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Potential of Vermifiltration Technique to Reduce Chemical Oxygen Demand, Biological Oxygen Demand, and Total Suspended Solid of Farm Dairy Effluent in Developing Countries: Case of Indonesian Farm Dairy Industry

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Abstract: Farm dairy effluent (FDE) contains high level of chemical oxygen demand (COD), biological oxygen demand (BOD), and total suspended solids (TSS) which caused river and groundwater pollution. To reduce those parameters, *vermifiltration* technique was utilized for dairy effluent treatment. It also could reduce greenhouse gas emissions, removing organic and excessive nutrients without odor and recovering manure nutrients in the treated dairy effluent and vermicompost. The objective of this study is to evaluate the potential of vermifiltration in reducing COD, BOD, and TSS of the FDE. Samples of wastewater were collected from dairy farm industry from 3542 of total cow populations located in Bandung regency, Indonesia. The sample characteristics of COD, BOD, TSS, pH, NH_3-N, organic carbon, and macro nutrients (total N, P_2O_5, and K_2O) were measured before and after vermifiltration treatment. Vermifiltration treatment will produce two types of products, i.e., tea water and vermicompost. The result showed that vermifilter removed the COD, BOD, and TSS of 93%, 95%, and 93%, respectively. The organic carbon NH_3-N and total macro nutrients generally decreased after treated by vermifilter (2.01 to 0.0001% of organic carbon, 718 to 3.75 mg L^{-1} of NH_3-N, 0.2 to 0.02% of total N, 0.19 to 004% of P_2O_5, 0.57 to 0.18% of K_2O); however, the pH was not significantly changing (from 8.13 to become 8.05). Vermicompost produced by vermifiltration beds by earthworms consumes sewage solids and excreting them in the vermicast which produces high macronutrients (2.4% of total N, 5.5% of P_2O_5, and 0.75% of K_2O), and organic carbon (15.6%), hence beneficial for soil fertilizer. Vermifilter effectively degrades the organic matter in the dairy effluent. Derivatives produced by the vermifiltration process, namely tea water and vermicompost, can be used as substitutes for irrigation materials and organic fertilizers on agricultural land and act as soil conditioners to improve soil properties.

Keywords: farm dairy effluent (FDE), vermifilter, vermicompost, COD, BOD, TSS

1. Introduction

Application of organic material to the soil is one of the most effective ways to increase soil carbon sequestration. This process involves increasing the amount of organic matter in soil, which in turn increases the amount of carbon stored in the soil. Sustainable management practice is one of way to achieve soil sequestration by the increasing of C (carbon) stock and reducing greenhouse gas (GHG) emissions [1]. Farm dairy effluent (FDE) can be applied to soil to increase soil carbon and improve soil fertility [2] because it contains organic matter and essential elements. When organic materials are added to the soil, the carbon is broken down by soil microorganisms and incorporated into the soil organic matter [3]. Studies have shown that the application of FDE to soil can increase the soil's mineralization potential and improve its microbial activity and functional diversity [4]. The mineralization of FDE in the soil can also contribute to the release of nitrogen and other nutrients that can be taken up by plants [5]. FDE refers to the liquid waste generated from dairy farming operations, such as milking parlors, barns, and feedlots [6]. This type of waste typically contains a mixture of water, urine, manure, and other materials such as feed, bedding, and cleaning agents. In developing countries such as Indonesia, the land application of FDE is a common practice for managing the waste generated from

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dairy farming operations. The Indonesian government recognizes the potential benefits of using dairy effluent as a fertilizer, including reduced waste volume, improved soil fertility, and increased crop yields [7]. However, FDE must be treated before irrigating to pasture or grassland. Meanwhile, in New Zealand, land application of FDE has been the alternative way to minimize the surface water contamination risk and to change cultural concerns about the addition of waste material to waterways [2].

Dairy effluent can have negative impacts on the environment if not properly managed, as it contains high levels of biological oxygen demand (BOD), chemical oxygen demand (COD), and total suspended solids (TSS) and nutrients such as nitrogen and phosphorus, as well as pathogens and other contaminants [8–10]. All those pollutants parameter could cause water pollution, soil degradation, as well as other environmental problems. The levels of BOD, COD, and TSS in FDE can vary depending on several factors, including the type of dairy operation, the composition of the feed and bedding materials, and the methods used to manage and treat the waste. Untreated FDE has a high COD content of over 15,000 mg/L and a BOD concentration of about 2,000 mg/L [9]. The COD level in dairy effluent is also high and reflects the amount of oxygen required to chemically break down the organic matter in the waste. The COD level can range from several 1000 to 10,000 mg/L [11] TSS refers to the amount of solid material suspended in the waste and can contribute to water quality problems such as turbidity, clogging of irrigation systems, and reduced light penetration in aquatic environments. TSS levels in dairy effluent can range from 100 to 1000 mg/L.

Most dairy farm in Indonesia uses a solid–liquid separation method to manage dairy wastewater. Solid manures are composted and used for grassland as organic fertilizer or as bedding. The liquid usually treated anaerobically in lagoons or reservoirs to waiting recycling as flushing water for cowshed and irrigating pasture and crops. However, Kupper et al. [12] state that the anaerobic lagoon creates suitable environments for methanogens which produce methane (CH_4). Therefore, there is a need to mitigate lagoon emissions while converting savings into carbon credits. Carbon credits are quantifiable and verifiable emission reductions that limit GHG emissions [13]. A sustainable wastewater treatment technology is required to reduce gas emissions from lagoons or dairy wastewater storage.

Vermifiltration is a sustainable technology for dairy effluent treatment with the advantages of reducing GHG emissions, removing organic and excessive nutrients without odor and recover manure nutrients in the treated dairy effluent and vermicompost [14]. Its technology has been tested to treat several types of wastewaters such as urban even dairy wastewater. Tomar and Suthar [10] state the vermifiltration significantly reduces the level of TSS, TDS, COD, NO_3-, and PO_4^3- urban wastewater with value at 88.6%, 99.8%, 90%, 92.7%, and 98.3%, respectively. Furthermore, Sinha and Bharambe [9] conducted a study on the dairy wastewater treatment using vermifilter which showed the removal efficiency of BOD, COD, and solids was 98%, 80–90%, and 90–95% [15].

The effective management of dairy wastewater poses a significant challenge in developing countries where there exists limited infrastructure and resources for wastewater treatment [16]. In terms of resources for research, development, and deployment of advanced technologies for dairy wastewater treatment, developed countries tend to have the upper hand. A technology of recent interest is vermifiltration, which involves the use of earthworms to decompose organic matter in wastewater. In the United States, numerous dairy farms have successfully adopted vermifiltration systems for treating their wastewater, resulting in enhanced water quality and decreased environmental impact [17, 18].

The objective of this research was to evaluate the affectivity of vermifiltration in reducing COD, BOD, and TSS of FDE and to investigate the several chemical characteristics of treated and untreated FDE. The results of the earthworm filtration wastewater treatment derivatives obtained were analyzed to investigate their properties, especially on the organic carbon and nutrients content.

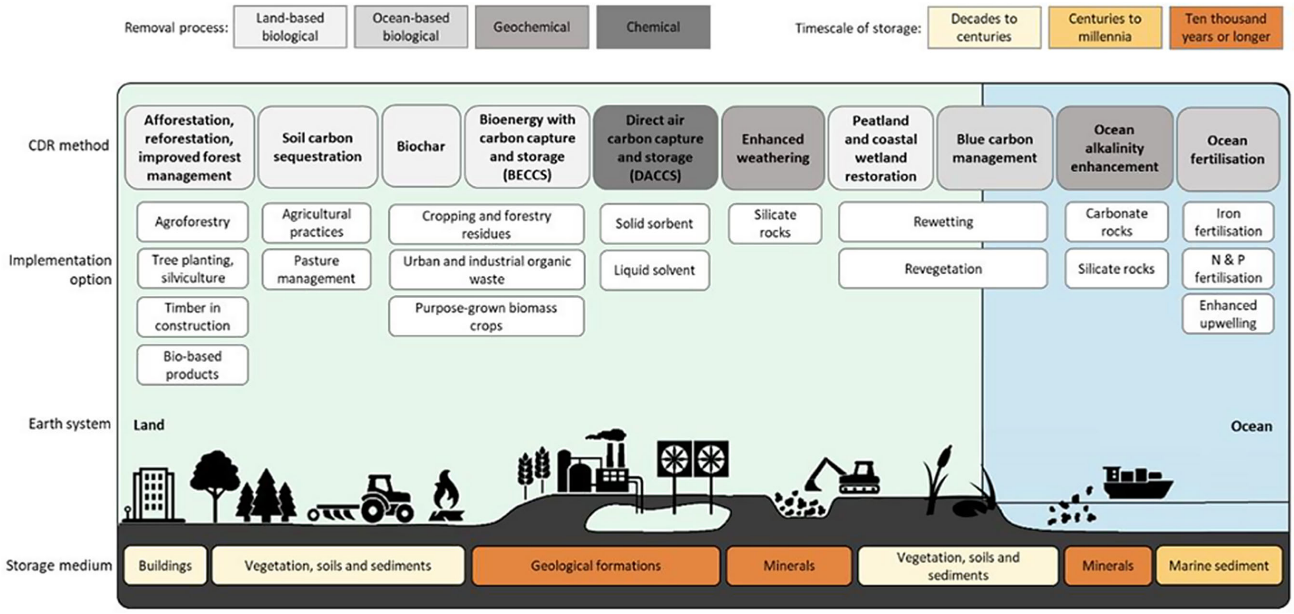
2. Literature Review

Human activities, principally through emissions of GHGs, have unequivocally caused global warming, with global surface temperature reaching 1.1°C above 1850–1900 in 2011–2020. Global GHG emissions have continued to increase, with unequal historical and ongoing contributions arising from unsustainable energy use, land use and land-use change, lifestyles and patterns of consumption and production across regions, between and within countries, and among individuals. From a physical science perspective, limiting human-caused global warming to a specific level requires limiting cumulative CO_2 emissions, reaching at least net zero CO_2 emissions, along with strong reductions in other GHG emissions. Reaching net zero GHG emissions primarily requires deep reductions in CO_2, methane, and other GHG emissions and implies net-negative CO_2 emissions. Carbon dioxide removal (CDR) will be necessary to achieve net-negative CO_2 emissions. Net zero GHG emissions, if sustained, are projected to result in a gradual decline in global surface temperatures after an earlier peak (Intergovernmental Panel on Climate Change, [19]). Figure 1 [20] depicts various CDR: afforestation/reforestation, soil carbon sequestration, biochar, etc.

One of the CDRs is soil carbon sequestration which refer to the efforts for enrichment soil organic carbon through composting, mulching, and application of treated FDE. Over the past few years, land application of FDE onto pasture has been conducted in several countries to avoid the surface water contamination risk and to change cultural concerns about the addition of waste material to waterways in New Zealand [2]. However, its application on soil has a limitation as it can lead to a decrease in surface water quality by increasing nitrate levels in groundwater [6]. The FDE containing dairy wastewater, fecal runoff, or a mixture of both has relatively low nutrient loads, confirming that their application rates should be between 205 and 2050 m^3 ha^{-1}, depending on the management system used [21]. Hence, FDE need to be treated before irrigating onto pasture as land application to reduce the toxicity pollutants and to avoid ground water contamination.

The dairy wastewater typically contains high levels of organic matter, nutrients, and suspended solids, which can lead to eutrophication and other environmental problems if discharged untreated. Therefore, discharging untreated dairy wastewater into streams will cause a serious problem of dissolved oxygen [11]. Nitrates have accumulated to a level that is associated with a potential environmental risk to groundwater contamination, so it is necessary to treat wastewater prior to application to pastures or crops to control their accumulation [22]. There are various types of

Figure 1
The taxonomy of carbon dioxide removals (CDRs) [20]



dairy wastewater treatment methods available, depending on the specific characteristics of the wastewater and the desired effluent quality. The anaerobic granular sludge sequential batch reactor can reduce 90% of COD, 80% of total nitrogen, and total 67% of phosphorus, at 8 h hydraulic retention time. However, its wastewater treatment has certain drawbacks, namely high energy consumption, cycle times that are difficult to adapt to small communities, and frequent disposal of sludge [23]. Another wastewater treatment that often used is by anaerobic treatment in lagoons or ponds to await recycling of organic compounds; nonetheless, it contributes to produce CH_4 and bad odors [12]. Vermifiltration system of sewage treatment is low energy dependent and has distinct advantage over all the conventional biological wastewater treatment systems – the "Activated Sludge Process," "Trickling Filters," and "Rotating Biological Contactors" which are highly energy intensive, costly to install and operate, and do not generate any income [15].

Vermifilter is an extension of soil filtration or biofiltration with earthworms to accelerate the decomposition process, using organic matter to produce fresh manure that can be used in agriculture to support healthy crop production [8]. The vermifilter remains unclogged due to the worms' burrowing activity, which enhances air circulation and promotes the movement of soil microorganisms. As a result, this boosts the population of soil microorganisms, leading to a faster breakdown of ingested organics [11]. During vermicomposting, earthworms ingest nearly their own weight of organic matter each day and excrete 60% of that weight as manure [24]. Vermifilter is a relatively new technology that treats organically contaminated wastewater using earthworms. In this technology, microorganisms play an important role in the worm filtration system and they also provide extracellular enzymes to facilitate the rapid decomposition of organic matter in the worm filter bed [10]. According to Choudhary and Medok [25], vermifiltration effectively removes the pollutants from wastewater and positively impacts on the environment. Centralized wastewater treatment also contributes to climate change because it produces GHGs that account for about 3–7% of total emissions [8].

Many studies are conducted to investigate the utilization of vermifiltration on FDE in reducing the toxicity pollutant especially on COD, BOD, and TSS level. The removal efficiency of BOD, COD, and solids of dairy wastewater after being filtered by vermifilter is 98%, 80–90%, and 90–95% achieved [9]. This study was in line with study by Choudhary and Medok [25] which results that the presence of earthworms in the vermifilter layer could effectively remove BOD and COD of 83.51% and 83.33%, respectively. Vermifilter produces two types of products, namely tea water and vermicompost. Vermicompost is a type of compost that is produced through the process of vermicomposting, which involves the use of earthworms to break down organic matter and produce a nutrient-rich soil amendment. The vermicompost filtration of the treated wastewater can be used for irrigation purposes and bio-fertilizer; vermicompost instead of unwanted sludge is also obtained [26]. The tea water also can be used as natural pesticide or fungicide to protect the plant from disease [27]. Vermicompost has several benefits for plant growth and soil health, including improving soil structure, increasing soil fertility, and enhancing plant growth and nutrient uptake [28]. It is also a sustainable and eco-friendly alternative to chemical fertilizers and can help to reduce waste and improve soil health.

3. Research Methodology

This study was conducted at the dairy farm industry located in southern Bandung, Indonesia, in August 2022 until October 2022. The effluent used in this study was obtained directly from the cowshed (flushing + manure) without going through a sedimentation process and separation treatments (untreated effluent). The collected samples were analyzed before being treated by using vermifilter to identify the initial characteristics of the effluent. Vermifilter was made by using drums with a volume capacity of 200 L and consists of gravel at the bottom layer with a volume of 20 L (1–2 cm) and 80 L of compost as a medium for earthworm growth. The compost produced by using a solid–liquid separation method (using separator) to manage liquid or slurry dairy manure and solid materials. The earthworm was added on the bed media at 5 days after loading the effluent. The number of worms that used as a decomposer is 500 g/drum. During the 80 days acclimation period, the effluent or slurry was added to vermifilter bed every day with a volume of 6 L/day.

The filtered leachate or tea water is collected for analysis on several parameters, namely COD, BOD, TSS, NH_3-N, and pH. Nutrient content was analyzed before and after vermifilter treatment of slurry. The standard method APHA 23rd 5210:2017 was used to measure BOD levels in the laboratory, which involves filling a diluted sample and inoculating, until overflow, into an airtight bottle of the specified size and incubating at specified temperature for 5 days. The COD was analyzed using potassium dichromate oxidation method following SNI 6869.2:2019 and measured with spectrophotometry. The TSS was measured with filtration and gravimetric and oven drying methods following SNI 6869.3:2019 [29]. NH_3-N was analyzed with distillation and titration method following SM APHA 23rd 4500:2017. The pH of tea water and slurry was measured with potentiometric method following SNI 6869.11:2019.

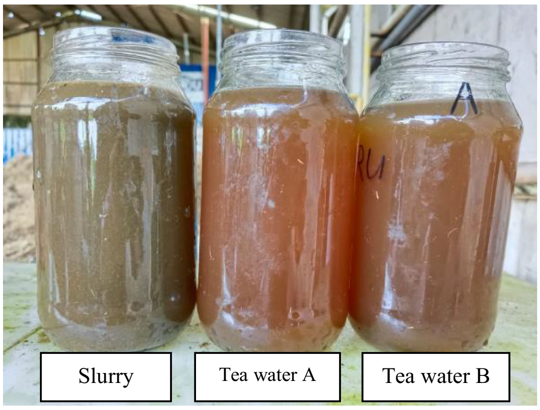
Vermicompost is analyzed to investigate the nutrient content (total nitrogen, phosphorus, and potassium) and other chemical properties (water content, pH, and organic carbon). Total N was measured with Kjeldahl method, which consists of digestion, distillation, and titration. Total P and K were analyzed with HNO_3 and $HClO_4$ oxidation and measured by spectrophotometry for P and atomic absorption spectroscopy for K. The organic C was measured with dry combustion method using furnace at temperature around 550–600°C. The vermifilter system was cost effective, 60–70% of cost reduction in managing FDE [30].

4. Result and Discussions

The study found that by loading 6 L of slurry can produce 3–3.5 L of tea water per day. Tea water can be obtained after the fifth day of watering on vermifilter media. FDE treatment using a vermifilter can remove the odor in the slurry after it is filtered into tea water. According to Sinha et al. [15], vermifilter is a process that is free from odors, resulting in clean and odorless water. Earthworm growth was observed during the study to see if the worms could survive or not after slurry application. At 80 days after watering, the vermifilter media was unloaded to harvest the earthworm and compost as organic fertilizer.

In this study, we found that adding FDE to vermifilter not only reduced toxic pollutants but also provided food for farmed earthworms, thereby increasing earthworm body weight and populations. The earthworms can live and reproduce well as indicated by the increase in total weight when harvested. The weight of earthworm increased up to 50% compared to the initial weight. Similar study was conducted by Raksasat et al. [31] which irrigate the combination of sewage and palm kernel oil expeller (PKE) into black soldier fly larvae bed media; the larval weight increased when PKE was blended into sewage sludge in G2 (4:1) and G3 (3:2) mediums, reaching the greatest value, 46.99 ± 2.09 mg/larva. The difference between effluent in slurry and tea water can be seen in Figure 2. The color of tea water is clearer than the slurry. Vermifilter can reduce sedimentation in tea water by up to 90% so that it can be used as a land application.

Figure 2
Physical appearance of slurry and tea water solutions



4.1. Changes of COD, BOD, and TSS after treatment

Levels of COD, BOD, and TSS of slurry and tea water are shown in Table 1. High COD levels can indicate the presence of toxic substances or other pollutants. The effluent management system by using vermifilter significantly decreases the COD levels from 14.729 to 1.089 mg/l. The tea water that resulted from the filtering of slurry showed the lowest COD compared to its value before treatment. The COD level of effluent effectively reduces up to 93% after being treated with a vermifilter system. It was in line with the study conducted by [24] which reduced the COD of urban wastewater to 87.6% after being treated by vermifilter. Vermifilter can reduce COD of FDE waste by 6% over municipal wastewater. This is because the COD content of FDE waste is much higher than municipal wastewater. Therefore, using vermifilter is very effective and convenient. This indicates that earthworm effectively degrades the organic matter in dairy effluent.

The BOD level of slurry decreases up to 95% after treatment by the vermifilter which started from 6062 to 316 mg/L (Table 1). Similar response was found by Sinha et al. [15] which results that vermifilter can reduce BOD of sewage by up to 95%. The results of this study show that the BOD values of untreated dairy wastewater (6062 mg L^{-1}) are higher than the treated dairy wastewater by vermifiltration (316 mg L^{-1}). This study found that vermifiltration system is effective in treating FDE.

Table 1
Percent removal of COD, BOD, and TSS after vermifiltration treatment

Characteristics	Sludge (before treatment)	Tea water (after treatment)	Percent removal
COD (mg L^{-1})	14,729	1,089	93%
BOD (mg L^{-1})	6,062	316	95%
TSS (mg L^{-1})	7,502	520	93%

Figure 3
Decreased levels of COD, BOD, and TSS from FDE after being treated into tea water

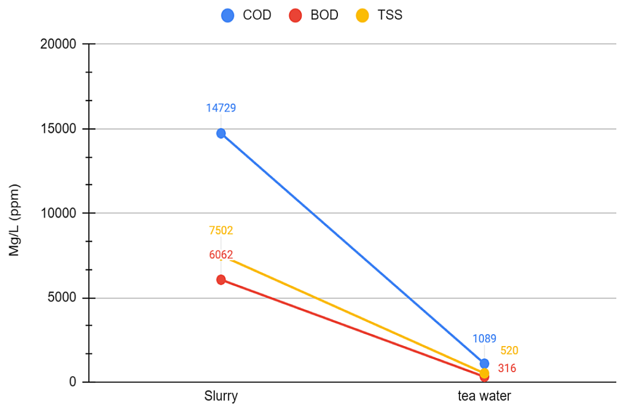


Table 2
Chemical characteristics effluent before and after treatment

Characteristics	Sludge (before treatment)	Tea water (after treatment)
NH_3-N (mg L^{-1})	718	3.75
pH	8.13	8.05
Organic carbon (%)	2.01	0.0001
Total N (%)	0.2	0.02
Total P_2O_5 (%)	0.19	0.004
Total K_2O (%)	0.57	0.18

High levels of TSS can be problematic, as they can clog irrigation equipment, reduce soil permeability, and increase the risk of water pollution. TSS level of effluent reduced from 7502 mg/L to 316 mg/L after filtered by vermifilter. In this study, vermifilter reduced 93% the TSS level of effluent, higher than the research resulted by Telang and Patel [30] which only reduced TSS level only to 84.27%. In general, wastewater treatment by using vermifilter is effective in reducing TSS levels in FDE [11]. These practices can help to remove solids from the effluent before it is applied to land, reducing the risk of environmental damage and ensuring that nutrients are used efficiently.

Percent removal of COD, BOD, and TSS after treatment results in 93%, 95%, and 93% respectively, as depicted in Figure 3. The FDE treatment using the vermifilter performed in this study showed very good results in reducing toxic pollutants. Even beyond the effectiveness of some studies that have been done before. Sinha et al. [15] discovered that the earthworm's body serves as a "biofilter," effectively eliminating over 90% of 5-day BOD, 80–90% COD, 90–92% TDS, and 90–95% TSS from wastewater. This is achieved through a general mechanism involving the "ingestion" and biodegradation of organic wastes, heavy metals, and solids from the wastewater, as well as the "absorption" of these substances through their body wall. The tea water which produced by vermifiltration resulted in lower COD, BOD, and TSS than slurry so that it can be used for the irrigation of agricultural land.

4.2. Changes of chemical characteristic after treatment

FDE can contain a significant amount of ammoniac nitrogen (NH_3-N), as it is a by-product of the decomposition of organic matter and animal waste. The concentration of NH_3-N in FDE can vary depending on factors such as the number of cows, the diet of the cows, and the management practices used to handle the effluent. In this study, the FDE in slurry form resulted in higher NH_3-N than the tea water (after treatment) with value at 718 mg L^{-1} and 3.75 mg L^{-1}, respectively. Result show that the NH_3-N removed from the FDE by vermifilter until 99% after treatment. The vermifilter bed media absorbs NH_3-N from FDE so that its concentration in tea water becomes much lower. Miito et al. [32] mentioned that the vermifilter system reduces emissions by 84–100% for NH_3, 95–100% for CH_4, and 58–82% for CO_2. This means that the vermicomposting process by worms is more efficient at retaining nitrogen (N) rather than releasing it as nitrous oxide (N_2O) [33]. According to the New Zealand Dairy Effluent Design Code of Practice, the average concentration of NH_3-N in FDE is typically in the range of 200–1500 mg L^{-1}, with peak concentrations during periods of high cow numbers or heavy rainfall events. This high concentration of NH_3-N in FDE (718 mg L^{-1}) can pose a risk to water quality if not managed carefully.

After vermifiltration treatment, the effluent pH not significantly changed but tends to lower. Both pH values were included in the alkaline criteria. Based on study by Sinha et al. [15], the pH value of FDE is almost neutralized by worms in the worm filter. It was similar to organic C that decreases after treatment from 2.01% to <0.0001%. FDE treatment by using vermifilter has even been reported to achieve organic removal efficiencies of up to 95%, depending on their retention time and the number of earthworms applied [26]. As the wastewater passes through the vermifilter media, the earthworm living media (compost) absorbs a significant portion of the solid content from the organic material, leading to a reduction in the organic C content. Solid compost, called vermicompost, can be applied as an organic fertilizer to increase essential nutrients and organic carbon of the soil. High organic carbon content also has a positive effect on providing food for microorganisms in the soil to increase their numbers.

The chemical characteristics of effluent before and after treated by vermifiltration were shown in Table 2. Macro nutrient such as total N, P_2O_5, and K_2O decreases with values 0.2% to 0.02%, 0.19% to 0.004%, and 0.57% to 0.18%, respectively after treated by vermifilter. The FDE tends to have higher potassium linier to its pH value, which is alkaline. Potassium is one of the alkaline cations that can increase the pH value when the concentration is high. Vermifilter bed media is also reported to serve as a means of absorption, enhancing nutrient removal [33]. Removing the nutrient content of FDE can reduce the risk of groundwater contamination, especially by ammonia and phosphate. In addition, total nitrogen and total phosphorus have been reported to be reduced by more than 10% in worm filters compared to activated sludge systems; NH_4^+-N was also reduced three times more in vermifilter [8]. In this study, total nitrogen, phosphorus, and potassium on tea water decreased by 90%, 98%, and 68% respectively. According to Dore et. al. [14], the phosphorous from dairy effluent was reduced by 84% (±8%) after treated by vermifilter. Due to the low concentration of nitrogen and phosphate in the tea water, the land's groundwater is safe despite regular irrigation.

4.3. Vermicompost characteristics

The earthworm bed media used is the result of separation between liquid and solids from effluent using a separator. It is referred to as semi compost because it still requires time and an incubation process before it is said to be compost. The characteristics of semi compost before and after load by FDE are

Table 3
Characterization of the compost before and after used as a vermifiltration media

Characteristics	Semi compost/ earthworms' bed (before loading the FDE)	Vermicompost (after loading the FDE)
Water content (%)	39.05	12.03
pH	7.0	7.5
Organic carbon (%)	15	15.6
Total N (%)	2.0	2.4
Total P_2O_5 (%)	2.1	5.5
Total K_2O (%)	0.15	0.75

shown in Table 3. Vermicompost (produced by earthworms in the vermifiltration bed because of eating sewage solids and excreting them with vermicast) is an excellent site for adsorbing heavy metals and contaminants in dairy wastewater [34]. The produced vermicompost by vermifilter has higher organic C and macronutrients after irrigating by the FDE. The increase in organic C and macronutrients after wastewater irrigation indicates that FDE has a rather high organic matter content.

Based on analysis result in Table 3, the semi compost resulted in higher water content than vermicompost with each value at 39.05% and 12.03%, respectively. After vermicomposting process, the water content of compost decreases up to 69% from the initial values. Vermicompost produced during the FDE's filtering process has higher organic carbon, total N, P_2O_5, and K_2O values with values of 15.6%, 2.4%, 5.5%, and 0.75%, respectively than compost produced before the FDE's loading, which has values of 15%, 2.0%, 2.1%, and 0.15%. In worm composting, earthworms have been found to convert organic matter into FDE, absorb the organic matter by its own weight, and excrete 60% of this weight [24] as a humus-, nutrient- and microbial-rich cast [33]. When loading FDE, organic matter accumulated in the vermicompost layer will then be consumed by earthworms and microorganisms to break down into nutrients and humus.

In general, macro nutrients in vermicompost tend to be higher than the semi compost. This is due to the addition of sewage to vermicompost, which contains many nutrients, and the activity of microorganisms that can break down organic matter into inorganic compounds. During the composting process, the organic matter in the effluent and vermifilter media undergoes an overhaul which produces several products, namely humus and mineral nutrients. The FDE used in this study has a high nutrient content, especially phosphorus.

Vermicompost or vermicast, also known as worm castings, is the organic material that is produced by earthworms as they digest organic matter such as food scraps, plant material, and other organic wastes. The participation of earthworms enhances the natural biodegradation and degradation of organic waste by 60–80% compared to conventional aerobic and anaerobic composting [33]. It contains a high concentration of beneficial microorganisms, enzymes, and plant nutrients, such as nitrogen, phosphorus, and potassium that can improve soil health and plant growth. Application of vermicompost to the soil has a beneficial effect as a soil ameliorant that can improve soil properties.

5. Conclusion

Vermifiltration is a low cost and eco-friendly technology which is recommended as the solution for dairy effluent treatment. Tea water produced by vermifiltration process resulted in odorless and clearer solution than the slurry. The sediments are reduced by up to 90% so it can be used for irrigation on land (land application) and flushing the barn cleaner. This study shown that application vermifilter in this study is highly effective by removing 93%, 95%, and 93% of COD, BOD, and TSS, respectively. Ammonia nitrogen in tea water was significantly reduced up to 99% after treatment. Hence, it can reduce the risk of groundwater contamination and will be safe when applied to the soil. Potential of tea water in application on pasture or grassland need to be investigated for its impact on soil and plant. The low content of BOD, COD, and TSS in tea water can certainly be an alternative to irrigating agricultural land during the dry season which requires a lot of water. Although small, tea water contains essential nutrients such as nitrogen, phosphorus, and potassium that plants need to grow and develop, reducing fertilizer and labor costs.

The vermicompost produced from the vermifiltration process contains humus, macronutrients, and organic carbon that are beneficial to the soil and plants if applied. It can be used on agricultural land even grassland as part of soil carbon sequestration, i.e., organic fertilizer to improve soil properties and plant production. Vermicompost application can reduce the use of synthetic fertilizers and even completely replace it when used regularly, to increase cost efficiency in the cultivation of grass as animal feed. Therefore, vermifiltration has a potential to apply in commercial scale on dairy industries as wastewater treatment because it is provided positive impact on the environment, economy, and people.

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Ethical Statement

This study does not contain any studies with human or animal subjects performed by any of the authors.

Conflicts of Interest

Joni Jupesta is an editorial board member for *Green and Low-Carbon Economy*, and was not involved in the editorial review or the decision to publish this article. The authors declares that they have no conflicts of interest to this work.

Data Availability Statement

Data available on request from the corresponding author upon reasonable request.

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