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Research on brewery wastewater treatment by lab scale constructed wetlands

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Abstract: Along with the development of the industry in Vietnam, the beery industry has contributed greatly to the state budget and creating jobs for labours. However, beer wastewater contains high organic matter, some wastewater discharged parameters such as BOD, COD, Nitrogen, Phosphorus, etc. usually exceed the permitted standards. Based on the above practice, the research was conducted to evaluate the effectiveness of the horizontal flow wetland model, laboratory scale with organic loading rate varying from 20, 40, 60, 80, 100, 120 kg COD/ha.day. The results show that the concentration of pollutants in the effluent can reach QCVN 40: 2011/BTNMT, column A, before discharged into the environment.

Keywords: Brewery wastewater; Constructed wetland; Horizontal flow wetland.

1. Introduction

Nowadays, the demand for beer is increasing day by day. The growth of the beer industry contributes to increasing products for society, serving people's lives, but on the other hand, it also entails the problem of production waste, especially, wastewater with high concentration of pollution poses a serious threat to the environment [1]. The beer wastewater contains a large number of suspended substances, COD and BOD and high acid content that needs to be treated before being discharged into the receiving water source [2–9]. All organics present in brewery wastewater are easy biodegradable. High BOD/COD ratio ranging from 1.5–2.0 is suitable for biological treatment [9–11].

Biological treatment by microalgae (*Dunalilla*) has reduced the organic matter content in wastewater [12]. The treatment of brewery wastewater through anaerobic AHR tank and aerobic system removed COD with 75%–97% efficiency [13–14]. A brewery (in NSW) [15] will undergo a number of pre–treatments, then enter the GWE ANUBIX–B anaerobic tank, where the COD content is treated by bacteria to reduce the organic matter concentration. At a traditional brewery in the city of Harare [16], the research evaluated the performance of the UASB tank in beer wastewater treatment. After 2 years of research, it was found that the use of the UASB can make the treated wastewater quality meet local requirements. Indicator of COD decreased by 57%, TSS and SS also decreased by 50% and 90%, respectively.

In Vietnam, breweries often use anaerobic, aerobic and reverse osmosis treatment methods to provide better removal efficiency [1–3, 11]. The combination of anaerobic treatment with aerobic treatment can remove 90–98% the high concentration of COD in brewery wastewater [3, 11].

In the process of industrialization and modernization, sustainable economic development and environmental protection are always concerned. The environmentally friendly treatment of industrial wastewater contributes directly or indirectly to the sustainable development of a country. To that end, biological processes are considered to play a major role. Bioremediation uses beneficial microorganisms [17–19] and plants [20–23] to degrade, reduce or detoxify pollutants.

Wetland wastewater treatment model is a method with many advantages, especially it is very suitable for Vietnamese conditions due to low construction and operating costs [20–23]. Mechanisms of wastewater treatment of wetlands include sedimentation, precipitation, chemisorption, microbial metabolism, and plant uptake [11]. Pollutants can be removed by multiple mechanisms simultaneously in the system. Many studies show that wetlands have the ability to treat wastewater with high concentration of nutrients such as domestic wastewater, industrial wastewater, agricultural wastewater, leachate... [24–28]. A study [25] in 2014 treated turbidity, DO, BOD_5, TP, TN very effectively with the average treatment efficiency of 94%, 86%, 80%, 88%, and 94%, respectyvly The research [26] conducted in 2018 with leachate after being biologically treated with a COD concentration of 575 mg/l passing through the wetland system, the BOD_5 treatment efficiency reached 96.48%, COD 83.24%, total N 91.43%, total P 77.84%, NH_4^+ 86.47%, color 87.91%. The wetland model of [28] was carried out to evaluate the growth and absorption of nitrogen and phosphorus added in the wastewater of intensive farming ponds of catfish using *Hymenachne acutigluma* with treatment efficiency TN, TP reached 80–84.8% and 93.3–95.6%, respectively.

Brewery wastewater contains high organic composition, wide pH range, remarkable TSS, Nitrogen, Phosphorus, Coliform content. When using traditional wastewater treatment technologies, it often costs a lot to invest in construction, chemicals as well as operation and maintenance. Many research works on constructed wetland technology show that this technology is completely in harmony with nature, does not generate a lot of secondary waste, has low investment costs, treat many types of wastewater from low to high loads, using a variety of available, easy–to–find natural plants. This technology can also handle nutrients (Nitrogen, Phosphorus). Plants after treatment from constructed wetlands can be used for different purposes such as forage, improving the local landscape.

In addition, *Colocasia esculenta* and *Caladium bicolor* are easy to find plants and has suitable characteristics for water purification such as growing well in flooded, polluted environments and having strong roots [29]. Therefore, this study evaluates the treatment efficiency of COD, TN, TP, TSS, Coliform of the horizontal-flow constructed wetland model at different loads with *Colocasia esculenta* and *Caladium bicolor*.

2. Materials and Methods

2.1. Objects, scope of research

Objects: Brewery wastewater of Heineken, laboratory model of constructed wetland with *Colocasia esculenta* and *Caladium bicolor*.

Scope: Laboratory scale.

2.2. Model

Laboratory scale of horizontal flow wetland model is made of 10mm thick glass. There are 3 models including:

- Blank model (without growing aquatic plants) – (BL)
- Model of planting *Colocasia esculenta* – (CE)
- Model of planting *Caladium bicolor* – (CB)

All 3 models are designed with the same tank size: length x width x height = 2.0m × 0.6m × 0.5m, length: width ratio is 3: 1 [30]. The bottom of the tank is arranged with a slope of 1% to ensure that the treated wastewater is completely collected [31]. The model has an external stainless-steel frame to increase the bearing capacity of the tank. On the side of the tank, there is an outlet pipe with a diameter of 27 mm that brings the effluent out.

Each model consists of 3 layers of materials arranged in a certain sequence [24, 29]:

- The top layer is a layer of fine sand with a diameter of 1–2 mm and a layer of soil with a total height of 150 mm. This layer of material is responsible for the main environment for plant roots to attach and develop.

- The middle layer is a layer of round gravel with a diameter of 5–10 mm, the height of this layer is 150 mm. The main task of gravel is to serve as a substrate for microorganisms to attach and grow, and a support layer for the fine sand layer and the upper soil layer.

- The bottom layer is a 10×20 mm rock layer, 100 mm high. The main task of the rock layer is to serve as a substrate for microorganisms to attach and grow, and at the same time a support layer for the gravel, fine sand and the upper soil layer.

The model of planting *Colocasia esculenta* and the model of planting *Caladium bicolor* are arranged in 2 different tanks, in continuous process, in natural conditions and started at the same time, following the operation parameters in Table 1.

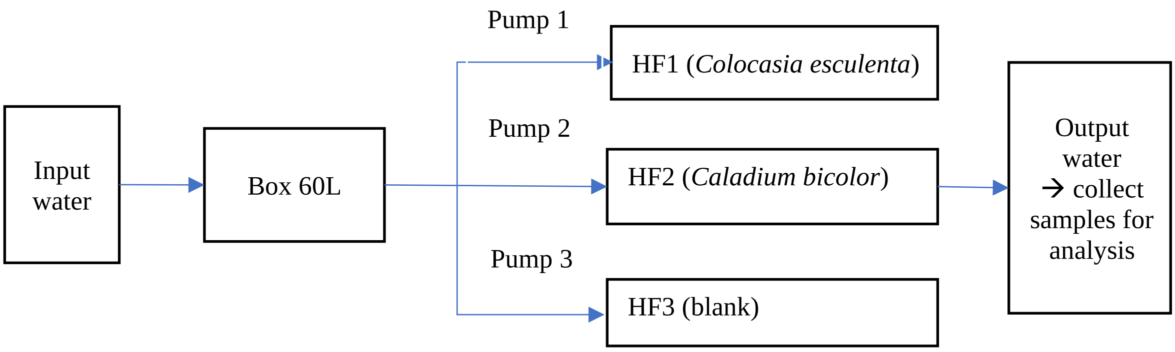

Figure 1. Experimental layout diagram.

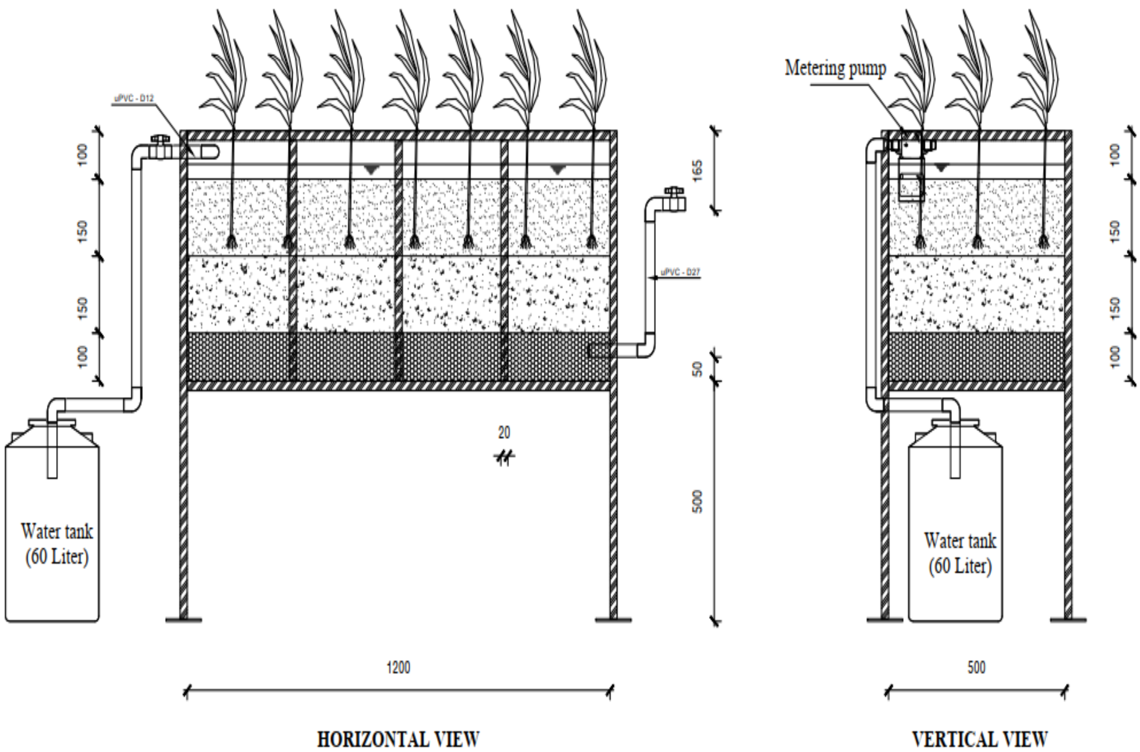

Figure 2. Research models.

Table 1. The operation parameters of 2 model.

No.	Organic loading rate (OLR) (kgCOD/ha.day)	Influent flowrate Q (L/day)	Hydraulic Retention time (day)
1	20	7,6	18
2	40	15,2	9
3	60	22,8	6
4	80	30,4	4.5
5	100	38,0	3.6
6	120	45,6	3

3. Results and Discussion

3.1. The variation of pH value in models

The pH value in the effluent of all 3 models ranged from 6.8–7.6 (7.1 ± 0.2) for the blank model, 7.0–7.8 (7.4 ± 0.19) for the CB model and 7.0–7.7 (7.3 ± 0.2) for CE model. In general, the pH value fluctuated around neutral values (7.1–7.4) that can meet column A of QCVN 40:2011/BTNMT (pH = 6–9) and suitable for plant growth (Figure 3).

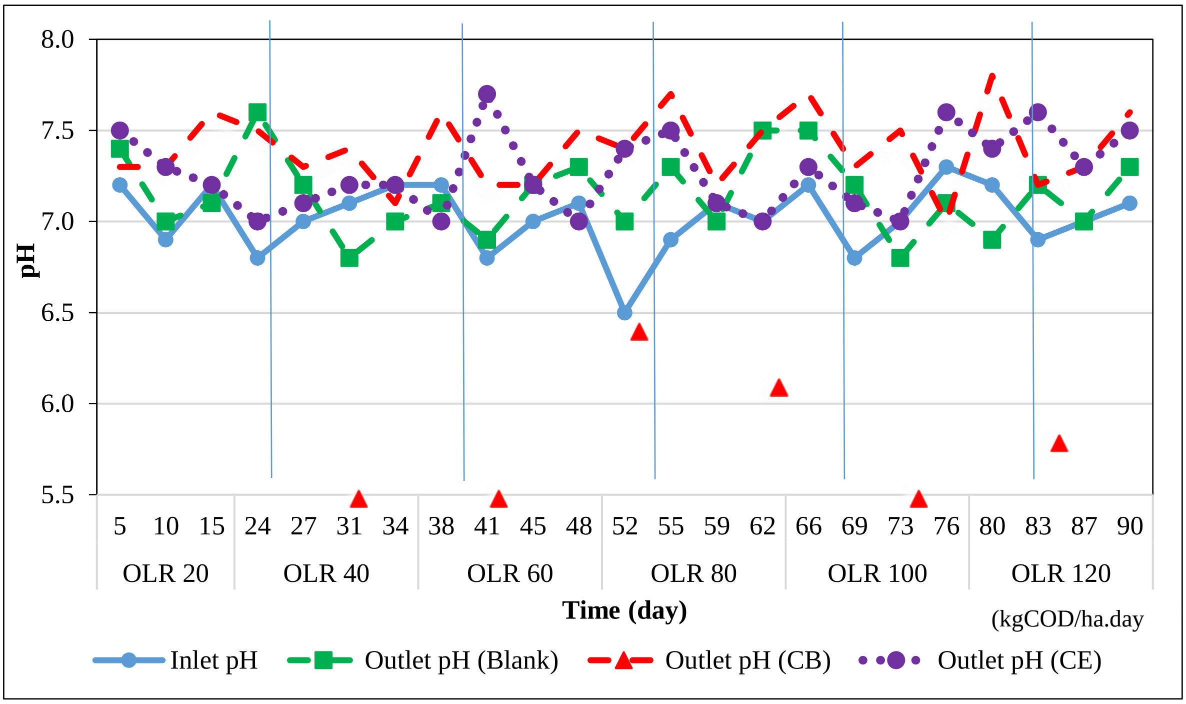

Figure 3. Variation of pH value during experiment.

3.2. The variation of COD removal efficiency

Figure 4 shows that the highest COD treatment efficiency of the model is 85% (CB model), 84% (CE model) compared to the blank model, only 29%. COD treatment efficiency increase steadily through the loads and reached at the highest efficiency at organic load of 80 kg COD/ha.day for *Caladium bicolor* and at 100 kg COD/ha.day for *Colocasia esculenta*. The reason are quickly growth of plants and microorganisms leading to increase the absorption organic matter. Compared with QCVN 40:2008/MONRE, the effluent COD concentrations of both planting models can meet the standard and the blank model is not. This result is quite similar to the research results of [29] but is lower than the research of [31], the COD removal efficiency can reach 95% when using *Canna hybrids*.

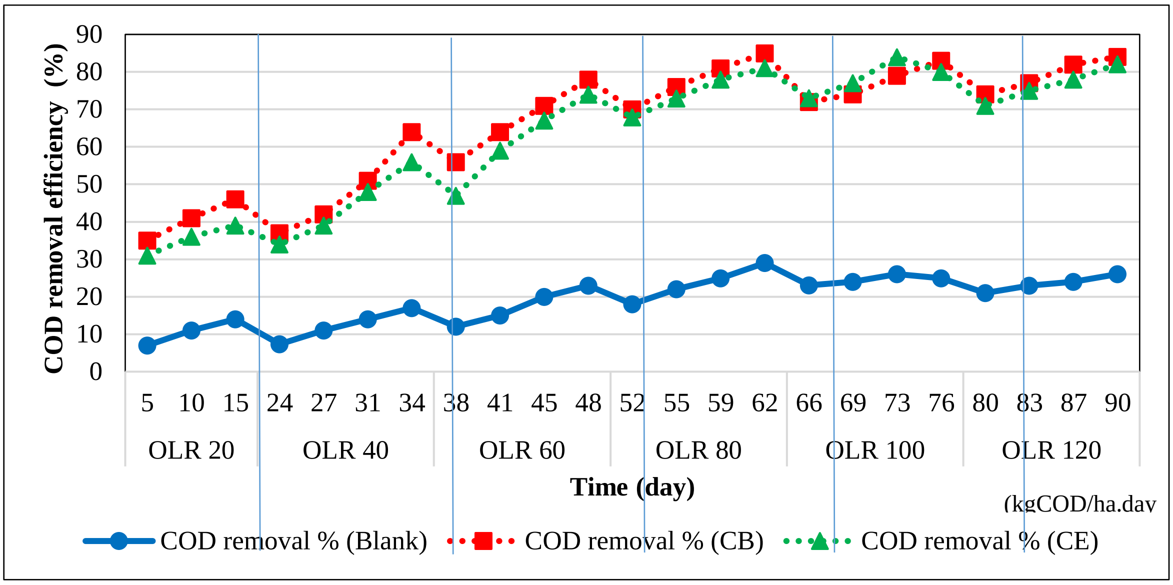

Figure 4. Variation of COD treatment efficiency at different loads.

3.3. The variation of TSS values

In the loading period of 60–80 kg COD/ha.day, TSS concentration in the influent fluctuates in the range of 119.2–143.8 mg/L, but TSS concentration of effluent ranges from 14–47 mg/L (CB model) and 13–44 mg/L (CE model) compared with 61–97 mg/L (blank model). The results of TSS values of the CB, CE model can meet the standards of QCVN 40: 2011/MONRE. The TSS removal efficiency was highest for the CB model (89.2%) and the CE model (88.4%) and compared with the blank model (48.6%). This result is quite similar to the other results, the TSS removal efficiency is from 47%–96% [29] and 88–92% [31], respectively.

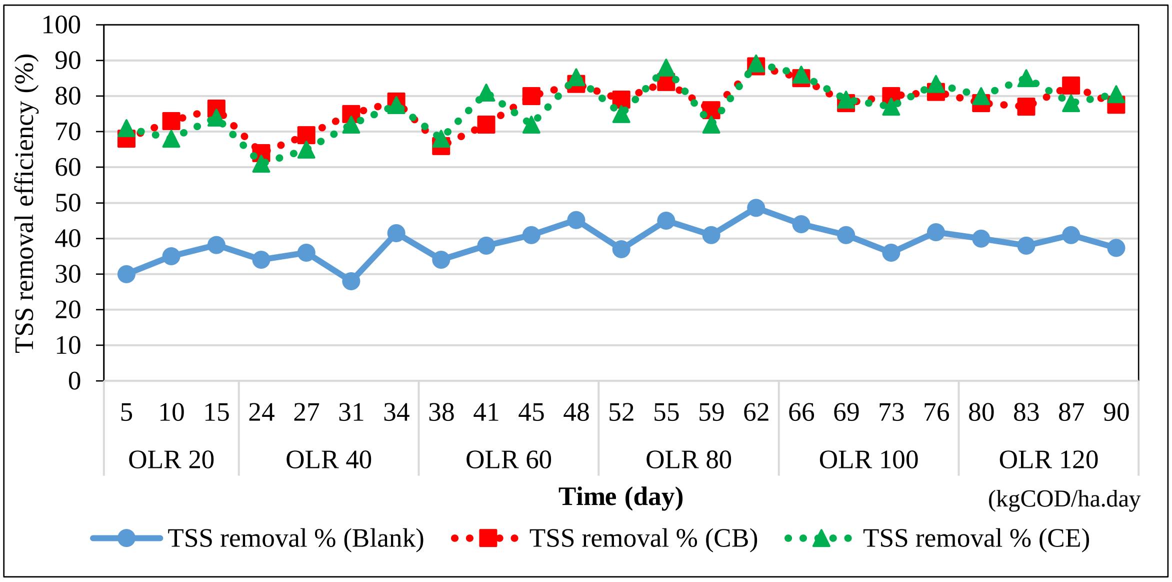

Figure 5. Variation of TSS values in wastewater at different loads.

3.4. The variation of Total Nitrogen (TN) removal efficiency

After 90 days of model operation, *Caladium bicolor* and *Colocasia esculenta* grew in height, body size and especially the roots, so that the microflora developed strongly. The highest TN treatment efficiency is 75% (*Colocasia esculenta*); 72% (*Caladium bicolor*), compared with the blank model 29%. For the blank model, due to the concentration of microorganisms attached to the filter material, the TN removal efficiency is lower. At loads of 80 kg COD/ha.day and 100 kg COD/ha.day those are the period of strong growth plant combined with more nitrifying and denitrifying microorganisms, the concentration of TN is mainly reduced due to nitrification and denitrification process. The TN values in the effluent of two planting models reached at QCVN 14:2008/MONRE, column A. This removal efficiency is lower than the results of [29], but is higher than the results of [31]: the TN removal efficiency is around 70%.

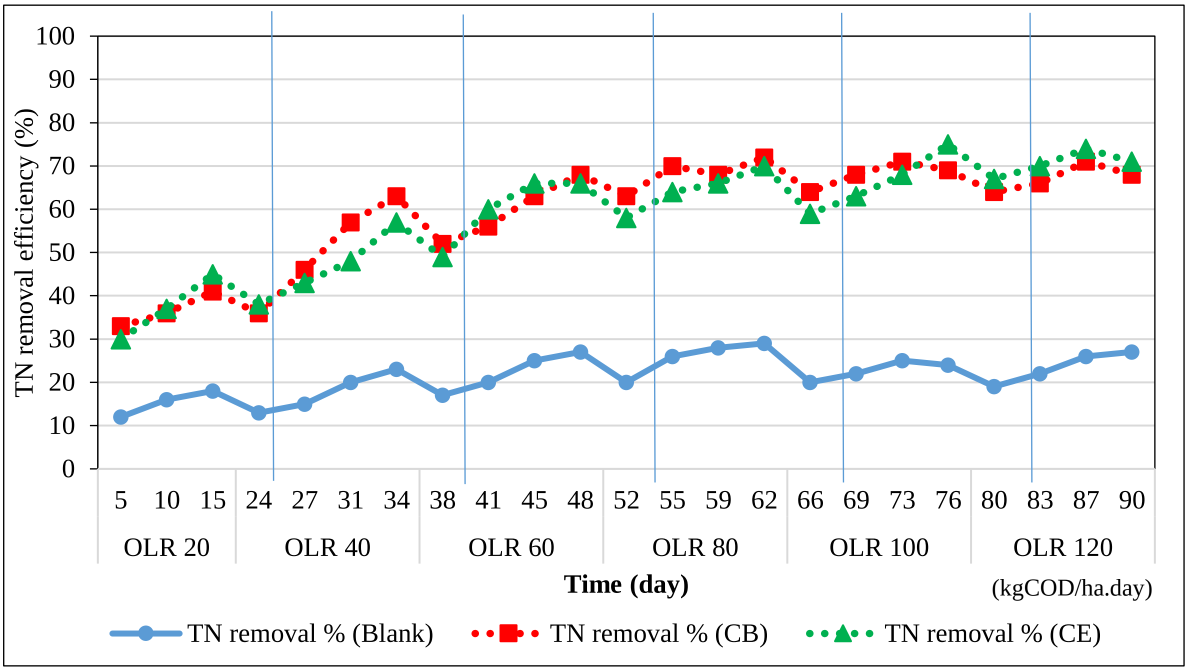

Figure 6. Variation of TN treatment efficiency at different loads.

3.5. The variation of Total Phosphorous (TP) removal efficiency

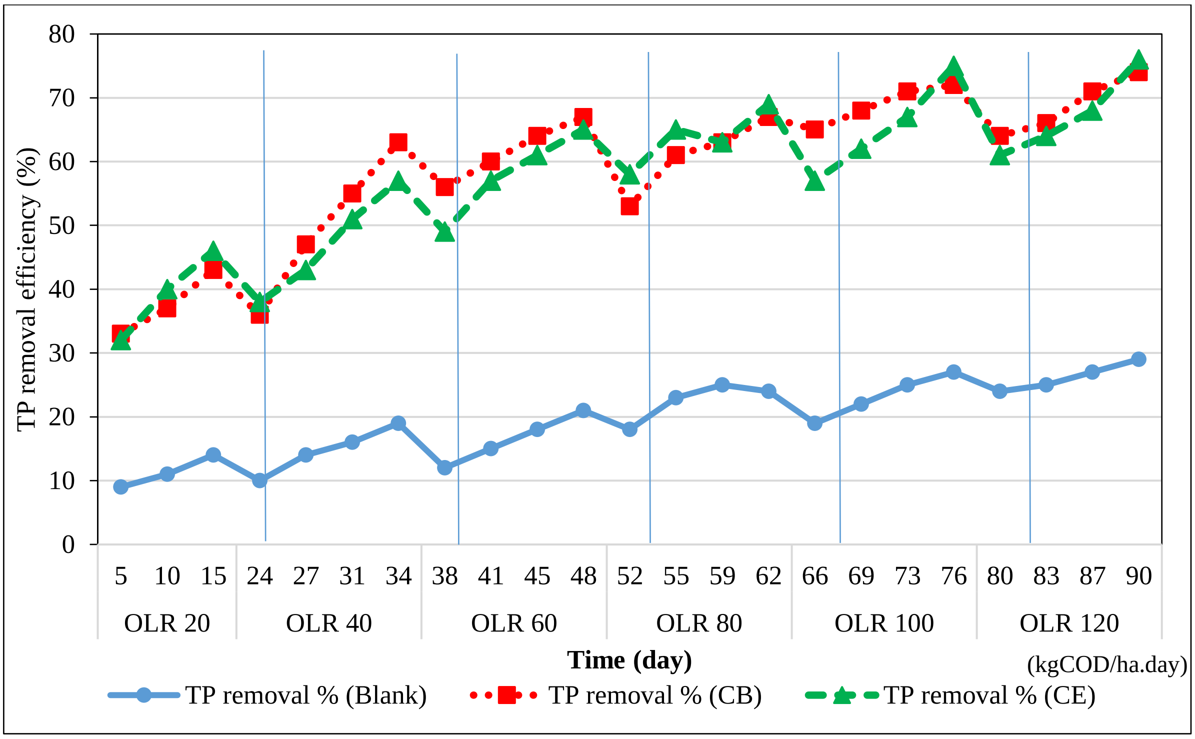

Figure 7. Variation of TP removal efficiency at different loads.

In general, TP treatment efficiency tends to increase with sampling times, the highest efficiency is 76% (*Colocasia esculenta*) and 74% (*Caladium bicolor*) and only about 29% compared to the blank model. The results are similar with the result of [21] treatment brewery wastewater with *Typha latifolia.*

Phosphorus is well reduced in the model by adsorbed by the roots and by adsorbent media. At the same time, the absorption and settling mechanism is enhanced by the mineral content in the filter material. They also use phosphorus as a substrate in the system.

Comparing the total phosphorus concentration in effluent using *Caladium bicolor* and *Colocasia esculenta* with those of QCVN 40:2011/MONRE, both achieved column A.

3.6. The variation of Coliform value

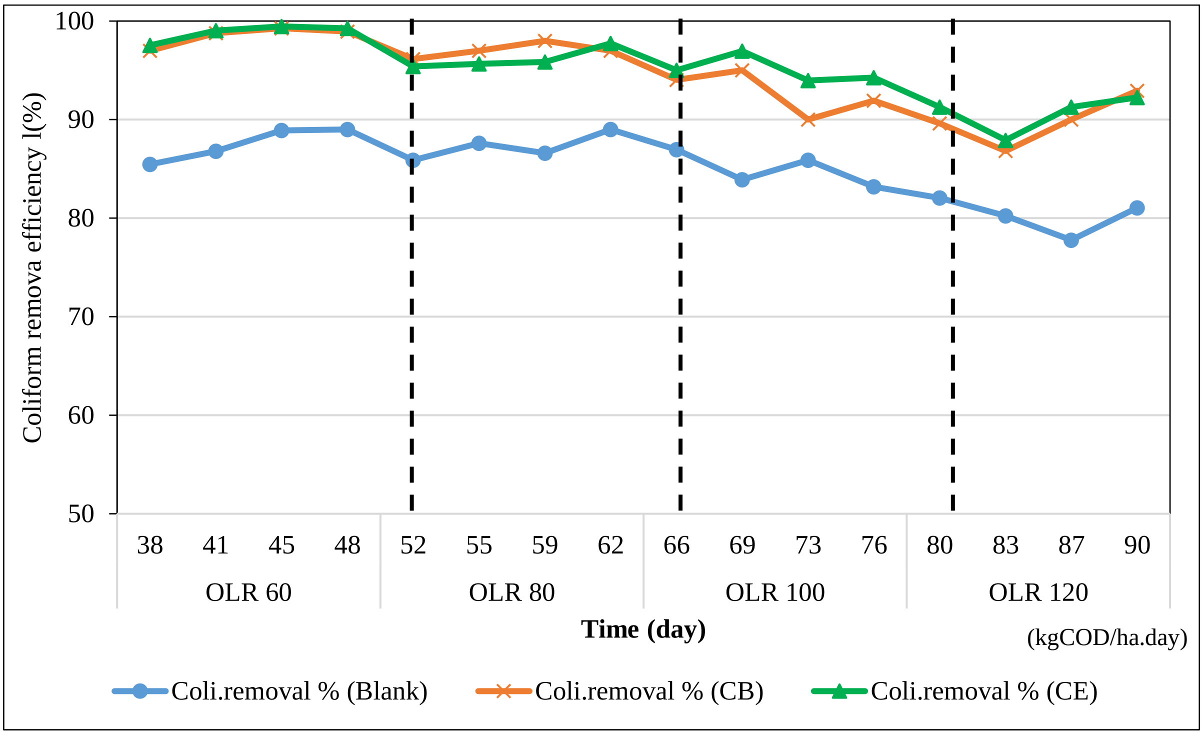

Figure 8. Variation of Coliform treatment efficiency at different loads.

The total Coliform removal efficiency of the wetland model for the *Caladium bicolor* model is 87–99%, the *Colocasia esculenta* model is 88–99% compared to the blank model is 78–89%. In general, the total Coliform removal efficiency of the wetland model gradually decreased when operating at higher organic loads because the retention time at high loads was shorter than before. The effluent Coliform concentration of both planting models can meet the QCVN 40: 2011/MONRE (column A).

The average treatment efficiency (95%) to remove Coliform in this experiment is also consistent with the study [29], the total Coliform efficiency is high and low volatility, stable in the range of 94% to 99%.

3.7. Plant growth process

During operation time, the growth indexes such as the number of branches, tree height, tree body size, etc. all increased fairly at different loads. This is a good sign that shows the plant's adaptation and growth in the actual wastewater and has good treatment capacity.

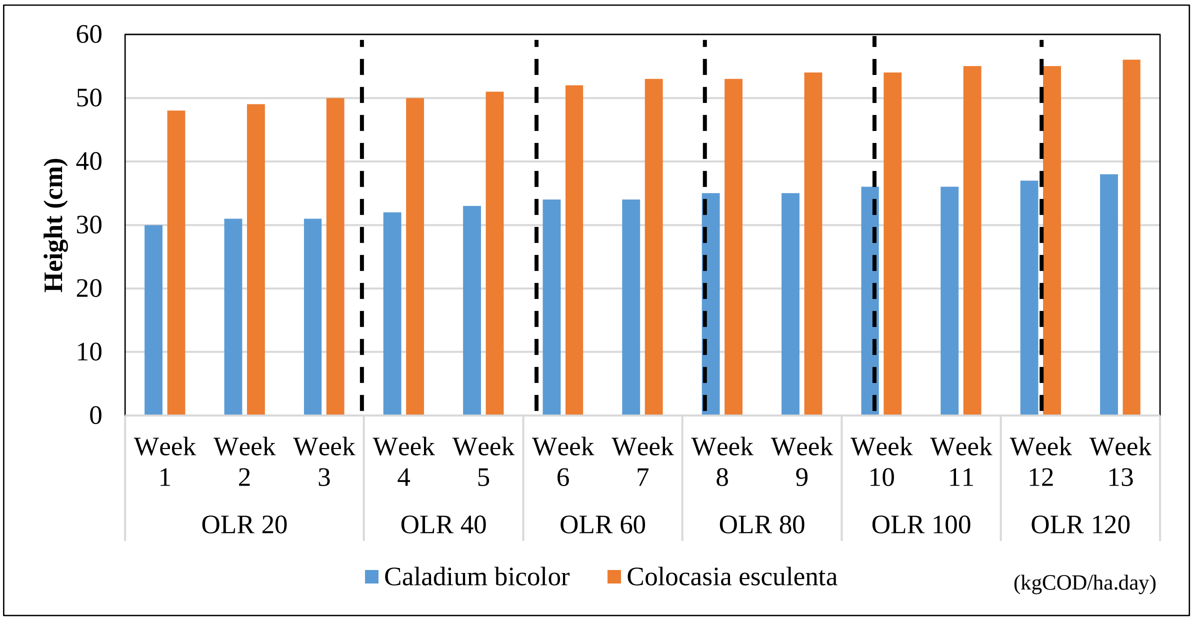

Figure 9. Tree height growth chart

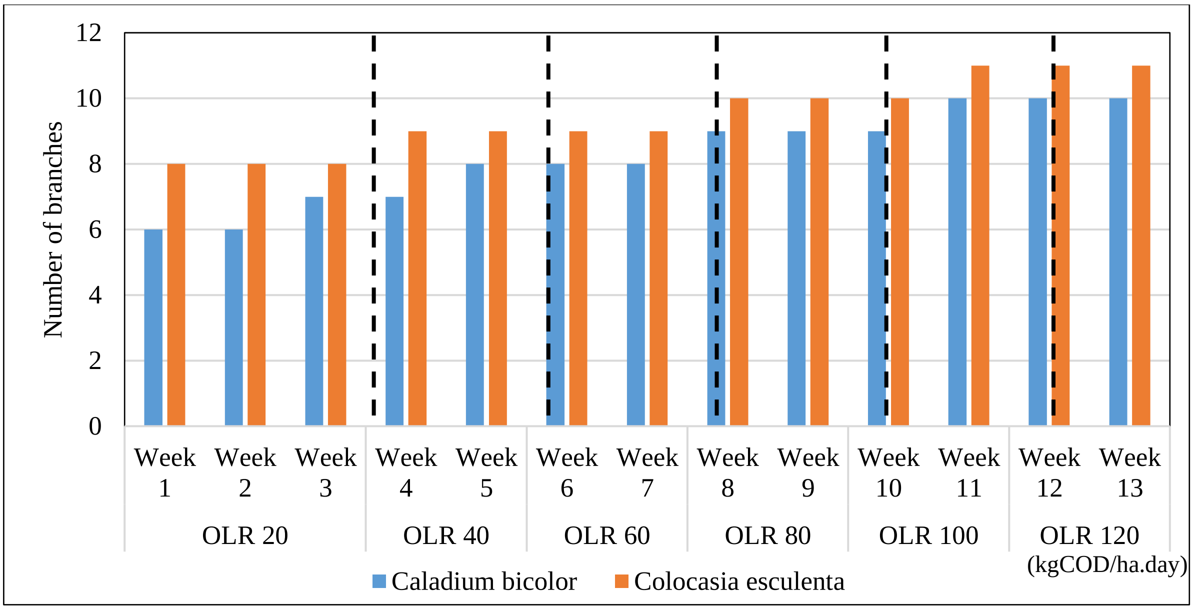

Figure 10. The growth chart of the number of branches

4. Conclusions

The number of pollutants in the brewery wastewater after treatment by constructed wetland has been significantly reduced. Treatment efficiency was highest at 80 kg COD/ha.day for the *Caladium bicolor* and 100 kg COD/ha.day for the *Colocasia esculenta*. Specific treatment efficiency is as follow: COD 84–85%, TSS 88–89%, TN 72–75%, TP 74–76% and total coliform > 90%. The difference between the treatment efficiency of the *Colocasia esculenta* and the *Caladium bicolor* is not significant (from 2–3%).

- It is necessary to continue to study the effectiveness of brewery wastewater treatment with higher loads, with other plant species and build a pilot model to apply this research in practice.

- It is necessary for further study the *Caladium bicolor* and the *Colocasia esculenta* in the treatment of other types of wastewaters to find out the other pollutant removal capabilities of these two plants.

Author contribution statement: Determine content, research methods, write reports: T.T.L; get sample, parsing: H.N.H.

Author Commitment Statement: The paper submitted with the full knowledge and consent of the author (if any), without any prior publishment or copy from other previous studies; There is no dispute of interest in the authors group.

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