АЭТЕРНА
НАУЧНО-ИЗДАТЕЛЬСКИЙ ЦЕНТР

ISSN 2541-8076

№ 4-1/2023

НАУЧНЫЙ

ЭЛЕКТРОННЫЙ

ЖУРНАЛ

Академическая Публицистика

НАУЧНЫЙ ЭЛЕКТРОННЫЙ ЖУРНАЛ «АКАДЕМИЧЕСКАЯ ПУБЛИЦИСТИКА»

ISSN 2541-8076

Учредитель, издатель и редакция
научного электронного журнала
«Академическая публицистика»:
Общество с ограниченной ответственностью «Аэтерна»
450057, г. Уфа, ул. Пушкина 120
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Верстка / корректура: Мартиросян О.В. / Некрасова Е.В.

Подписано для публикации на сайте
https://aeterna-ufa.ru
11.04.2023 г.

Формат 60x90/8.
Усл. печ. л. 39.50.

Электронные текстовые данные (6,26 Мб).

Цена свободная.
Распространяется по подписке.

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ГЕОЛОГО-МИНЕРАЛОГИЧЕСКИЕ НАУКИ

УДК 574

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THE EFFECTIVENESS OF UPFLOW SLUDGE BLANKET FILTRATION – USBF TECHNOLOGY FOR TO LICH RIVER WATER TREATMENT IN HANOI, VIETNAM

Abstract

This paper reports the results of applying Upflow Sludge Blanket Filtration - USBF technology to treat Tolich river in Hanoi, Vietnam. The system was operated continuously for 31 days with HRT of 10h, the average MLSS content in the anoxic compartment reached 3794 mg/L, and 2769 mg/L in the aerotic compartment respectively. The microorganisms grew very well and stably, thus this content is relevant for the removal of pollutants in Tolich river. The biological sludge in the aerobic compartment during the treatment process had the highest SVI value of 126 and the lowest value of 49 mg/g. The removal efficiency for TSS was from 90.83 to 98.06%; COD was 88.4 – 96.1%; NH_4^+-N was 78.30 – 92.85%; PO_4^{3-}-P was 77.09-87.42%. The content of pollutants such as TSS, COD, NH_4^+, PO_4^{3-} after treatment by the USBF system was much lower than National technical regulation - QCVN 08:2015 - BTNMT. Generally, the USBF technology is a possible option to apply to treatment of the To Lich river in Hanoi in particular and rivers in other large urban areas in Vietnam in general, in order to bring environmental purity to the community, and other major cities in Vietnam.

Keywords

COD, TSS, amonium, phosphor, treatment, USBF.

1. Introduction

To Lich River is a small river, flowing from West Lake, passing through 6 districts of Hanoi and discharged into Nhue River. To Lich River not only creates the landscape of the city, but also carries out waste water to processed plants. Currently, To Lich river water is heavily polluted with complex wastewater components and properties, mainly organic substances, nitrogen compounds, phosphorus compounds, pathogenic bacteria, heavy metals, causing strong odors, black, effervescent water, affecting the landscape, aquatic animals as well as the landscape, environment and people's lives around the To Lich River.

Facing with the fact that the To Lich River has been heavily polluted, for many years, the authorities have struggled to find relevant solutions to revive the Tolich River such as: using SBR (Mello 2019; Aboodi et al. 2017), AAO, Constructed Wetland technologies (Rahman et al. 2020; Omondi and Navalia 2020)... however, each technology has its advantages and disadvantages. And the main disadvantage is that it is not consistent with reality in Hanoi.

The basic activated sludge process combined with an anoxic process and suspended sludge settling in a biological treatment plant has been enhanced by Bio-USBF (Up-flow Sludge Blanket Filtration). It takes up less space and related equipment as a combined system. The USBF technique is based on the upflow sludge blanket clarifier concept. The wastewater travels from the bottom of the settling tank through a specifically constructed partition system where the hydro flocculation process occurs after being disturbed in this compartment, which has a trapezoidal form. The trapezoidal clarifier maintains a constant flow rate from bottom to top of the sump, allowing for a progressive decrease in velocity gradient (Mesdaghinia et al. 2010).

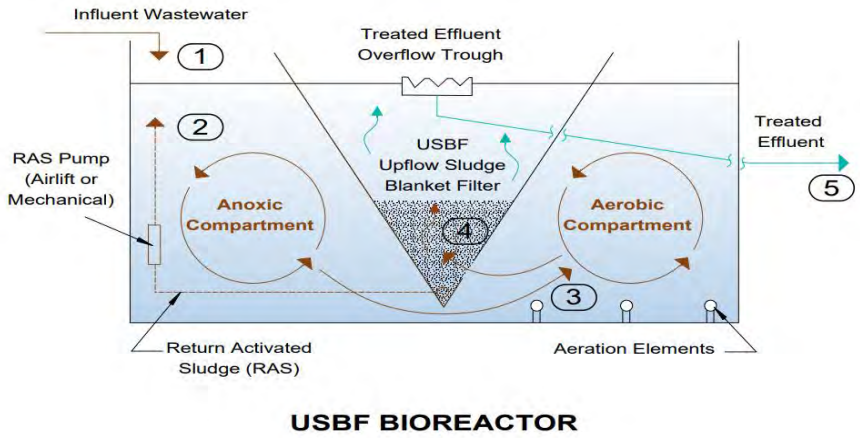

Figure 1 – Diagram of USBF technology (Mesdaghinia et al. 2010)

The tank is designed to remove COD, BOD, and nutrient removal (N and P). All biological treatment and sludge separation processes are provided within the compact integrated biological reactor (IBR). The IBR contains three consecutive biological zones:

A. denitrification zone or anoxic zone

B. nitrification zone or aeration zone

C. anaerobic zone or separation zone

Anaerobic and denitrification zones are mixed by mechanical mixers, in the nitrification zone is a fine-bubble aeration system with very high oxygen transfer efficiency providing the oxygen delivery and mixing. The pressure air for aeration is provided by blowers.

The USBF separator is build-in in nitrification zone and provides the outflow of treated water. The separated sludge from USBF separator together with nitrates from nitrification zone is recirculated into the denitrification zone, and the mixed liquor from the end of denitrification zone is recirculated to the anaerobic zone. The wastewater inflows into anaerobic zone where it meets with activated sludge recirculated from the denitrification zone. The phosphorus accumulating organisms in activated sludge take in anaerobic conditions some substances from wastewater and release some accumulated phosphorus.

The mixed liquor from anaerobic zone then flows into denitrification zone, where facultative aerobic organisms in activated sludge are taking the oxygen from recirculated nitrates for oxidation and consumption of some substances from wastewater. By this process, nitrates are converted to gaseous nitrogen, which is released to air, and it thus reduces the concentration of total nitrogen in water. The mixed liquor from denitrification zone then flows to nitrification zone, where proceeds the oxidation and consumption of remaining organic substances from wastewater and ammonium is oxidized by nitrification bacteria to nitrates, which are then recirculated to denitrification as described above. The phosphorus accumulating organisms there due to proceeding phosphorus release take in presence of oxygen surplus of phosphorus and convert it to deposited polyphosphates, which results in biological dephosphorization.

USBF technology is a technology that has not been widely disseminated in Vietnam, the system is compact in size, easy to install, convenient, with high processing efficiency, suitable for crowded urban areas where there limited area.

2. Materials and Methods

2.1. Cultivation of enrichment cultures of microorganisms

2.1.1. *Aerobic microbial enrichment culture*

Aerobic microorganisms were obtained from biological sludge in the aerobic biological treatment tank of the wastewater treatment system. The sludge was centrifuged cold at 4°C at 8500 rpm for 15 minutes. After pretreatment, aerobic bacteria were cultured enriched in the following enrichment cultures: Weigh 200 g of dewatered sludge into a 1L DURAN®-Flaschen culture flask (Schott, Mainz), supplemented 800 ml of nutrient solution (according to ATCC medium 1490) was placed in the flask and then mixed with air at a rate of 1 Ln/L/min continuously for 20 days, at room temperature (25-30°C). In the process of microbial enrichment culture, after 2 to 3 days, add nutrient solution by settling the microbial solution for 30 to 60 minutes, decant clear water, add nutrient solution. and continue to inject air into the tank.

2.1.2. Anaerobic microbial enrichment culture

Anaerobic microorganisms were obtained from biological sludge in the anaerobic biological treatment tank of the wastewater treatment system. The sludge was centrifuged cold at 4°C at 8500 rpm for 15 minutes. After pretreatment, bacteria were cultured enriched in the following enrichment cultures: Weigh 200g of dewatered sludge into a 1L DURAN®-Flaschen culture flask (Schott, Mainz), supplemented with 800 ml of nutrient solution (Andreas O. Wagner et al. 2019), aerate N_2 into the flask for 10 minutes to expel all dissolved oxygen in the solution. Then, install a stirrer with an impeller to stir the solution at a constant speed of 50 rpm at room temperature (25-30°C). Nutrient solution is added regularly (2-3 days once). Anaerobic microorganisms were cultured and enriched continuously for 20 days.

2.1.3. Microbial adaptive culture in the USBF system

Before operating the system, the enriched cultured microorganisms are put into the anaerobic and aerobic compartments of the system so that the microorganisms can adapt and grow accordingly as follows:

Aerobic microorganisms after enrichment culture are put into the aerobic compartment, anaerobic microorganisms after enrichment culture are put into the anaerobic compartment of the treatment system, both microorganisms are mixed. Dilute with To Lich river water with the concentration of MLSS about 2500 - 4000 mg/L and continue to culture, acclimatise in anaerobic and aerobic environment of the treatment system with a retention time of 24 hours for 53 consecutive days. During the culture process, measure the increased biomass by determining the MLSS index.

2.2. Characteristics of To Lich river water

To Lich river water used in the study was taken at the area of Hoang Quoc Viet bridge, with the content of some main components as follows: pH: 7.28 - 7.84; COD: 123 - 143.9 mg/L; TSS: 67-113 mg/L; NH_4^+-N: 10.30 - 29.50 mg/L; Ntot: 28.72 - 30.51 mg/L; NO_3^--N: 3.13 - 3.84 mg/L; PO_4^{3-}-P: 2.68 - 5.26 mg/L;

2.3. Experimental set up

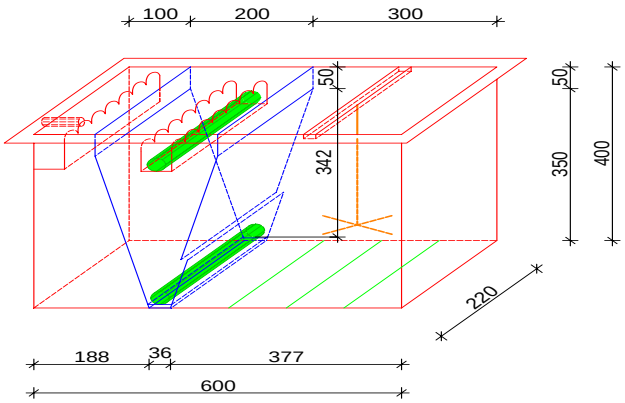

Figure 1 – Scheme of the USBF system

The system is made of stainless steel, with a length of 60 cm, a width of 30 cm and a height of 40 cm with a processing capacity Q = 140 l/d. The inside is designed into 3 compartments including: Anoxic compartment (HRT: 2.2h), aerobic compartment (HRT: (6h) and USBF compartment (HRT: 1.8h). In the anaerobic and aerobic compartments, two stirrers are installed with blades of 8 cm long, and 1.5 cm wide, and they are operated continuously at a speed of 60 rpm to stir. evenly throughout the system operation. The aerobic compartment is installed with an aeration system with an air distribution rig that is 3 silicon rods, each 20 cm long, the distance between the bars is 10 cm, fixed at the bottom of the aerobic compartment connected to the air compressor, aims to provide oxygen to aerobic microorganisms at a rate of 13 (m^3/h).

To Lich river water is continuously pumped into the anaerobic compartment with a flow of Q = 5.9 l/h. Water, after passing through the anaerobic compartment, continues through the aerobic compartment and then into the USBF compartment, then through the serrated trough to collect water on the surface of the compartment, then is taken out by a one-way valve, the wastewater is treated after treatment. is stored in a plastic tank containing the outlet water.

During operation, the amount of sludge in the USBF compartment is automatically brought back to the anoxic chamber by the sludge circulation pump, with a cycle of 2 hours, and the sludge circulation pump once in 15 minutes.

The system was operated continuously for 1 month from October 8, 2021 to November 8, 2022 and are operated with a retention time of 10 hours for the whole system.

2.4. Sampling and Analytical methods

During the microbial enrichment culture period, samples were taken daily to check the SVI and MLSS contents in the anaerobic and aerobic compartments. During To Lichriver water treatment operations, samples are taken at the input and output of the system to evaluate the treatment efficiency of some key parameters such as: TSS, COD, BOD_5, total of P and total of N. Samples were taken daily in anaerobic and aerobic compartments at a depth of 20 cm to determine SVI and MLSS indices to assess the level of microbial activity in the system. The samples were analyzed following the standard methods.

3. Results and discussion

After 1 month of operation for domestic wastewater treatment, the USBF system continued to be used for research and evaluation of the effectiveness of To Lich river water treatment. The system is operated continuously for 31 days and has the HRT of 10 h. The results of studying the efficiency of To Lichriver water treatment by the USBF system are shown in Figures 3 to 8.

The obtained results show that, during the operation of the system with To Lichriver water, the MLSS content in the anoxic and aerotic compartments is quite stable despite the change in inlet wastewater characteristics (See Fig. 3) .

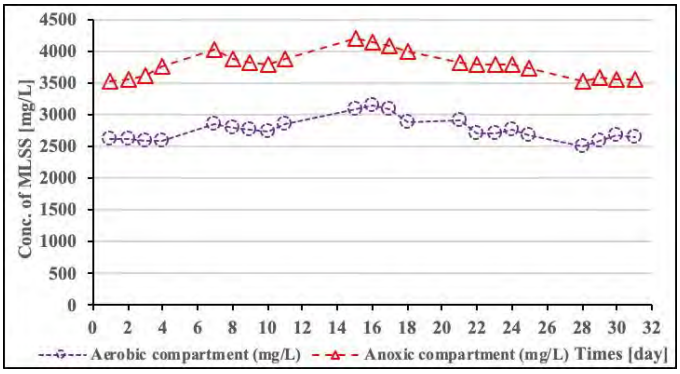

Figure 3 – The MLSS content during To Lichriver water treatment in USBF

The values of MLSS in the anoxic compartment ranged from 3530 to 4191 mg/L (mean 3794 mg/L), and in the aerotic compartment between 2514 and 3147 mg/L (mean 2769 mg/L). It shows that microorganisms in both compartments grow very well and stably and with this content, it is quite suitable for removing pollutants in wastewater. (Toledo-Cervantes et al. 2019).

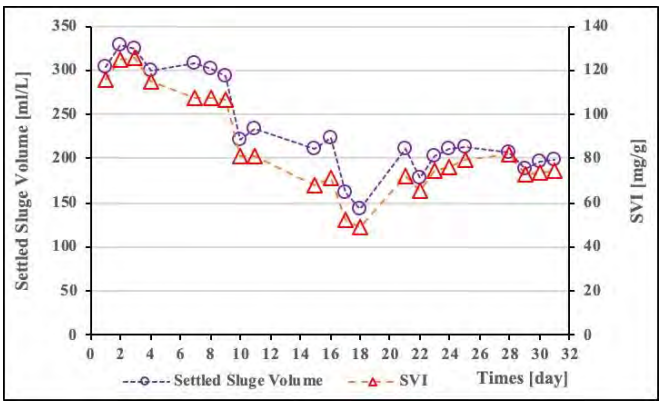

Figure 4 – The SVI change in the aerobic compartment of the USBF system during To Lich river water treatment.

Meanwhile, the SVI index in the aerobic bioreactor of the USBF system tended to decrease from day 2 to day 18, then tended to stabilize after day 21 (See Fig. 4). During the To Lichriver water treatment process, the highest SVI value was 126 and the lowest was 49, which proves that the biological sludge in the aerobic compartment during the To Lichriver water operation has good settling properties. (Cleary and Eckenfelder 2013; Boutchich et al. 2015). This positively affects the removal of suspended solids in the USBF compartment. Although the observed input TSS value fluctuates quite a bit, the output TSS value is quite stable. The TSS value after leaving the system decreased from 67-112 mg/L to 1.3 - 10.6 mg/L (average at the outlet was only 7.17 mg/L), corresponding to the removal efficiency from 90.83 to 90.83 mg/L. 98.06% (See Fig. 5). The observed high TSS removal efficiency of the system for To Lichriver water could be attributed to the low TSS content in the To Lichriver water and the low SVI of the activated sludge. In the USBF system, the high TSS removal efficiency can be attributed to the adsorption of suspended

substances on the bioflocs, on the other hand, the aerobic compartment of the system has a relatively low SVI, so the the suspended solids settling process went very well (Boutchich et al. 2015). In addition, the decomposition of organic compounds by aerobic microorganisms as well as heterotrophic denitrifying bacteria contributes significantly to the decomposition of organic compounds in particular and suspended solids in general (Bothe et al. 2006).

The obtained results show that the USBF system has a high TSS removal efficiency, quite similar to other studies (Salama et al. 2020) and the TSS content after passing through the system is much lower than with QCVN 08/2015 BTNMT.

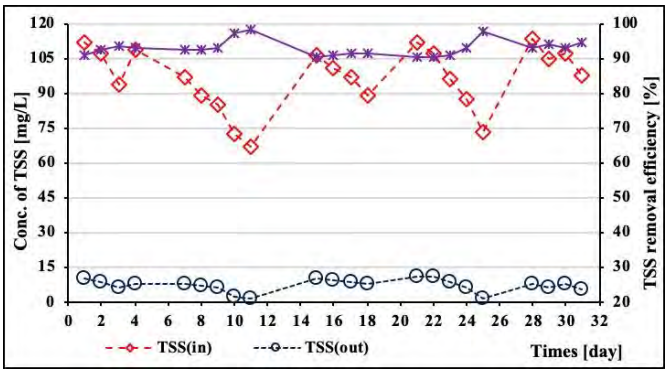

Figure 5 – The TSS removal efficiency of USBF system in To Lichriver water treatment process

For COD because during operation of To Lich river water treatment, its content is observed at low inlet, its value fluctuates in the range of 120-143 mg/L, after passing through the system, the value Its value was reduced to about 4.8-16.6 mg/L (mean 8.1 mg/L), removal efficiency was 88.4 - 96.1% (mean 93.92%) (See fig. 6).

In To Lich river water, the low COD content is partly due to dilution, partly because the biodegradable organic compounds have been partially removed during the migration process, the remaining organic compounds remain. However, thanks to anaerobic and aerobic biological processes as well as upstream filtration of the USBF compartment and low SVI, COD is removed with quite high efficiency (Wang et al. 2014).

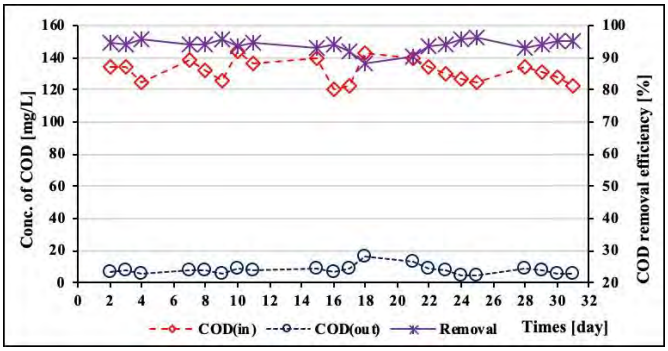

Figure 6 – The COD removal efficiency of USBF system in To Lichriver water treatment

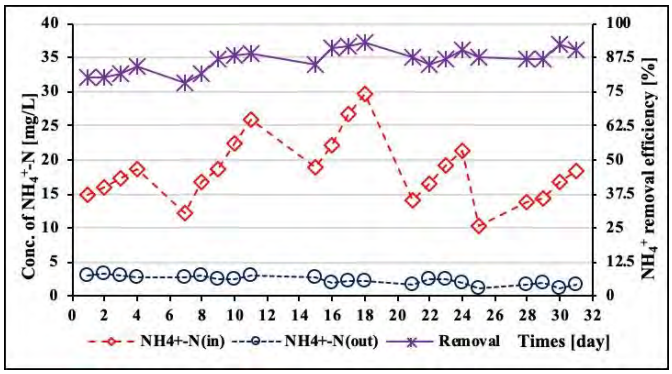

Figure 7 – NH_4^+ removal efficiency of USBF system in To Lichriver water treatment

As for the NH_4^+ indicator, the NH_4^+-N content at the inlet of To Lich river water is low, its value is in the range of 10.25 - 29.55 mg/L and it fluctuates quite strongly, however, after going through the content system, NH_4^+-N decreased to 1.27 – 3.19 mg/L and relatively stable was observed. The treatment efficiency for NH4+-N of the system was 78.30 – 92.85% (average 86.54%) (See fig. 7).

The obtained results show that, during the operation of the USBF system to treat To Lich river water, although the input NH_4^+-N content is low, the NH_4^+ removal efficiency in To Lich river water is not high. The reason may be that when the NH_4^+ content is low, it is more difficult to remove NH_4^+. However, the output water has low NH_4^+-N content if compared with other biological systems, the NH_4^+ removal efficiency in the USBF system is higher and the output NH_4^+ content is more stable (Waqas et al. 2020).

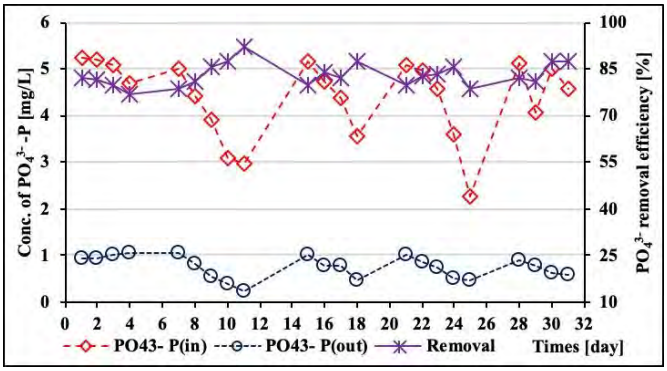

Figure 8 – The PO_4^{3-} removal efficiency of USBF system in To Lichriver water treatment

For Phosphor removal, during the operation of the To Lich river water treatment system, the PO_4^{3-}-P concentration was observed at the inlet low, its value in the range 2.26-5.26 mg/L (average 4.39). mg/L), after passing through the USBF system its value decreased to about 0.24-1.07 mg/L (mean 0.75 mg/L), corresponding to a removal efficiency of 77.09-87.42% (mean). 83.05%) (See fig. 8). The reason may be due to the load of organic compounds, the input nitrogen and phosphorus content in To Lich river water is lower than that of domestic wastewater. Dissolved organic compounds are fermented at Aerobic and Anoxic compartments in To Lichriver water to create products that create a special composition of microorganisms, making them have a lower phosphorus storage capacity, thus their removal efficiency is lower (Bunce et al. 2018; Khorsandi et al. 2011). However, the content of P in the output water is lower than National technical regulation - QCVN 08/2015 BTNMT.

4. Conclusions

Since To Lich river water is the main reservoir of domestic wastewater from surrounding households, it has similar characteristics to domestic wastewater but with lower concentrations of pollutants. A number of pollution indicators present in To Lichriver water after being treated with the USBF system is significantly reduced, specifically: The SVI index is also lower than in the domestic wastewater treatment process, thereby helping the process Better suspended solids settling; TSS content is 1.3 – 10.6 mg/L (average output is only 7.17 mg/L); COD remains 4.8-16.6 mg/L (average is

8.1 mg/L); NH_4^+-N to 1.27 – 3.19 mg/L and PO_4^{3-} -P to 0.24-1.07 mg/L (mean 0.75 mg/L). Experimental results show that using the USBF system to treat To Lich river water can meet the criteria of surface water according to the allowed standards of Vietnam, it is an appropriate choice both economically and technology to treat To Lich river water, contributing to reducing environmental pollution in Hanoi city, preserving the urban landscape of Hanoi.

Acknowledment

The authors would like to sincerely thank the Institute of Biotechnology - Institute of Environmental Technology, Vietnam Academy of Sciences; Center for Environmental Treatment - Military Institute of Science and Technology; Department of Chemistry – Faculty of Basic Sciences – University of Mining - Geology has facilitated and support in the research process.

Authors' contributions

Nam Nguyen Hoang: makes an important contribution in proposing ideas and designing research; checks data; data processing; examines the knowledge content of the article; the ratification of the final draft before submitting it to the scientific journal. Ngoc Tran Thi: makes an important contribution in proposing ideas and designing research; checks data; data processing; seriously examines the knowledge content of the article; the ratification of the final draft before submitting it to the scientific journal. Dung Nguyen Hoang: makes contribution in experiment implementation, data collection, data analysis and translation; has contributed to the drafting of the article.

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