliosus* (58 ÷ 73%), in tanks with *Impomoea aquatic* Forsk (60 ÷ 72%), in tanks with *Enydra fluctuans* Lour (50 ÷ 75%). In the second stage, control tanks decreased 18,6 ÷ 21% TSS, while in tanks with *Cyperus alterfoliosus* decreased from 16,6 ÷ 21,9% TSS, in tanks with *Impomoea aquatic* Forsk decreased 17.7 ÷ 18.8% TSS, in tanks with *Enydra fluctuans* Lour decreased 13,8 ÷ 25%.

- **Variation of DO over time:** DO value of growing plant tanks tended to increase over time, reflecting DO values at the mid and late experiment higher than input DO values. In the first stage, DO in the control tanks increased from 0,3 ÷ 0,7 mg /l while in *Cyperus alterfoliosus*, *Impomoea aquatic* Forsk, *Enydra fluctuans* Lour tanks increased respectively 0,5 ÷ 2,1 mg /l; 0,9 ÷ 1,2mg /l; 0,8 ÷ 0,9 mg /l. In the second stage, DO in control tanks increased from 0,4 ÷ 1,8 mg /l while in *Cyperus alterfoliosus*, *Impomoea aquatic* Forsk, *Enydra fluctuans* Lour tanks increased respectively 1,1 ÷ 1,5 mg /; 0,5 ÷ 0,9mg / l; 0,7 ÷ 1,2mg / l. Photosynthesis process by chlorophyll is one of the most important contributors to produce 66% to 200% higher oxygen content in growing plant tanks than non- growing plant tanks.

- **Variation of organic pollutants over time:** After the first stage, 15 ÷ 20% COD in control tanks were cleaned, while in *Cyperus alterfoliosus*, *Impomoea aquatic* Forsk, *Enydra fluctuans* Lour tanks

there were 61 ÷ 81%, 35 ÷ 55, 31 ÷ 57 COD in Nhue River water was absorbed by these macrophyte and self-cleaning process of water. In both stages, if there were 29 ÷ 68% COD in control tanks, while 80 ÷ 83%, 70 ÷ 86%, 65 ÷ 85% COD respectively were taken from Nhue River water environment by *Cyperus alterfolious*, *Impomoea aquatic* Forsk, *Enydra fluctuans* Lour.

- **Variation of Total Coliform over time:** Reduction of total coliform in *Cyperus alterfolious* tank was faster than in *Impomoea aquatic* Forsk, *Enydra fluctuans* Lour tanks, possibly due to longer and thicker root systems of *Cyperus alterfolious* provide more viable living environment for useful microorganism. Coliform was killed by sunlight and these useful microorganism. Besides, oxygen content increases in environment also destroy a significant portion of Coliform that prefer to live in anaerobic environment.

- **Variation of nitrogen and phosphorus compounds over time:**

After experiment, 49 ÷ 65% of ammonia, 49 ÷ 60% of phosphate was removed from water in control tanks while 89 ÷ 93%, 84 ÷ 96%, 80 ÷ 95% of ammonium and 88 ÷ 91%, 80 ÷ 95%, 82 ÷ 96% of phosphate was removed respectively in tanks of *Cyperus alterfolious*, *Impomoea aquatic* Forsk, *Enydra fluctuans* Lour.

After 14 self-cleaning days, in control tanks, the water was not eligible for irrigation standard while in growing plant tanks, water quality meet irrigation standard on ammonium and phosphate parameters, except for *Impomoea aquatic* Forsk, *Enydra fluctuans* Lour tanks in Cau To and Cau Chiec.

- **Variation of Fe, Zn over time:** Fe and Zn concentration were high in Nhue River water, especially in Cau To. After 7 days, Fe concentration decreased from 6% to 9% in control tanks. In *Cyperus*

*alterfolious*, *Impomoea aquatic* Forsk, *Enydra fluctuans* Lour tanks, respectively decreased 53 ÷ 68%, 44 ÷ 69%, 38 ÷ 71% Fe concentration.

After 7 days, content of Zn decreased slowly, from 1% to 12% in control tanks, decreased more than in *Cyperus alterfolious*, *Impomoea aquatic* Forsk, *Enydra fluctuans* Lour tanks (respectively 21 ÷ 48%, 14 ÷ 47%, 16 ÷ 57%). By the end, total amount of Zn decreased 3 ÷ 16% in control tanks, 60 ÷ 83%, 44 ÷ 80 % 45 ÷ 82% respectively in *Cyperus alterfolious*, *Impomoea aquatic* Forsk, *Enydra fluctuans* Lour tanks. The lower concentration of heavy metal in water environment after experiment was partly due to absorption of aquatic macrophyte, partially absorbed by aquatic macrophyte roots, and partly deposited in sediment....

#### 3.4.3.2. Variation of sediment parameters

Against to tend to lower pH, organic substances, nutrient compounds in river water due to growing of aquatic macrophyte, organic content, and nutrient compounds in Nhue River sediments have increased at the end of experiment. Increment of pollutants in sediments was due to deposition and precipitation processes of pollutants.

Organic compounds has increased from 2 to 4.5% in control tanks sediment increased from 15 ÷27% in growing plant tank sediment. For TN, increased from 1,9 ÷ 6% in control tank sediment, increased from 19 ÷23% in growing plant tank sediment. TP increased from 9 ÷17% in river sediment in control tanks, while increased of 24 ÷36% in sediment in growing plant tanks. For Zn and Fe, the tendency is reversed; in control tanks, concentration of Fe and Zn increased respectively 10÷12%, 8 ÷9,1% in river sediments while in growing plant tanks concentrations of Fe and Zn precipitated respectively 3 ÷ 6%, 6,4 ÷7,5

% in river sediments. Precipitation of these heavy metals was lower in control tanks, possibly due to pH in growing plant tanks tend to decrease, leading to decrease formation of precipitation of Fe and Zn compounds

### **3.5. Biological solution for improvement of environmental pollution in Nhue River**

- **Used model** is surface flow wetland model. Model design has to meet the main goal is to let river water to come into active biological surface - macrophyte roots with adherent microorganisms. Aquatic macrophytes are grown within floating bed with 1meter wide from riverbank.

- **Location:** From Cau To to Cong Than section river, with 32 km long, 18 meter wide, 2,1 m deep. In this section river, flow is slow, very suitable for growth of aquatic macrophyte.

- Used aquatic macrophyte: *Cyperus alterfolious*; *Ipomoea aquatica* Forsk; *Enydra fluctuans* Lour.

- Planting time: For *Cyperus alterfolious*: April, May, September, October; For *Ipomoea aquatica* Forsk: from April to August; For *Enydra fluctuans* Lour: from April to October.

+ Appropriate density and biomass harvest:

For *Cyperus alterfolious*: It is recommended to grow plant with density from 1,7 to 3,5 kg fresh weight / m<sup>2</sup>; For *Ipomoea aquatica* Forsk, *Enydra fluctuans* Lour: optimal density is 1,5 to 2,5 kg fresh weight / m<sup>2</sup>.

+ Periodic harvest: *Ipomoea aquatica* Forsk, *Enydra fluctuans* Lour: After 10 ÷ 22 days, stem should be cut from the root 10cm, after 3 months harvest whole stem, roots and leaves; *Cyperus alterfolious*:

After 21÷ 42 days, cut the whole stem up to 10 cm from the root, after 6 months, remove all parts of plant.

+ Biomass after treatment: should be encouraged using for biogas or material for gasification to generate gas energy and electric energy for areas that lack electricity or production facilities.

## CONCLUSIONS AND RECOMMENDATIONS

### Conclusions

1. On water and sediment quality of Nhue river section from Cau To to Cong Than:

- Nhue river water quality is heavily polluted by organic substances, total nitrogen, total phosphorus and a significant content of Fe and Zn. Water quality parameters of COD, BOD<sub>5</sub>, NH<sub>4</sub><sup>+</sup>, PO<sub>4</sub><sup>3-</sup>, Fe, Zn were high and exceeded limited value B1 of QCVN 08: 2008/BTNMT in most study sites. Polluted level is different significantly from dry and rainy seasons.

- Nhue River sediment is heavily polluted by organic substances and heavy metal such as Cd, Pb, Zn. These parameters are very high in Nhue River sediment, exceeding limited values of QCVN 43: 2012 / BTNMT for sediment quality.

2. High diversity of vascular aquatic macrophyte in Nhue River Basin ecosystem was observed with 33 species living in. 18 species of above species play important role in purifying polluted water.

3. Experimental results showed that 3 species of aquatic macrophyte, *Cyperus alterfolious*, *Ipomoea aquatica* Forsk, *Enydra fluctuans* Lour were able to absorb high concentrations of TN, TP, Fe, Zn in Nhue River water. Specifically, absorption of *Cyperus alterfolious* was 23,8 ÷ 32,8% TN, 30,4 ÷ 33,6% TP, absorption of *Ipomoea aquatica* Forsk

was 21,0 ÷ 27% TN, 23,9 ÷ 30,4 TP, absorption of *Enydra fluctuans* Lour was 1,8 ÷ 32,1% TN, 1,8 ÷ 29,3% TP. Self-cleaning process of water environment in control tanks has been found to be less effective than tanks with aquatic macrophyte. At the end of experiment, in the tanks with aquatic macrophyte, Nhue river water quality almost met irrigation water quality standards of BTNMT (QCVN 08:MT/BTNMT/2015).

4. Environmentally-friendly biological solutions model to improve Nhue River water environment: surface flow wetland model with three species as *Cyperus alterfolious*, *Ipomoea aquatica* Forsk., *Enydra fluctuans* Lour. Appropriate planting time for well growing of aquatic plants, plant- floating bed does not affect much to water flow creating beautiful ecological landscape are also proposed in the model. Biomass after treatment should be encouraged using for biogas or material for gasification. In addition to these aquatic macrophytes, other species such as *Eichhornia crassipes*, *Pistia stratiotes* L. can be used as indigenous aquatic macrophytes that have been shown to be effective in many previous studies.

### **Recommendations**

1. Based on results of this research, it is recommended to use 3 aquatic macrophyte speices: *Cyperus flabelliformis* Rottb, *Ipomoea aquatica* Forsk, *Enydra fluctuans* Lour in model of free - water surface flow wetland to improve Nhue River water quality as follows: Growing *Cyperus flabelliformis* Rottb along Nhue River section from Cau To to Cau Chiec; Growing *Ipomoea aquatica* Forsk in combination with *Enydra fluctuans* Lour along Nhue River section from Cau Chiec to Dong Quan. Combinating growing three speices along river section from Dong Quan to Cong Than.

2. It is necessary to research more about other aquatic macrophyte species in Vietnam and aquatic macrophyte growing widely to purify water in polluted rivers in inner city, industrial region, craft villages.

**LIST OF ARTICLES BY AUTHOR RELATING TO  
THIS DISSERTATION**

1. **Vu Thi Phuong Thao** (2014), “Assessing water quality of Nhue River from headwaters to Cau Chiec” *Journal of Marine Science and Technology*, ISSN: 1859-3097, No 3, Volume 14, 2014, pages 280-289.
2. **Vu Thi Phuong Thao**, Le Xuan Tuan (2014), “Content of some heavy metals in water and in *Impomoea aquatic* collecting from Nhue River”, *International conference on Advances in Mining and tunneling, 10/2014, Vung Tau, Viet nam, Publishing House for Science and Technology*, page 582 – 587.
3. **Vu Thi Phuong Thao**, Le Xuan Tuan, Nguyen Manh Khai (2014), “Status on water pollution of Nhue River, *Journal of Science on Natural Resources and Environment*, No 4, 2014, pages 118-125
4. **Vu Thi Phuong Thao**, Dinh Thai Hung, Do Cao Cuong (2015), “Lead accumulation ability of *Ipomoea aquatic* Forsk. and *Ehydra fluctuans* Lour. collected from Nhue river section from Cau chiec to Cong Than”, *Journal of Science on Natural Resources and Environment*, No 7, 3/2015, pages 24 – 29.
5. **Vu Thi Phuong Thao**, (2015), “Content of some heavy metals in water and in sediment of Nhue River section from Cau To to Cong Than”, *Journal Natural Resources and Environment*, ISSN 1859- 1477, No 24 (230), pages 30 – 32.
6. **Vu Thi Phuong Thao**, Nguyen Manh Khai, Tran Thi Kim Ha (2016), “Effect of using *Cyperus alternifolius* to improve water quality of Nhue river”. *International conference on Earth Sciences and sustainable Geo- resource Development. 11/2016, Hanoi, Vietnam. Transport publishing House*, pages 105 – 109.