JEE Journal of Ecological Engineering

Journal of Ecological Engineering 2023, 24(6), 348–365
https://doi.org/10.12911/22998993/163273
ISSN 2299–8993, License CC-BY 4.0

Received: 2023.03.16
Accepted: 2023.04.18
Published: 2023.05.01

Treatment Ability and Community Responses of Candung as an Appropriate Technology to Maintain Irrigation Water Quality

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ABSTRACT

With the burgeoning population, the community activities, such as laundering, washing, or even bathing, have expanded along the irrigation canal. Consequently, some chemicals from those activities are released and pollute the water body. Besides, the discharge of wastewater into the irrigation system is also an issue of public health concern, because it creates an environment conducive to the reproduction of any pathogenic agent. Using candung as constructed wetlands (CW)-like to treat the irrigation water in rice paddies would be an interesting tool for removing pollutants from the irrigation water. Candung, as a locally used CW in Bali Island, has been applied in the rice field long time ago. The present study aimed to examine candung as a local attached CW or treating irrigation water and analyse the community awareness regarding the candung application. The result showed a positive effect of candung in maintaining the water quality parameters, such as TSS, BOD, COD, and nutrients with certain aquatic plants (*Nelumbo nucifera, Nymphaea tetragona, and Pistia stratiotes*). The knowledge, behaviour, and action of the local subak community were still limited, whereas they had positive perceptions and responses about candungthe potential of candung as an agrotourism attraction in the village as well.

Keywords: candung, constructed wetland, irrigation water, *Nelumbo nucifera, Nymphaea tetragona, Pistia stratiotes, agrotourism*.

INTRODUCTION

The irrigation water in villages in tropical countries is facing a reduction in water quality. It urgently needs to be concerned, so it can be effectively utilized as irrigation water for agriculture, aquaculture and potentially even household needs (Goyal et al., 2021). The rapid changes in land and water use due to dynamic farming intensity constitute the main factor affecting water quality and quantity, ecology, and biodiversity globally (Alavaisha et al., 2019). The community activities have expanded along the irrigation canal, such as laundering, washing or even bathing. Solid waste is also dumped in the channel and causes floods during the rainy season because of clogging with plastics. The type of pollutants within domestic wastewater can significantly vary based on location and pollutant type (Abbasov & de Blois, 2021; Sumantra et al., 2022). Consequently, some chemicals from those activities are released and pollute the water body. Besides, the discharge of wastewater into the irrigation system is also an issue of a public health concern as the dormant odour and suitable breeding of any pathogen (Shukla et al., 2020; Wijaya & Soedjono, 2018b).

The main source of agricultural irrigation water comes from surface water. Due to the spatial difference in water content in wetlands, streams and rivers, assessment is necessary to provide robust insights into the quality and quantity of water that enter the paddy fields (Alavaisha et al., 2019; Elias et al., 2014). Human activities around the paddy fields influence the nutrient input in the irrigation system, which leads to water physico-chemical conditions. The trophic state is defined by the factors that are related to nutrient contents, algae biomass and water transparency (Ayoade et al., 2019; Soedjono et al., 2018; Sumantra et al., 2022; I. Wijaya et al., 2017). It causes water quality deterioration due to the discharge of untreated wastewater from the municipality (Abou-Elela, 2019; Soedjono et al., 2018).

Therefore, pre-treatment is urgently needed before the irrigation water enters the paddy fields, using natural treatment process such as the constructed wetland. Agricultural practices have been developed using large amounts of chemical fertilizers and pesticides to sustain yields and productivity. This practice raised the level of nutrients reaching the aquifers, therefore contaminating the surface and groundwater (Aguilar et al., 2019). Constructed wetland (CW) is an engineered system that simulates processes from natural wetlands. With low external energy requirements, it improves water quality by means of a combination of physical, chemical, and biological processes (Ruiz, 2007). The last few years showed that artificial or constructed wetlands were frequently used to treat wastewater due to their low-cost operation and maintenance, low energy consumption and ease of operation (Aboukila & Elhawary, 2021). It consists of vegetation, substrates, microorganisms, and soil components to support the water treatment process (Abou-Elela, 2019; Wijaya & Soedjono, 2018a). Managing surface water pollution is critical for the economy, ecosystem, and human health concerns. CW can be installed in a pond that acts as a catchment area, flood controllers, and groundwater runoff. The CW has a role as trash trap and sedimentation storage so the water can be free of debris and sediment loads (Adek Rizaldi & Limantara, 2018). The present study aimed to examine candung as a local attached constructed wetland for treating irrigation water, with additional plants cultivation and analysing the community awareness regarding the candung application.

METHODOLOGY

Study location

The research was conducted in a local irrigation water community named Subak Lepud. It is located in Baha Village, Badung Regency, Bali Island. It was supported by the Subak Lepud community and also farmers around the subak area. Candungs were built in the corner of each paddy fields area and connected to the irrigation water system along the paddy fields area. It is a 1×1 m area bordered by higher subsoil levels in order to maintain the water overflow. Within about 50 cm of depth, candung could receive and hold about 0.5 m^3 of water at a time. The solid content of irrigation water could be settled during the storage of candung. There were three water plants used in candung, such as *Nelumbo nucifera*, *Nymphaea tetragona*, and *Pistia stratiotes.* Those plants are commonly used as decorative plants at home, in parks or gardens; meanwhile, in this research, they were used as emergent plants. The water will flow along the irrigation channel, enter candung, which is installed in the entrance and flow to the paddy field.

Water quality sampling

The irrigation water samples were collected from 15–20 cm below the surface in the month of September 2021. Those were taken in candung box, which is placed right before the irrigation water enters the paddy fields. The water samples were taken at the upstream, midstream, and downstream points. Sample water was also taken from each candung box right after those stream points. There are three candung boxes at each point (upstream, midstream, downstream). Those candungs represent the different water plants mentioned above. Accordingly, 12 water samples have been analysed in this study. The samples were preserved and analysed for physico-chemical characteristics. Total dissolved solids (TDS) and total suspended solids (TSS) were measured by using filtration and gravimetric method. The accuracy of those methods is well documented in the scientific literature (Rahmanian et al., 2015). A 100 mL water sample was poured into weighed glass fibre filter of a specified pore size before starting the vacuum filtration. The filter was taken up after the completion of the filtration and placed in an aluminium dish in an oven at 100 °C for 2–3 hours to completely vaporize the remaining water. Afterwards, the filter paper was weighed, and the gain in filter weight showed the TSS contents in mass per volume of the filtered sample (mg/L). The TDS were determined by the gravimetric method. After filtration for TSS analysis, the filtrate was placed in the oven at above 100 °C until all the water was totally evaporated. The remaining mass of the residue represents the TDS in the water sample. The chemical compound such as dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), ammonium and phosphate were measured according to the standard method (Apha/Awwa/Wef, 2012). The samples were measured in the Laboratory of Health of Bali Province in triplicate.

Community responses questionnaire

A community perspective has been analysed through a questionnaire with five variables, such as knowledge, behaviour, action, perception, tourism potential and health food material. The knowledge variable is interpreted as the understanding of the Subak Lepud members towards candung and water plants on agricultural land. In this study, the knowledge variable was measured by six indicators, namely: (1) the benefits of candung and water plants for environmental preservation; (2) the impact that occurs if candung and water plants are not preserved; (3) the benefits of water plant species (such as *Nelumbo nucifera*, *Nymphaea tetragona*, and *Pistia stratiotes*) in aquatic ecosystems; (4) the impact of destroying and removing phytoremediation plant species from the environment; (5) the importance of conserving water plant species as phytoremediation/toxic absorbers; and (6) procedures for the preservation of candung and water plants.

The attitude variable is interpreted as the reaction of Subak Lepud members from their understanding of candung and water plants on agricultural land. In this study, the attitude variable was measured by five indicators, namely: (1) participating in conserving candung and water plants to maintain the balance of the ecosystem; (2) participating in conserving candung and water plants as an environmental conservation measure; (3) participating in conserving candung and water plants for subak irrigation which are polluted by waste; (4) taking part in maintaining the local wisdom of candung and water plants because it can improve the ecological and economic welfare of the community; and (5) participating in conserving water plant species as phytoremediation/toxic absorbers. The action variable is defined as the actions committed by members of the Subak Lepud against candung. In this study, the action variable was measured by five indicators, namely: (1) not creating candung and planting water plants in candung; (2) not making candung and planting water plants so that the rice planting area is wider; (3) conserving candung and water plant species because they have important ecological functions that are beneficial; (4) planting water plants in candung (such as *Nelumbo nucifera*, *Nymphaea tetragona*, and *Pistia stratiotes*), because they have economic value; and (5) participating in the conservation of candung and water plants that absorb poisons/contaminants. The perception variable is interpreted as the views of Subak Lepud members regarding the benefits of candung on agricultural land. The perception variable is measured by five indicators, namely: (1) the sustainability of candung and water plants can be beneficial for the balance of aquatic ecosystems; (2) the benefits of candung and water plants in maintaining and improving water quality; (3) the benefits of candung and water plant species for organisms that live in rice fields; (4) the benefits of preserving candung and water plants to overcome water pollution that enters rice fields; and (5) the benefits of conserving candung and water plants for the community.

The variable of the potential for educational tourist attractions is interpreted as the views of Subak Lepud members regarding the potential of candung and water plants on agricultural land as educational tourist attractions and healthy food providers. In this study, the variable of the potential of educational tourist attractions was measured by five indicators, namely: (1) candung and water plants (such as *Nelumbo nucifera*, *Nymphaea tetragona*) have subak local wisdom values; (2) candung and water plants that absorb pollutants (such as *Nelumbo nucifera*, *Nymphaea tetragona*, and *Pistia stratiotes*) will be able to produce healthy food products; (3) candung and pollutant-absorbing water plants (such as *Nelumbo nucifera*, *Nymphaea tetragona*, and *Pistia stratiotes*) can be used as educational tourist attractions; (4) support from subak members in the conservation of candung and water plants (such as *Nelumbo nucifera*, *Nymphaea tetragona*, and *Pistia stratiotes*); and (5) a district/provincial government policy is needed for the conversation of candung and water plants as educational tourist attractions.

Inferential analysis was carried out by using Path Analysis with the help of the SmartPLS program. The analysis was first performed to evaluate the structural model by taking into account the Q^2 predictive relevance model. The goal was to measure how well the observed values were generated by the model. Q^2 is based on the coefficient of determination of all dependent variables. The value of Q^2 has a range of $0 < Q^2 < 1$, the closer to 1, the better the model. In this structural model, there are three endogenous (dependent) variables, namely: Perception, Action and Potential, so three coefficients of determination (R^2) can be determined, which are the basis for calculating the Q^2 predictive relevance model.

To obtain data that has good calibration for each of the variables studied, the research instrument needs to be tested for its validity and reliability. Thus, it is important to carry out tests to ensure the level of validity and reliability of the research instrument is in accordance with the specified criteria. Testing the research instrument was carried out by means of a trial (pre-research) by distributing 35 questionnaires to Subak Lepud members. The validity test aims to measure whether the research instrument is valid or not. The research instrument is said to be valid if the instrument is able to accurately measure what is to be measured (Ghozali, 2009). Testing the validity of this instrument uses the validity of the criteria calculated through corrected item correlation analysis. Through this analysis, the research instrument is said to be valid if it has a correlation coefficient above 0.30. Meanwhile, the reliability test aims to measure the internal consistency of an indicator of a variable. High-reliability results provide confidence that all individual indicators are consistent with their measurements (Wijanto, 2008). This reliability test uses the one-shot method or is done only once, which is measured using Cronbach Alpha (α) analysis. A variable is said to be reliable if it has a Cronbach Alpha (α) value above 0.60 (Nunally, 1960 in Ghozali, 2009). The results of testing the research instrument from the questionnaire trial (n = 35 samples) that was carried out can be presented in Table 1.

The information from Table 1 shows that all statement items from five variables, namely knowledge, experience, intention, action and potential were valid (correlation coefficient was above 0.30) and showed a good level of reliability

Table 1. Recapitulation of research instrument testing results

No	Variable	Item	Validity test (koef. r)	Reliability test (koef. *Cronbach Alpha)*
1.	Knowledge	$Know_1$	0.915	0.982
		$Know_2$	0.963	
		$Know_3$	0.970	
		$Know_4$	0.931	
		$Know_{.5}$	0.970	
2.	Experience	Exp_1	0.942	0.933
		Exp_2	0.727	
		Exp_3	0.947	
		Exp_4	0.781	
3.	Intention	$Intent_1$	0.934	0.964
		$Intent_2$	0.858	
		$Intent_3$	0.943	
		$Intent_4$	0.819	
		$Intent_5$	0.966	
4.	Action	Act_1	0.742	0.945
		Act_2	0.865	
		Act_3	0.929	
		Act_4	0.913	
		Act_5	0.821	
5.	Potential	Pot_1	0.743	0.943
		Pot_2	0.881	
		Pot_3	0.914	
		Pot_4	0.802	
		Pot_5	0.904	

(Cronbach's Alpha correlation coefficient (α) was above 0.60). Thus, the research instrument (questionnaire) could be used and distributed to all predetermined target samples. The data collected was 182 units out of 200 units which were distributed to all members of Subak Lepud. The results of the further examination showed that the 182 data units had been filled in completely, so they were ready for further analysis.

RESULTS AND DISCUSSION

Candung as a locally appropriate technology

The silt that may be drifted along the irrigation system needs to be removed in a sedimentation chamber before entering the paddy fields. This candung will help reduce the clogging irrigation system as well as eliminate a large part of the particulate organic load and forms of nutrients entering ponds. The candung pool is shallow and sealed around to maintain the overflow. Soil is the main substrate of candung with thickness up to 50 cm and thus, it allows the formation of wetland plants (Abou-Elela, 2019). According to Kadlec (Kadlec & Wallace, 2008), there are four main principles of constructed wetlands, including candung. They are balancing the conversion rate of natural wetlands resulting from agriculture and urban development, improving the water quality after the treatment, flood control and supporting food production. Candung can be considered as part of the wastewater treatment system to provide physical and biological treatment. Vegetation, substrates, soils, microbes, and water are the essential components of the technique. To remove various contaminants, it employs complex processes involving physical, chemical, and biological mechanisms (Abou-Elela, 2019). The wastewater treatment in candung is commonly practiced through biological processes (like microbial activity and plant uptake) and physicochemical processes (like precipitation, adsorption, and sedimentation) (Biswas et al., 2021). As a system, candung belongs to a free water surface constructed wetland (FWSF) which operates like a natural wetland. One of the important parts of candung is the emergent plans which have several purposes and be mutual with the microorganism. The stems and submerged leaves support the growth of bacteria, and the leaves above the surface shade the water as well as reduce the potential for rapid algae growth, whereas oxygen from the atmosphere is transported from the leaves down to the roots, which supports the plant growth.

Constructed wetlands (CWs) for wastewater treatment are a natural, simple, low construction and maintenance cost, and environmentally friendly method, representing alternative and promising solutions for environmental protection and preservation. CWs are most suitable for small areas and rural communities (Abbasi et al., 2019). Water and nutrient recycling are emerging and part of water management. Proper wastewater treatment is an issue in sustainable development related to water demand and designed due to growing populations, whereas global climatic changes have increased water stress conditions, especially in limited water resource areas (Barbagallo et al., 2014). In constructed wetland systems, plants can play an important role in the removal of nutrients from wastewater compared to unplanted wetlands. Macrophytes can improve wastewater quality by helping to settle suspended solids, directly taking up nutrients, and providing support for microbial flora (Lin et al., 2002).

Therefore, the seasonal selection of plants for constructed wetlands should be an important part of wastewater treatment management in a CW system. Most of the previous research on constructed wetlands covered one plant season, but the period of vegetative growth followed, culminating in death. After completion of a life cycle, plants leave, roots begin to die, and if plants remain in the CW, decay from the plant material will release nutrients back to the CW. Therefore, appropriate plants for the specific season will optimize the function of the constructed wetland.

Treatment ability of candung

The pH, total suspended solid (TSS), and total dissolved solid (TDS)

The pH is one of the important water quality characteristics that represent the acidity or alkalinity of the water sample. A pH below 7.0 is considered acid, while the pH above 7.0 is alkaline (Sawyer et al., 2003). The hydrogen-ion concentration is very important to speed up the biochemical process, which is also depending on the current enzyme. The enzyme sometimes needs a certain pH value to achieve the best reaction rather than a lower pH or higher pH. The pH affects the suitability of available water to support the living organism (Qasim, 1999; Tchobanoglous et al., 2002). Acidic water can affect the corrosion of metal; meanwhile, alkaline is presenting disinfection of the water. The normal drinking water pH range is around 6.5–8.5 (World Health Organisation (WHO), 2017). The pH in the 12 water samples showed a pH range between 7.0–8.0. The lowest pH was found at the upstream point with 7.39; meanwhile, the highest one was found at the downstream point after the candung with *Nymphaea tetragona.* According to the pH analysis, the pH value from the upstream to the downstream increased from 7.39 to 7.88.

After passing through the candung, there were some changes to the pH value. After the upstream, the pH value of the effluent of candung with *Nelumbo nucifera, Nymphaea tetragona*, and *Pistia stratiotes* was 7.42; 7.64; 7.43, respectively. In the mid-stream, the pH was measured at 7.71; 7.75; 7.71, respectively, for three candungs; meanwhile, the downstream were 7.93; 7.81; and 7.79. All the pH values of those effluents were covered by the national pH threshold of 6-9. According to Amic and Tadic (Amić & Tadić, 2018), the pH value of various stream water environments is in the range of 6.5 to 8.5, while pH below 4 (acid) and above 10 (base) creates a damaging living environment. The pH trend of the effluent is shown on Figure 1.

The presence of various solid particles, whether suspended or dissolved, is characterized by the physical water quality (Soedjono et al., 2018; Wijaya & Soedjono, 2018). The solid shows the amount of particle or slurry left when the water is totally removed. The total solid is the content of solid in a sample after the sample has been dried at over 100 °C for 24 hours and compared to the original mass of the sample. Total dissolved solids (TDS) is the sample that only can appear under dry conditions, while total suspended solids (TSS) still remain intact when placed into the water (Hamilton & Zhang, 2003; Ramesh & Jain, 2017). Total solid is represented by the sum of TDS and TSS. Water with a high

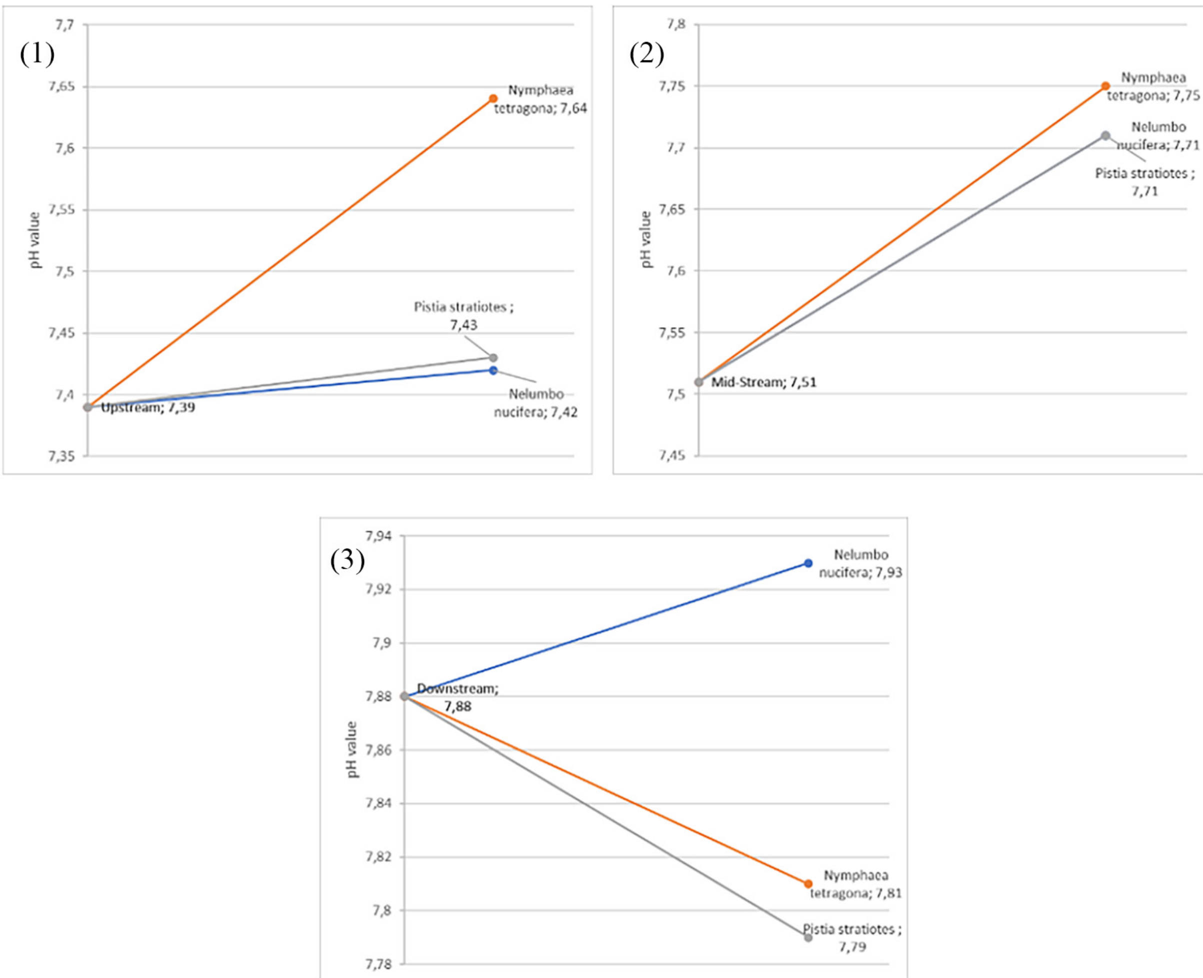

Figure 1. The pH value in each effluent of candung from upstream (1), mid-stream (2) and downstream (3)

dissolved solid concentration has an adverse impact on irrigation crops and plants; meanwhile, the highly suspended solid can cause a scum layer (floating solid) or build-up sediment (sink solid) (Ayoade et al., 2019; M. Faisal et al., 2015). The limits of TSS and TDS according to the national water quality standard for class II are 50 mg/L and 1000 mg/L, respectively. The TSS concentration increased from the upstream to the downstream due to the wastewater discharged along the stream.

The TSS measurement showed various changes in the TSS concentration in the effluents after passing through candung. At the upstream point, the TSS of effluent increased after candung with *Nelumbo nucifera and Pistia stratiotes* with 85 mg/L and 59 mg/L, respectively. There was no change of TSS after candung with *Nymphaea tetragona* at 39 mg/L. TSS contributes to the sediment in the water body and potentially causes oxygen depletion. It is important to control the treatment process following the effluent regulation (Hudson, 2010; Wijaya et al., 2019). According to the national water quality standard classification (*Peraturan Pemerintah Republik Indonesia Nomor 82 Tahun 2001 Tentang Pengelolaan Kualitas Air Dan Pengendalian Pencemaran Air*, 2001), those concentrations were out of Class II water quality and belonged to Class III. The effluent TSS from candung at the mid-stream and downstream has declined for all plants. The decreasing TSS indicates that the plants have promoted the solid to settle down as sediment. The highest removal of TSS was found in the mid-stream and downstream's candung for *Nelumbo nucifera* (60.34%) and *Pistia stratiotes* (63.75%), respectively. The TSS concentration from the upstream, midstream, and downstream can be seen in Figure 2.

Total dissolved solids (TDS) indicate the dissolved salt in the water sample out of the suspended solid (SS). The TDS concentration is related to electrical conductivity or conductance. It shows the ability of water to transmit an electrical

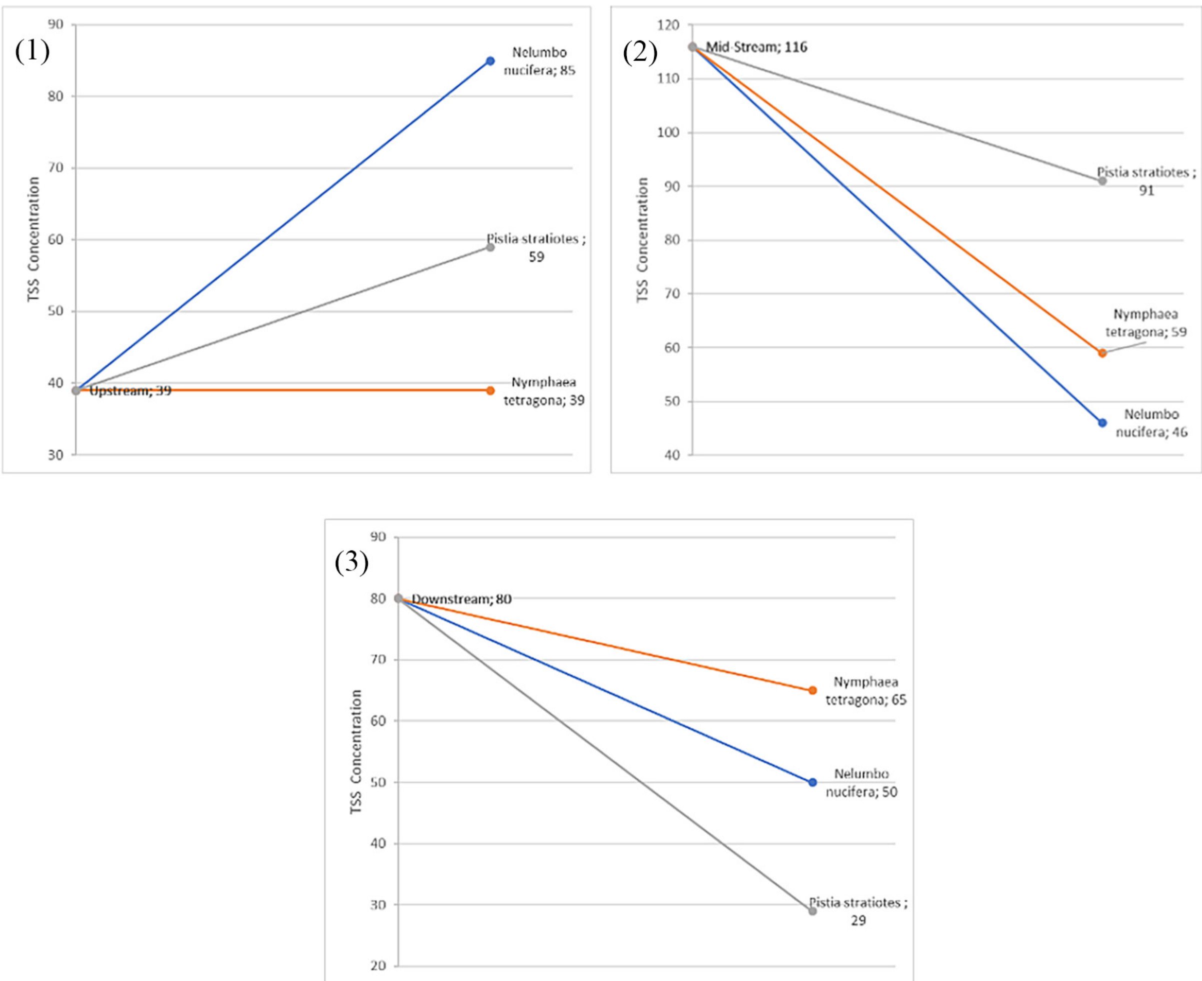

Figure 2. The TSS concentration in each effluent of candung from upstream (1), mid-stream (2) and downstream (3)

current that increases as the TDS concentration increases (Larrarte & Pons, 2011; Ramesh & Jain, 2017). TDS consists of various inorganic salts, such as sodium (Na^+), calcium (Ca^+), magnesium (Mg^+), potassium (K^+), chloride (Cl^-), nitrates (NO^{3-}), and bicarbonates (HCO^{3-}). According to World Health Organization (WHO) standard for water quality, the permissible TDS for agriculture is in the range of 450–2000 mg/L (Jamei et al., 2020). In a stream and rivers, the conductivity capacity is altered by various factors, such as soil type, rock type, and the presence of dissolved solids (Vadde et al., 2018). TDS consists of ionic constituents that conduct electricity. TDS and bulk conductivities of sediment in the water body are generally higher at contaminated locations (Atekwana et al., 2004). Water with high TDS has been known to cause a detrimental effect on organism's health due to its adverse effect on feedstock (Sharma et al., 2017). A study from Devesa and Dietrich (Devesa & Dietrich, 2018) stated that the TDS also could represent the mineral content in the water body and affect the taste of the water. It can be considered with a concentration of TDS>150 mg/L. The TDS analysis in this study showed that the TDS concentration was very low under the national water quality standard classification (*Peraturan Pemerintah Republik Indonesia Nomor 82 Tahun 2001 Tentang Pengelolaan Kualitas Air Dan Pengendalian Pencemaran Air*, 2001), which is 1000 mg/L.

TDS in the upstream point was measured at 138.9 mg/L, while in the mid-stream and downstream was 133 mg/L and 127 mg/L, respectively. Candung has no significant effect on the TDS concentration after the water passes it through. The lowest TDS concentration from the candung was found at the mid-stream point after candung with *Nymphaea tetragona,* which was 119,5 mg/L. A low TDS is also found in the study by Mazood et al. (Mazood et al., 2023), which is in a range of 99.6–101.2 mg/L with a standard value in the range of 400–500 mg/L. The decline of TDS concentration after all candungs is presented in Figure 3.

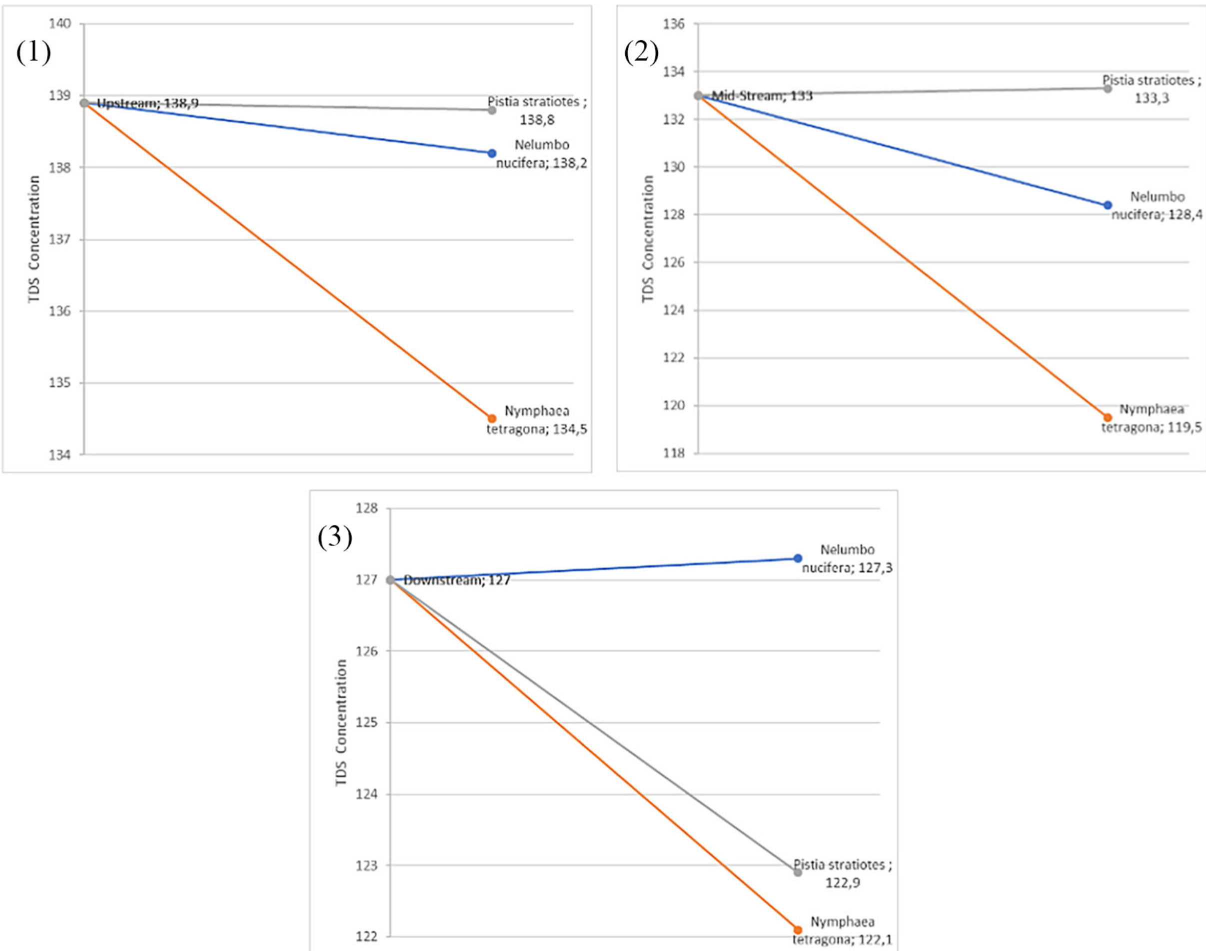

Figure 3. The TDS concentration in each effluent of candung from upstream (1), mid-stream (2) and downstream (3)

Biological oxygen demand (BOD)

An enormous BOD concentration in the water body damages the water quality. It causes a low dissolved oxygen (DO) condition and an unfavourable life environment for the aquatic organism. BOD and DO have an exchange relationship with the riverbed, nitrification and denitrification (Koklu, 2009). BOD represents the total oxygen consumption to break down the organic material, which is performed by aerobic biological microorganisms (Faisal et al., 2020; Gu et al., 2013). It provides the information about available biodegradable fraction which is loaded in the water (Jouanneau et al., 2013). The decrease in BOD is possibly caused by the oxidation of organic matter, which provides the energy resource for the microorganism metabolic process and is synthesized into cell mass (Marcato et al., n.d.). BOD is a commonly used parameter for assessing the biodegradability of dissolved organic matter in water bodies (Simon et al., 2011).

The aerobic microbiological degradation and sedimentation/filtration processes are the primary causes of BOD decrease. In subsurface flow wetlands, organic molecules can be destroyed both aerobically and anaerobically. Atmospheric oxygen diffusion, convection (wind effect), and/or macrophyte root transfer into the plant rhizosphere can provide oxygen for aerobic breakdown. Without oxygen, anaerobic organic elimination might take place inside the media pores. Anaerobic degradation is a two-step process undertaken by anaerobic heterotrophic bacteria in wetlands. Acid-forming bacteria synthesize organic materials into new cells, organic acids, and alcohols in the first phase (fermentation). Methane-forming bacteria, in the second stage, continue the oxidation (methanogenesis) by turning organic molecules into new bacterial cells, methane, and carbon dioxide. In the anaerobic zones of wetlands, fermentation and methanogenesis occur (Abedi & Mojiri, 2019; Kadlec & Wallace, 2008). The BOD concentration from the upstream is in the range of 1–5 mg/L (Figure 4), which belongs to the water class I-III according to the national water quality standard (PP No.8/2001). BOD was classified as low BOD

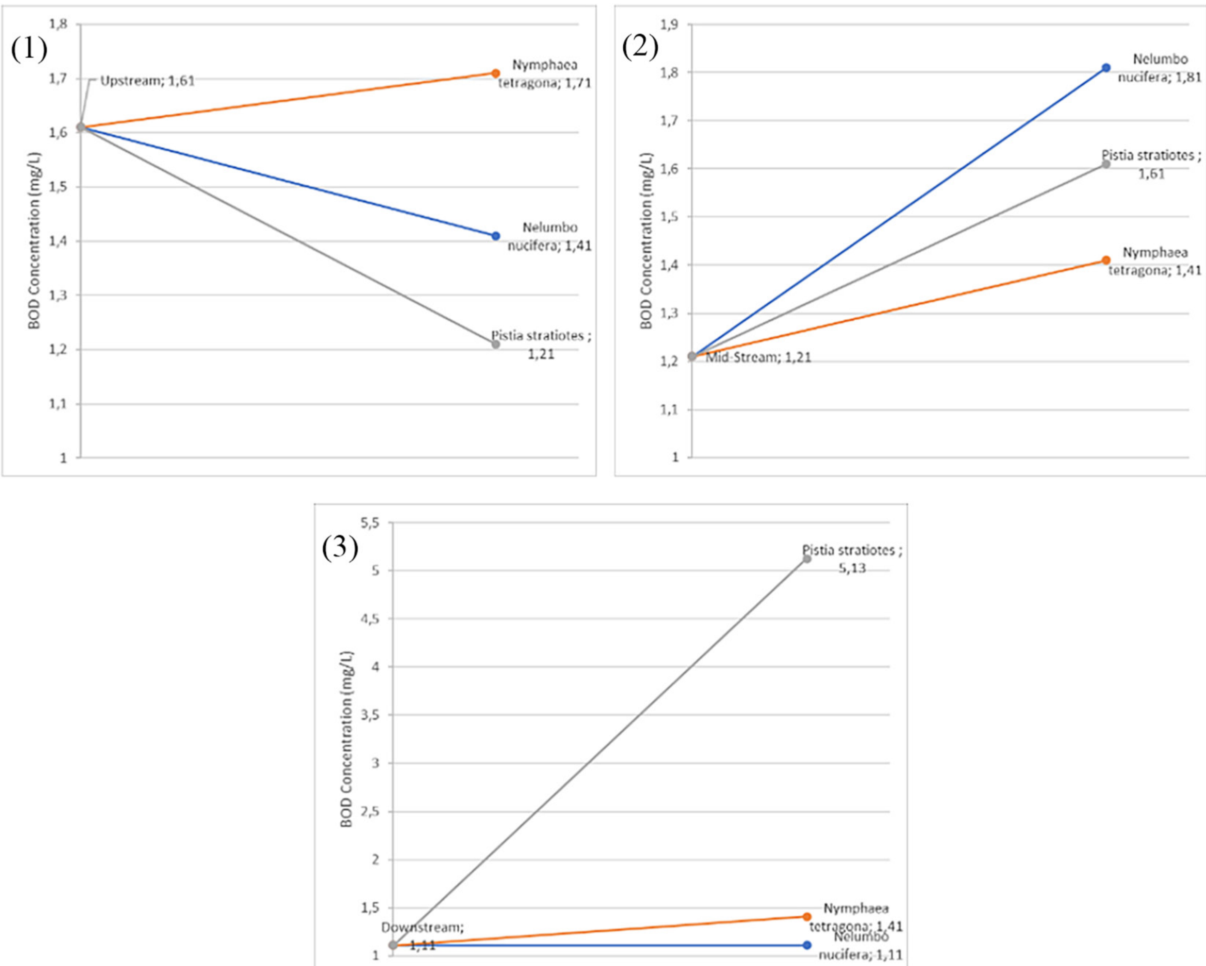

Figure 4. The BOD concentration in each effluent of candung from upstream (1), mid-stream (2) and downstream (3)

concentration in all streams. In the upstream, the BOD was measured at 1.61 mg/L; in the mid-stream was 1.21 mg/L and in the downstream was 1.11 mg/L. The BOD decreased from the upstream to the downstream, which indicates the removal along the stream. The role of water plants has shown the changes of BOD in the stream water. The lowest BOD concentration was found in candung upstream area with *Pistia stratiotes* with 1.21 mg/L. In the midstream, the BOD was found to increase to 1.81 mg/L in candung with *Nelumbo nucifera,* and in the downstream, there were significant changes of the BOD in candung with *Pistia stratiotes* with 5.13 mg/L. The increase in BOD indicates that more dissolved oxygen in the stream is depleted. It could be caused by the settlement of debris, leaves, woods, dead plants and animal that becomes biomass and carbon sources.

Chemical oxygen demand (COD)

COD is described as the number of oxygen equivalents used in oxidizing the organic matter of samples by strong oxidizer agents such as dichromate or permanganate. The higher the chemical oxygen demand, the greater the concentration of pollution in the water sample (G. H. Faisal et al., 2020). COD is considered one of the most important water quality parameters of wastewater. The typical BOD/COD ratio for untreated household wastewater is 0.3–0.8; a BOD/COD ratio of 0.5 or above indicates that the available organics are easily degradable by microbes, whilst a ratio below 0.3 indicates that the available organics are harder to break down by microorganisms (Kadlec & Wallace, 2008). According to the results of COD concentration after passing through each candung, the effluent of candung at the upstream and downstream gave negative results or significantly increased the COD. The BOD/COD ratio was found very low in all water sources (upstream, middle stream and downstream), below the threshold value to provide a proper environment for the microorganism, which is at least 0.5 or above. It results in low organic removal

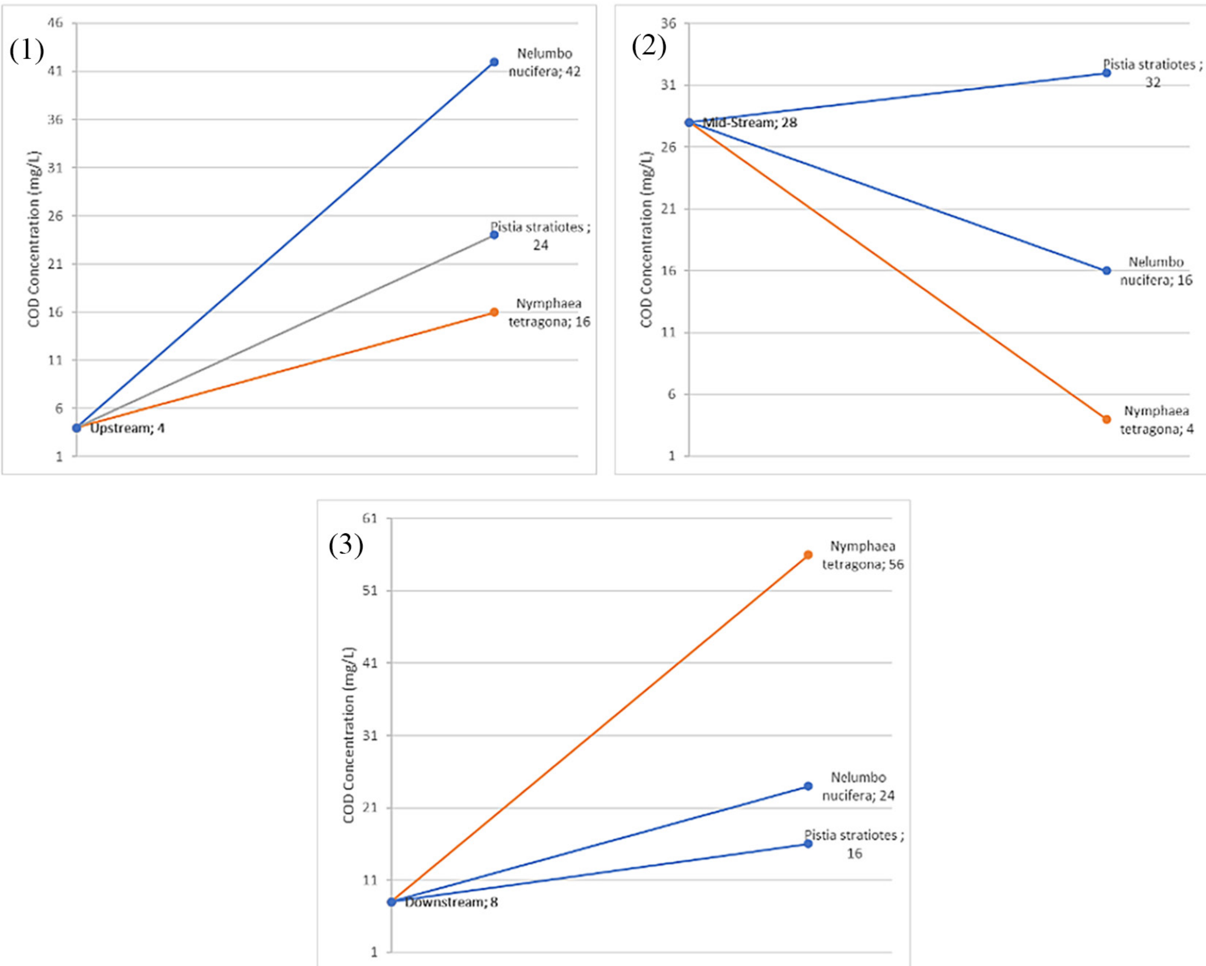

Figure 5. The COD concentration in each effluent of candung from upstream (1), mid-stream (2) and downstream (3)

Table 2. The BOD/COD ratio of each stream and candung

Parameter	Raw water	Nelumbo nucifera	Nymphaea tetragona	Pistia stratiotes
Upstream	0.40	0.03	0.11	0.05
Mid-Stream	0.04	0.11	0.35	0.05
Downstream	0.14	0.05	0.03	0.32

percentages because of the decrease in microbial activities to degrade the organic matter. A low BOD/COD ratio gives more insight into the COD concentration, whereas the organic matter that has to be degraded with chemical oxidants, such as potassium dichromate, is higher than the biodegradable (BOD). Besides, the presence of humic material in candung also contributes to the higher COD concentration. Humic substances contain carbon, hydrogen, oxygen, nitrogen and small amounts of sulphur and phosphorus. The humic substances contained in products are commonly used in agriculture as part of the fertilizer, but on the other side, their rise is also a sign of organic pollutant levels, colour intensity, and chemical activities in the water (Rupiasih, 2016). The trend of COD concentration in the effluent of candung is presented on the Figure 5 and the the ratio of BOD/COD on the Table 2.

Nutrient content

The most important organic forms of nitrogen in constructed wetlands are ammonium (NH_4^+), nitrite (NO_2^-), and nitrate (NO_3^-). Gaseous nitrogen can be present as dinitrogen (N_2), nitrous oxide (N_2O), nitrous oxide (NO_2 and N_2O_4), and ammonia (NH_3). Various forms of nitrogen are always involved in the chemical conversion of inorganic compounds to organic compounds and from organic compounds to inorganic compounds (Abba et al., 2021). Some of these processes require energy (usually from an organic carbon source) to continue, while others release the energy that the organism uses for growth and survival. All of these transformations are necessary for the normal functioning of wetland ecosystems, and most chemical changes are facilitated by the production of enzymes and catalysts by organisms that benefit them (Vymazal, 2007). Ammonia is converted from its organic form through a complex, energy-releasing, multi-step biochemical process. In some cases, this energy is used by the microorganisms for growth and ammonia is incorporated directly into the microbial biomass. Nitrogen assimilation refers to various biological processes that convert inorganic forms of nitrogen into organic compounds that function as components of cells and tissues. The two forms of nitrogen commonly used for assimilation are ammonia and nitrogen nitrate. Ammonia nitrogen is a suitable nitrogen source for assimilation because it is reduced more energetically than nitrate. Ionized ammonia can be adsorbed from solution by cation exchange reactions with detritus, inorganic deposits, or soil. The adsorbed ammonia is loosely bound to the substrate and is easily released when the hydrochemical conditions change (Ribeiro et al., 2022). At a given concentration of ammonia in the water column, a certain amount of ammonia is adsorbed and saturated at the available binding sites. When the concentration of ammonia in the water column decreases, some of the ammonia desorbs and rebalances with the new concentration. The higher the ammonia concentration in the water column, the more ammonia is adsorbed. When wetland substrates are exposed to oxygen, perhaps due to regular aeration, the adsorbed ammonium can be oxidized to nitrate. Ammonium ions (NH_4^+) are generally adsorbed on clay as exchangeable ions and are chemically adsorbed by humic substances or fixed to the clay lattice. It seems that these reactions can occur at the same time.

According to ammonium concentration analysis, it was found that the ammonium concentration was increasing from the upstream to downstream. In the upstream, the candung with *Nelumbo nucifera* showed the best result with 99.11% removal of ammonium; meanwhile, the candung with *Nymphaea tetragona* had 33.23% removal, but after the candung with *Pistia stratiotes* had a negative result, which was higher than the influent. In the mid-stream, candung with *Nelumbo nucifera* and *Pistia stratiotes* has a similar result on ammonium removal, about 33%-36%. In the downstream, the ammonium concentration was found at 1.911 mg/L (*Nelumbo nucifera*), 1.169 mg/L (*Nymphaea tetragona*), 1.174 mg/L (*Pistia stratiotes*) with the range of ammonium removal 16–17%. The candung with *Nelumbo nucifera* gave the best result in all three stream areas. The trend of nitrogen concentration in the effluent is shown on the Figure 6.

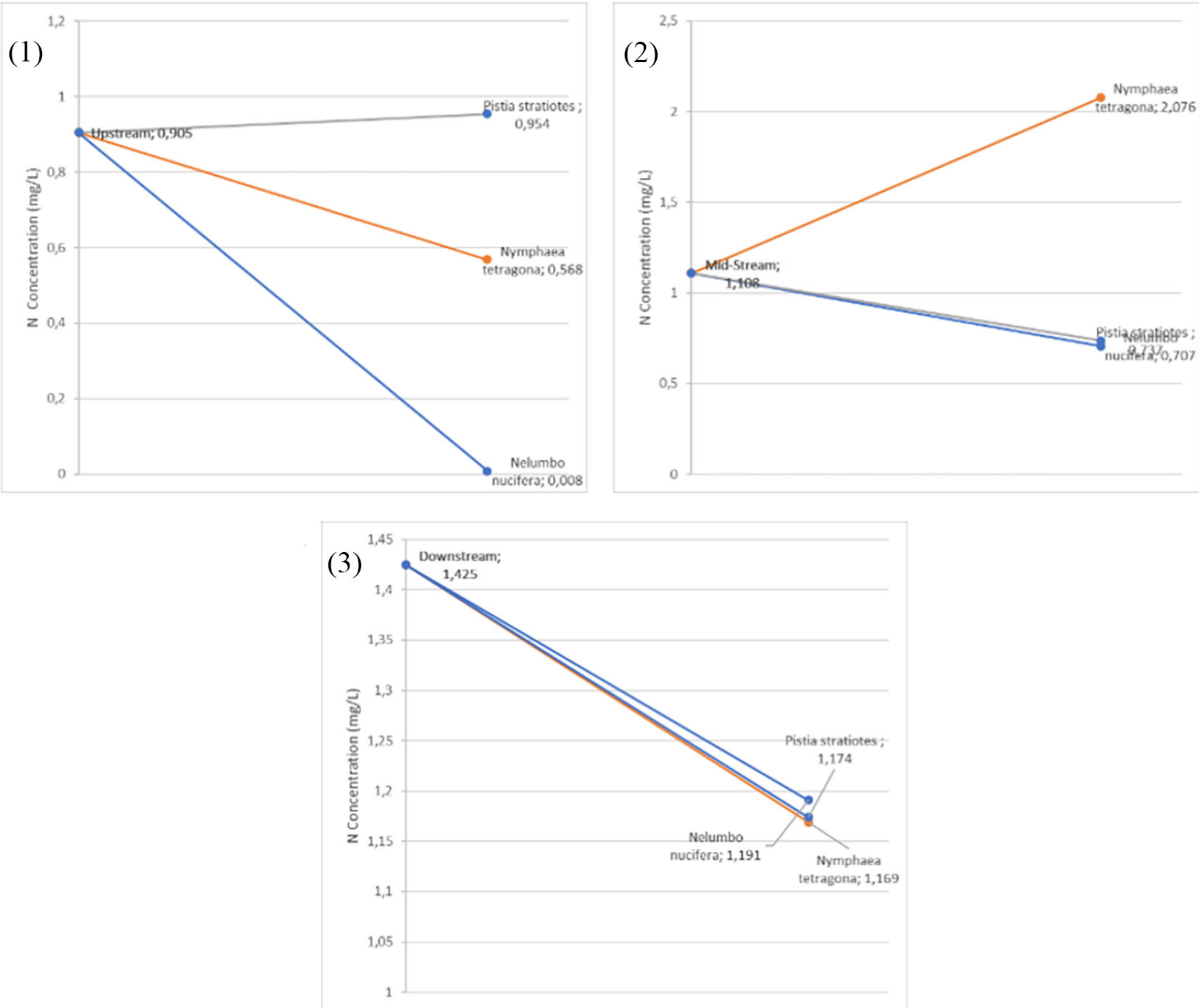

Figure 6. The nitrogen concentration in each effluent of candung from upstream (1), mid-stream (2) and downstream (3)

Community responses on the application of candung to maintain the irrigation water

Respondent demographic

The results of the descriptive analysis of the demographics of the respondents aim to obtain an overview of the respondent's profile regarding age, education level, and land area. The results of the analysis obtained for the demographics of the respondents can be presented in Table 3.

Table 3 shows the demographics of respondents based on age, showing more respondents over 50 years with a distribution of 86.3%. Furthermore, it was followed by the respondents of 40–49 years (11.5%), 30-39 years (1.6%), and under 30 years (0.5%). The information from the distribution of respondents by age indicates that most of the members of Subak Lepud are old enough to work on the land they own.

In terms of respondent demographics based on education level (Table 3), Subak Lepud members dominantly have senior high school/equivalent education, namely 45.1%, followed by those with junior high school education (25.3%), elementary school (18.1%), and the least, bachelor's degree (11.5%). This information illustrates that the level of education of Subak Lepud members is still very low because the majority are below bachelor's degree, namely 96.6%. On the basis of this information, the members of Subak Lepud are still working on their agricultural land in the traditional way.

In terms of land ownership (Table 3), Subak Lepud members dominantly own more than 34 acres (36.3%) of land to cultivate. Next, followed by arable land ownership of 20–24 acres (17.6%), 30–34 acres (14.8%), 25–29 acres (14.3%), under 15 acres (10.4%), and the least, 15–19 acres (6.6%). On the basis of this information, it can be said that the land cultivated by Subak Lepud members is quite extensive. This descriptive analysis was carried out to find out the description of

Table 3. Respondent demographics

Number	Description	Number of People	Percentage (%)
1	Age		
	< 30 years	1 person	0.5
	30–39 years	3 people	1.6
	40–49 years	21 people	11.5
	50–59 years	88 people	48.4
	> 59 years	69 people	37.9
2	Education level		
	Elementary school	33 people	18.1
	Junior high school	46 people	25.3
	Senior high school/equivalent	82 people	45.1
	Bachelor's degree	21 people	11.5
3	Land area		
	< 15 acres	19 people	10.4
	15–19 acres	12 people	6.6
	20–24 acres	32 people	17.6
	25–29 acres	26 people	14.3
	30–34 acres	27 people	14.8
	> 34 acres	66 people	36.3
Total		182 people	100

the respondents' responses regarding the statements in the research instrument, especially the variables studied. The analysis was conducted by calculating the average (mean) based on the percentage of respondents' responses to each indicator in the research variables, namely: knowledge (know), experience (exp), intention (intent), action (act), and potential (pot). The higher the average value obtained, the better the respondent's response to the indicator or variable.

Community knowledge

The knowledge variable is defined as the understanding that Subak Lepud members have of the functions and benefits of candung and water plants on agricultural land. In this study, the variable knowledge is measured by five indicators, namely: (1) the function of improving water quality (know1); (2) the function of increasing land quality (know2); (3) the benefit of increasing biodiversity (know3); (4) the benefit of improving the quality of food products (know4); and (5) the benefit of reducing the use of pesticides (know5). The description of the knowledge variable of Subak Lepud members can be presented in Table 4.

From the information in Table 4 above, it appears that the knowledge of Subak Lepud members regarding candung and water plants on agricultural land was still relatively limited or lacking, considering the average perception obtained was 2.36. Other information that can be conveyed is that members of Subak Lepud understood the function of candung and water plants to improve water quality because they had the highest average compared to other indicators (2.49). Meanwhile, the benefits of candung and water plants for

Table 4. Description of respondents on knowledge variable (know)

Description		Response (%)					Average (mean)
		1	2	3	4	5	
1	The function of improving water quality (know1)	25.8	28.0	19.8	24.2	2.2	2.49
2	The function of increasing land quality (know2)	25.8	30.2	23.6	18.1	2.2	2.41
3	The benefit of increasing biodiversity (know3)	25.8	32.4	26.9	14.8	-	2.31
4	The benefit of improving the quality of food products (know4)	25.8	36.8	19.2	18.1	-	2.30
5	The benefit of reducing the use of pesticides (know5)	25.8	34.6	23.1	16.5	-	230
Knowledge variable (know)							2.36

Table 5. Description of respondents on experience variable (Exp)

Description		Response (%)					Average (mean)
		1	2	3	4	5	
1	The use to reduce waste pollution (exp1)	9.9	9.9	59.3	18.7	2.2	2.93
2	The use as a medium for absorbing toxic in the field (exp2)	9.9	9.9	57.1	23.1	-	*2.93*
3	The use to maintain the balance of the land ecosystem (exp3)	9.9	9.9	59.3	20.9	-	2.91
4	The use to produce healthy rice (exp4)	9.9	9.9	59.3	20.9	-	2.91
Experience variable (Exp)							2.92

improving the quality of food products and reducing the use of pesticides were the lowest known to members of Subak Lepud, because they obtained the lowest average, which was equal to 2.30.

Community experience

The experience variable is interpreted as the experience felt by Subak Lepud members in utilizing candung and water plants on agricultural land. In this study, the experience variable (exp) is measured by four indicators, namely: (1) the use to reduce waste pollution (exp1); (2) the use as a medium for absorbing toxic in the field (exp2); (3) the use to maintain the balance of the land ecosystem (exp3); and (4) the use to produce healthy rice (exp4). The description of the experience variable (exp) of Subak Lepud members can be presented in Table 5.

On the basis of the explanation in Table 5, the experience of Subak Lepud members regarding the use of candung and water plants on agricultural land was still relatively low, considering the average perception obtained was 2.92. In other words, Subak Lepud members did not take advantage of the application of candung and water plants on cultivated agricultural land. Other information that can be conveyed is the experience of using candung and water plants to reduce waste pollution and toxic absorbing media on land tended to be practised by Subak Lepud members, because they obtained an average that was equally greater than the other indicators (2.93).

Community intention

The intention variable in this study is defined as the desire or interest of Subak Lepud members to cultivate candung and water plants on agricultural land. In this study, the variable intention (intent) is measured by five indicators, namely: (1) interest in cultivation (intent1); (2) interest in preservation (intent2); (3) plan of use (intent3); (4) inviting other fellows (intent4); and (5) socialization of use (intent5). The description of the intention variable of Subak Lepud members can be presented in Table 6.

From Table 6, it appears that Subak Lepud members tended to be interested in using candung and water plants on cultivated agricultural land with consideration of the average perception obtained at 3.17. Other information that can be conveyed is that the cultivation of candung and water plants tended to be of interest to members of Subak Lepud because it obtained the highest average, namely, 3.19. Meanwhile, members of Subak Lepud were of very little interest in preserving and planning the use of candung and water plants because they had the lowest average score, which was 3.15.

Community action

The action variable (act) is interpreted as the reaction of Subak Lepud members to cultivate candung and water plants on agricultural land. In this study, the action variable (act) was measured

Table 6. Description of respondents on intention variable (Intent)

Description		Response (%)					Average (mean)
		1	2	3	4	5	
1	Interest in cultivation (intent1)	3.3	1.6	69.8	23.1	2.2	*3.19*
2	Interest in preservation (intent2)	3.3	1.6	72.0	23.1	-	3.15
3	Plan of use (intent3)	3.3	1.6	72.0	23.1	-	3.15
4	Inviting other fellows (intent4)	3.3	1.6	69.8	25.3	-	3.17
5	Socialization of use (intent5)	3.3	1.6	69.8	25.3	-	3.17
Intention variable (intent)							3.17

by five indicators, namely: (1) the construction of candung and water plants at the inlet water (act1); (2) the construction of candung and water plants together with all subak members (act2); (3) the selection of candung and water plants that effectively absorb pollutants (act3); (4) the cultivation of candung and water plants with economic value (act4); and (5) the preservation of candung and water plants for all subak members (act5).

The results of the description of the action variable (act) in Table 6 show that Subak Lepud members were quite enthusiastic about cultivating candung and water plants on agricultural land, taking into account the average perception obtained by 3.15. Furthermore, it can be said that the construction of candung and water plants at the inlet position is believed to be carried out by Subak Lepud members because it obtained the highest average compared to other indicators, namely, 3.19. Meanwhile, the response to the construction of candung and water plants together with all subak members was the least, with an average of 3.13.

Community potential

The potential variable (pot) is interpreted as the view of Subak Lepud members regarding the opportunities that can be generated from the cultivation of candung and water plants on agricultural land. In this study, the potential variable (pot) is measured by five indicators, namely: (1) increasing the value of local wisdom of subak (pot1); (2) producing sustainable healthy food products (pot2); (3) creating educational tourist attractions (pot3); (4) adding economic value to all subak members (pot4); and (5) preserving biodiversity in the land (pot5).

The description of the potential variables (pots) of Subak Lepud members in Table 7 shows that Subak Lepud members quite believed the cultivation of candung and water plants on agricultural land could provide promising opportunities in the future. This result is in accordance with the consideration of the average perception for the potential variable (pot) of 3.35. Furthermore, it can be said that the cultivation of candung and water plants is believed to have the potential to increase the value of subak's local wisdom, because it obtained the highest average (3.43), followed by the potential to create educational tourist attractions (3.35), and produce sustainable healthy food products (3.35). The lowest response from Subak Lepud members was on the indicator of biodiversity preservation on land (3.32). The results of this analysis can provide clues that Subak

Table 7. Description of respondents on action variable (Act)

Description		Response (%)					Average (mean)
		1	2	3	4	5	
1	The construction of Candung and water plants at the inlet water (act1)	6.6	4.9	53.3	33.0	2.2	3.19
2	The construction of Candung and water plants together with all subak members (act2)	7.1	5.5	54.9	32.4	-	3.13
3	The selection of Candung and water plants that effectively absorb pollutants (act3)	6.6	4.4	57.7	31.3	-	3.14
4	The cultivation of Candung and water plants with economic value (act4)	6.6	4.2	57.9	31.3	-	3.14
5	The preservation of Candung and water plants for all subak members (act5)	6.6	4.4	57.6	31.4		3.14
Action variable (Act)							3.15

Table 8. Description of respondents on potential variable (pot)

Description		Response (%)					Average (mean)
		1	2	3	4	5	
1	Increasing the value of local wisdom of subak (pot1)	3.3	-	49.5	45.1	2.2	*3.43*
2	Producing sustainable healthy food products (pot2)	3.3	2.2	51.1	43.4	-	3.35
3	Creating educational tourist attractions (pot3)	3.3	-	55.5	41.2	-	3.35
4	Adding economic value to all subak members (pot4)	3.3	-	57.7	39.0	-	3.32
5	Preserving biodiversity in the land (pot5)	3.3		57.8	38.9		3.32
Educational tourist attraction potential							3.35

Lepud members tended to believe that the results of the cultivation of candung and water plants have the opportunity to increase the value of local wisdom, create educational tourist attractions, and produce sustainable healthy food products.

Inferential analysis

The inferential analysis used in this research is path analysis. Path analysis is a development of regression analysis that examines the causal relationships that occur in the variables studied, either directly (direct effect) or indirectly (indirect effect). The use of the AMOS program in this study is to help obtain a path diagram model simultaneously. Meanwhile, the use of regression analysis is to obtain a path diagram model that needs to be done in stages.

On the basis of the results of data analysis using path analysis with the decomposition model, namely the causal influence between variables, the factors that can determine the potential of cultivation of candung and water plants in Subak Lepud can be identified. The variables studied include knowledge (know) and experience (exp) as exogenous variables. Meanwhile, intention (intent) and action (act) are identified as intervening (mediation) variables and potential (pot) variables as endogenous variables in the path diagram model.

The path diagram model that is formed needs to be tested for model validation using the total determination coefficient (Dillon et al., 1984) with the following formula:

$$R_m^2 = R_{pe1}^2 \cdot R_{pe2}^2 \cdot R_{pe3}^2$$
$$R_m^2 = 0.429 \cdot 0.494 \cdot 0.607 = 0.1286 \quad (1)$$

where: model validation – 1 - R^2_m;
model validation – 0.9334 or 93.34%.

The results of the model validation mean that the diversity of the data can be explained by the path diagram model of 93.34%, while the remaining 6.66% is explained by other variables (which are not in the model) and errors. Thus, the results of the path analysis can be further explained by decomposing it into standardized regression coefficients. The decomposition of the results of the standardized path analysis (Table 8) shows that the five direct effect pathways have a significant effect (p *value* <0.05). In the indirect effect test using Sobel's test, three significant paths were obtained (p *value* <0.05).

In further explanation, it can be said that *knowledge* has a positive and significant effect on *intention* with a path coefficient (standardized) of 0.308. The results of this analysis indicate that the knowledge of the cultivation of candung and water plants obtained will increase the interest of Subak Lepud members in using candung and water plants on cultivated agricultural land. Likewise, the effect of *experience* on *intention* has a positive and significant influence with a path coefficient (standardized) of 0.393. This result means that the more experienced Subak Lepud members are in the cultivation of candung and water plants, the more interest they have in using candung and water plants on cultivated agricultural land.

The information from Table 9 shows that *intention* has a positive and significant effect on *action* with a path coefficient (standardized) of 0.703. These results provide a direction to increase the interest of Subak Lepud members in cultivating candung and water plants, which will escalate the application of candung and water plants on their agricultural land. In other effects, *intention* has a positive and significant influence both directly and indirectly on *potential*, with a

Table 9. Decomposition of path analysis results (standardized)

Effect	Causal Effect		
	Direct effect	Indirect effect	Total effect
Intention ← Knowledge	0.308^S	-	0.308
Intention ← Experience	0.393^S	-	0.393
Action ← Knowledge	-	0.217^S	0.217
Action ← Experience	-	0.276^S	0.276
Action ← Intention	0.703^S	-	0.703
Potential ← Knowledge	-	0.230^S	0.230
Potential ← Experience	-	0.293^S	0.293
Potential ← Intention	0.526^S	0.221^S	0.747
Potential ← Action	0.313^S	-	0.313

Note: S – significant, NS – not significant.

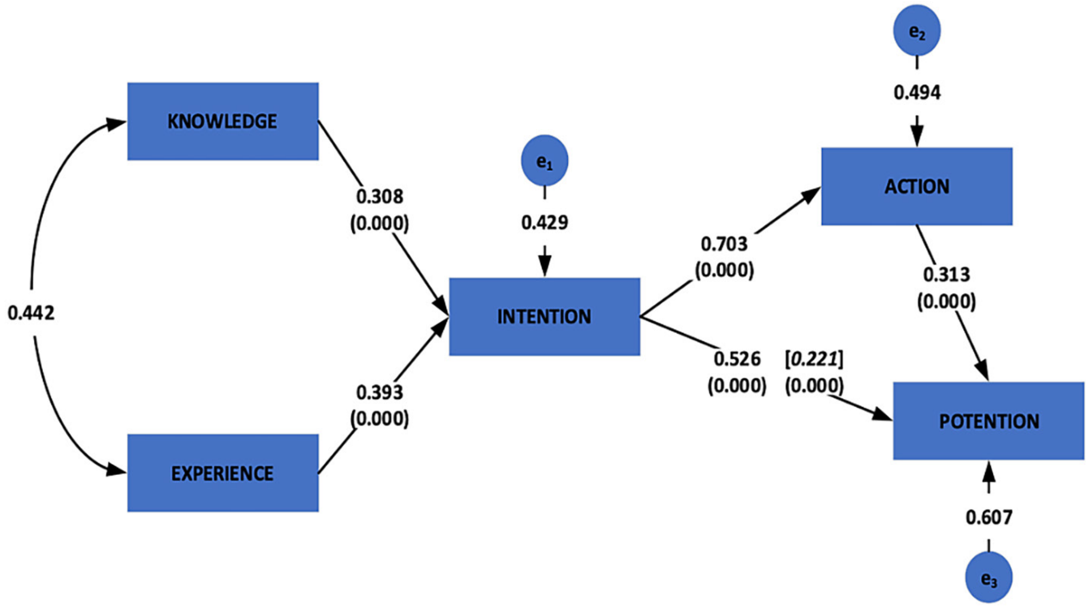

Figure 7. Analysis results path diagram model (Standardized)

direct effect path coefficient (standardized) of 0.526 and an indirect effect path coefficient (standardized) of 0.221. The results of the analysis indicate that the increased interest of Subak Lepud members in cultivating candung and water plants can provide a more promising potential for cultivated agricultural land if it is based on real and serious actions. Meanwhile, the *action* to cultivate candung and water plants was found to have a positive and significant effect on *potential* with a path coefficient (standardized) of 0.313. In order to clarify the results of the analysis obtained, a path diagram model can be presented in Figure 7.

On the basis of the information in Table 8 and Figure 1, it can be found that *intention* derived from *experience* will have a greater impact on the *actions* that Subak Lepud members will take to cultivate candung and water plants if sourced from *knowledge*. This finding certainly further confirms the *potential* obtained by Subak Lepud members from the results of cultivating candung and water plants on cultivated agricultural land.

CONCLUSIONS

Candung is one of the local wisdom in Bali Island, acting as a constructed wetland that aims to maintain the irrigation water before entering the paddy fields. It is also a preservation of the paddy field ecosystem in order to prevent pollution and ensure the food material (rice) is safe. The effect of candung in maintaining the water quality showed a good result in removing the water quality parameters, such as TSS, BOD, COD, and nutrients with certain water plants (*Nelumbo nucifera, Nymphaea tetragona, Pistia stratiotes*). The knowledge, behaviour, and action of the local subak community were still limited, whereas they had positive perceptions and responses about candung's potential as an agrotourism attraction in the village.

Acknowledgements

The authors thank to the National Agency for Disaster Management for funding this research under Bali Ideathon Program year 2021 with contract number K.155/B.01.01/LPPM-UNMAS/VII/2021.

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