Enrichment of Soil and Local Materials to Purify Pollutant Indicators in Wastewater on Smallholder Cattle Farms in Indonesia

Aflizar[1], Amrizal[3], Saifullah P. Melafu[4], M. Septian[2], Farez Z. Melafu[5] and Jamaluddin[6]
[1]*Applied Master of Food Security Study Program, Politeknik Pertanian Negeri Payakumbuh, Indonesia*
[2]*Agricultural Mechanization Technology Study Politeknik Pertanian Negeri Payakumbuh, Indonesia*
[3]*SMA Negeri No.2 Kodya Payakumbuh, Bukit Sitabur Payakumbuh Timur, Indonesia*
[4]*Agricultural Water Management Study Program Teknologi Pertanian, Politeknik Pertanian Negeri Payakumbuh, Indonesia*
[5]*SMA Negeri No. 3 Kodya Payakumbuh, Nan Kodok Payakumbuh Utara, Indonesia*
[6]*Agricultural Water Management Study Program Teknologi Pertanian, Politeknik Pertanian Negeri Payakumbuh, Indonesia*

Keywords: Wastewater, Cattle Farm, STBM, Ecotechnology, Soil of Mt. Sago, Local Material.

Abstract: To purify the pollutants Cattle Farm Wastewater, a STBM system was built. Cattle Farm Wastewater that smells bad with pollutant indicators exceeds the quality standards allowed by the Indonesian government. There are two main components that make up the STBM system, namely The Permeable Layer (LP) is made of palm fiber and a layer of crushed stone arranged around a Mixed Soil Layer (LTC) composed of a Permeable Layer (LP) made of fibers and a layer of crushed stone arranged around a Mixed Soil Layer (LTC) arranged in a stone pattern brick. LTC raw material is a mixture of clayey clay, sawdust from coconut trees and iron waste from a lathe with a dry weight ratio of 3: 1: 0.04 where this local material is native to Indonesia. In this experiment, a field scale STBM system was built with dimensions (50 cm long x 50 cm wide x 200 cm high). Sources of wastewater cattle farm pollutants come from urine, feces and water for washing cow pens. Generally, wastewater is discharged directly into the surrounding environment so that it has polluted the waters. By using the force of gravity, cattle waste water is discharged into the STBM system with a hydraulic loading rate (HLR) of 34,6 M^3/m^2/day. Average removal efficiency of Total Suspended Solids (TSS) , Biochemical Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD), Nitrate-Nitrogen (NO_3^--N), Phosphorus (PO_4^- -P) , Oils and Greases, salinity (EC), Total Dissolved Solid (TDS) and salt (NaCl) were 82, 96, 63, 74, 96, 68, 99, 96 and 81 % respectively. The STBM system is also able to remove colors and odors in cattle farm wastewater. This study recommends that the STBM system is good for removing contaminants from cattle farm wastewater in rural and urban areas in Indonesia because it is efficient and able to remove BOD, phosphorus, nitrogen, EC, TDS, NaCl, colors and odors with simple operations.

1 INTRODUCTION

Public and privately owned cattle farms are widespread in rural areas in Indonesia. In general, the liquid waste that is produced poses a big problem because it is discharged directly into the environment without being processed, causing an unaesthetic odor and polluting the waters. In fact, in the countryside there are many cattle farms that support the economy of the small people. Unfortunately, the impact of environmental pollution has been forgotten. Few cattle ranchers are aware that cattle ranching wastewater has caused damage to ecosystems and subsequently the extinction of certain organisms and a decrease in water quality in rural areas in Indonesia.Wastewater which is generally discharged into waters contains high concentrations of nutrients, organic matter and pathogens, causing serious problems. One solution is to treat the liquid waste itself to purify the pollutants contained in it (Lahbib LATRACH1, 2014). There is no cheap and easy-to-operate technology that is made from native Indonesian materials, so the STBM system is introduced in Japan, known as the MSL system.The technology to treat wastewater such as wetland lagoon and sand filter works well (Masunaga T, 2007). However, it requires a large area of land and

Aflizar, ., Amrizal, ., Melafu, S., Septian, M., Melafu, F. and Jamaluddin, .
Enrichment of Soil and Local Materials to Purify Pollutant Indicators in Wastewater on Smallholder Cattle Farms in Indonesia.
DOI: 10.5220/0011818400003575
In *Proceedings of the 5th International Conference on Applied Science and Technology on Engineering Science (iCAST-ES 2022)*, pages 526-531
ISBN: 978-989-758-619-4; ISSN: 2975-8246

the price is still too expensive for developing countries (Lahbib LATRACH1, 2014). Activated carbon oxidation adsorption technology, chemical oxidation and digestion methods have good performance but are still expensive and difficult to operate. One of the simple, inexpensive and simple technologies in operation for wastewater treatment, the MSL system or in Indonesia is popularly known as STBM (Sistim Tanah Berlapis Melafu). The STBM system has succeeded in purifying liquid waste in Japan and Indonesia. Furthermore, this STBM system has also been tested in China, in Thailand, in the United States, in Morocco to purify domestic wastewater and wastewater from tofu factories in Indonesia (Rahmiana Zein, 2017). It called MSL system.

The STBM system is made from natural soil and local materials, the structure is innovative so that it is not easily clogged and is able to treat wastewater with a high flow rate and is able to reduce nutrients and organic matter in the wastewater. The STBM system has the advantages of flow rate (HLR), high simple maintenance and an effective service life of 20 years. STBM systems can be made from locally available materials in rural and urban areas such as soil, iron pellets, sawdust. According to (Masunaga T, 2003) the MSL or STBM system has an aerobic layer and an anaerobic layer where the aerobic permeable layer is based on zeolite or split rock. Meanwhile, mixed soil layers that are anaerobic can be arranged based on a brick pattern or imitate a soil horizon pattern. The wastewater that enters the MSL or STBM system is then purified by filtration, reabsorption and biodegradation.

In this study, an STBM system with a height of 2 (two) meters was made with raw materials derived from local natural resources, namely inceptisol soil, sawdust, palm fiber and crushed stone to purify pollutants and contaminants in cattle farm wastewater. This study aims to assess the performance of the STBM system in purifying physicochemical pollutants contained in cattle farm wastewater in Indonesia.

2 MATERIAL AND METHODS

2.1 Description of Experimental Soil and Local Material Enrichment as STBM System

The STBM system consists of 2 (two) main components, namely a mixed soil layer (SML) and a permeable layer (PL) made of split stone (3-4 cm diameter) and palm fiber (*geotextile*). The structure of the STBM system in the field used in this study is presented in Figure 1. In the installation of the STBM system for the experiment, holes were made on a sloping land (200 cm high, 50 cm wide, 50 cm long). The mixed soil layer is arranged in a brick pattern surrounded by a layer of gravel and palm fiber. The mixed soil layer was made from local sandy loam soil (*Inceptisol*) mixed with sawdust from coconut trees (*Cocos nucifera*), iron pellet waste from a lathe with a ratio (3 : 1 : 0.04) each based on dry weight. (Figure 2 a, b, c, d). Iron pellets from a lathe were cut to a size of 2 cm and sawdust from coconut trees (1–2 mm), (Fig. 2 d, e). The basic chemical and physical properties of the soil used were Total Kjedahl Nitrogen 4.8 g/kg, C-organic 6.37%, pH 5 with texture sandy clay loam (order Inceptisol) and blackish brown soil color. Wastewater from cattle farms from the rest of cow dung, urine and bathing cows which smells foul is collected from the beef cattle fattening pen at the Politeknik Pertanian Negeri Payakumbuh (Figure 2 f, g). The wastewater tank is installed above the STBM system and by gravity, the cattle farm wastewater is channeled or discharged into the STBM system. Wastewater is taken twice a week and discharged into the STBM system at a Hydraulic Loading rate (HLR) of 34,6 M^3 /m^2/day. Aeration or natural air flow from pipes placed above the STBM system which aims to create aerobic and anaerobic conditions in the STBM system (Figure 1).

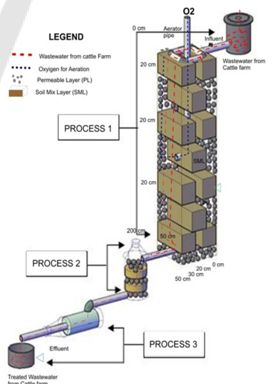

Figure 1: Structural Design of Brick Type STBM system to purify pollutants in cattle farm wastewater.

At almost the same time raw and foul-smelling cattle farm wastewater and cattle farm wastewater that has been treated by this system are collected about once a month for testing the chemical and physical pollutant parameters collected by plastic bottles on the influent and effluent of the STBM system.

Figure 2: Materials for STBM system, Wastewater Source from Cattle Farm and brick type STBM system: (A) Local soil, (B) sawdust, (C) iron pellets, (D) split stone, (E) palm fiber, (F) Cattle farming (G) Wastewater from cattle farms, (H) STBM system brick arrangement (i) the STBM system is installed underground.

2.2 Analytical Methods in the Laboratory

Samples of cattle farm wastewater before being processed and after being processed STBM were stored in a refrigerator at a temperature of 4oC as much as 1000 ml at each sample point. In the analysis of chemical parameters of wastewater such as oil and fat (grease and oil) were analyzed gravimetrically using hexane solvent and a separating funnel. Nitrogen nitrate (NO_3^--N) concentration was analyzed by concentrated sulfuric acid method and measured by Genesys 10s UV-VIS Spectrophotometer with a wavelength of 432 nm. Phosphate concentration (PO4-P) was measured by molybdate method and ascorbic acid was measured by Genesys 10s UV-VIS spectrophotometry. Chemical Oxygen Demand (COD) was analyzed by dichromate reflux method. Biochemical Oxygen Demand was measured in 5 test days (BOD5) using the Warburg method. Salt (NaCl), Total Dissolved Solid (TDS),

Electrical Conductivity (EC) and pH were measured using a multiparameter probe with the Mi 170 Bench meter. For testing physical parameters such as suspended solids analysis (TSS) with the gravimetric filtration method. Color and Odor parameters used organoleptic method using 40 respondents.

2.3 Data Processing for Mapping the BOD Distribution in the STBM System

Surfer 9 software from Golden Software was used to map the vertical distribution of BOD and analyze the pattern of wastewater movement in the STBM system. Surfer® 9 operation can be done by self-study, we use universal kriging. polygons are created from the sample points and also estimate the BOD value in the unsampled area. Surfer® 9, produced by Golden Software, Inc. (Golden Colorado) is a three-dimensional surface mapping software that is relatively inexpensive and easy to use by scientists and engineers.

3 RESULTS AND DISCUSSION

3.1 STBM System Performance Causes Loss of Pollutant Parameters in Cattle Farm Wastewater

Cow farm wastewater changes from very smelly to odorless and there is also a change in color from blackish brown to slightly clear. The average organic matter removal efficiency (BOD5) is 96% and COD is 63% respectively. The removal efficiency of Total Suspended Solids (TSS) is 82%. Occurrence of odor removal, color and organic matter in wastewater by the STBM system because it is absorbed by the mixed soil layer (SML) because SML acts as a bioreactor due to the presence of microorganisms in the SML soil to degrade organic matter in mixed soil layers by converting organic matter in wastewater into H_2O and CO_2 and absorb color and odor. The facts in Table 1 also show that the STBM system is able to process nutrients, odors, colors and organic matter during the experiment without clogging the STBM system with a wastewater discharge (HLR) of 1440 L/ m^2/hour or 34,6 M^3/m^2/day.

The mean removal efficiencies of PO_4-P and NO_3-N were 98% and 74%, respectively (Table 1). The physicochemical content of water processed by cattle farms by the STBM system for TSS, pH, BOD_5, NO_3^- -N has met the recommended quality standards for disposing of cattle farm liquid waste under Indonesian law (Table 1). However, a little more to be still above the quality standards for COD, phosphate and oil and grease, it is recommended to incubate cattle farm liquid waste for 3-7 days mixed with local soil with a ratio of liquid waste to soil, which is 100:1. Regarding the removal of P and N, the results also show that the STBM system is very effective in removing PO_4^- -P and NO_3^- -N in Cattle Livestock Wastewater. The average nutrient transfer by the STBM system for TSS, BOD_5, COD, NO_3^- -N, PO_4^- -P, TDS and EC were 82%, 96%, 63%, 74%, 98%, 96% and 96%.

Table 1: Average Concentration Level of Cow Farm Wastewater and Wastewater Treatted with STBM System (Average + Standard Deviation), Percentage of Allowance and Allowed Limit for Cow Farm Wastewater.

Parameter ***Polutant***	***Cattle farm*** ***Waste water***	***STBM system*** ***Treated water***	***RP (%)***	***Absolute removal rate (g/m2/day)***	***Admissible limit for wastewater release****
NaCl(%)	23,55 ± 0.6	4.40 ± 0.06	81.31	14420,0	-
TDS (mg/L)	1965+17	75,5+3	96.16	2724,66	750
EC (uS/m)	3930 ± 8	151.0± 4	96,16	-	1500
Grease and Oil (mg/L)	44 ± 0.5	14.0 ± 0.05	68.18	43,26	1
PO4-P (mg/L)	34.0 ± 0.1	0.57 ± 0.05	98.32	48,49	0.2
NO3-N (mg/L)	1.64 ± 0.4	0.42 ± 0.05	74.23	1,76	10
COD (mg/L)	34.2 ± 13	12.8 ± 4	62.57	46,72	40
BOD5 (mg/L)	156 ± 5	5.75 ± 0.3	96.31	217,4	100
pH	8.55 ± 0.04	7.39 ± 0.1	-	-	6 - 9
TSS (mg/L)	3825 ± 6	707.0 ± 0.5	81.51	458,56	100
Odor	Smells really bad	No bad smells	-	-	-
Color	Brawniest Black	A Bit Clear	-	-	-

* Admissible limit for wastewater cattle farm release by Indonesia overnment 1995

RP: Removal Percentage

Notes: NaCl, salts; TDS, total dissolved solid; EC, electric conductivity; PO_4^--P, orthophosphates; NO_3^--N, nitrate; COD, chemical oxygen demand; BOD_5, biological oxygen demand measured in a 5-day test; TSS, Total suspended solids;

Despite the characteristics of cattle farm wastewater, with HLR or flow rate, the composition and dimensions of STBM systems differ from those made in Morocco, the United States, China and Japan. However the organic matter removal efficiency was similar to that reported by other studies. in Indonesia, the NO3-N removal efficiency was high (73%) in this study and comparable to that observed by (Masunaga T, 2005) at 75% and (Lahbib LATRACH1, 2014) ie 71%. The efficiency of removing NaCl, TDS, EC and odors in the STBM system is also very efficient. The color loss was somewhat similar to, ranging from 52 to 67%. (Rahmiana Zein, 2017) found that the removal efficiency of BOD5 was 96%.

This phenomenon can be explained based on research (Masunaga T, 2007) that the efficiency of NO3-N removal is due to the ability of the soil and local materials in the STBM system. Where can absorb NH4-N. In addition, the presence of an aerator that delivers oxygen into the STBM creates aerobic and anaerobic conditions in the STBM system to accelerate the chemical process of alternating nitrification and denitrification.

This is the benefit of enriching local soil and materials in constructing STBM systems such as inceptisol soil from Mount Sago, local sawdust, local geotextiles, local crushed stone. The optimal condition of the STBM system results in high efficiency performance in NO_3-N removal. The percentage of PO_4-P removal was very high (98%) in the STBM system. Because according to and iron rusts into Fe^+ in mixed soil layers in the STBM system and results in the binding of PO4- ions. Results are similar to those obtained. Domestic wastewater treated by the MSL system in Japan is capable of PO_4^--P removal between 44% and 88%, with HLR flow rates of 7.9 – 76 L/m^2/day, respectively. Meanwhile, the STBM system is capable of removing 98% of PO_4^--P because the height of the structure is 200 cm, which is 2 times higher than MSL in Japan. The absolute allowance by the STBM system in this study is quite high in the purification of cattle farm wastewater because the HLR is quite high, namely 34,6 M^3/m^2/day (Table 1). The study reported that for domestic wastewater treated with the MSL system in Japan with an HLR of 190 - 1824 L/m^2/day, the absolute discharge rate ranged from 20 - 219 COD g/m^2/day, 6.31 - 127 BOD5 g/m^2/day and 12.96 - 150 TSS g/m^2/day. This absolute pollutant removal rate increases with increasing HLR from 504 - 1992 L/m^2/day but the relative pollutant removal efficiency decreases to a low because the residence time of wastewater effluent in the MSL system is shorter. Research reported that with low HLR the MSL or STBM system is more efficient than other natural systems such as artificial wetlands because it requires more land while STBM requires much less land area for installation. Therefore, the MSL or STBM system becomes feasible to purify cattle farm wastewater to overcome the problem of wastewater in urban and rural areas in Indonesia.

3.2 Vertical Distribution of BOD Pollutant Purification Parameters in STBM System

Figure 2 shows the process of BOD, color, odor, nutrients and organic matter in cattle farm wastewater that can be removed with a very efficient STBM system. Why BOD, color, odor, nutrients and organic matter can be removed from cattle farm wastewater because Odor and Color are absorbed or absorbed or removed by carbon present in mixed soil layers. Carbon comes from local soil and Sawdust. Meanwhile, organic matter in cattle farm wastewater is consumed by microorganisms as an important source of carbon (C) for microorganisms. Based on reports and (Chen Xin, 2008) that in the STBM system, local soil is used as the main raw material, as well as a source of microorganisms that act as bioreactors that function to purify pollutants contained in cattle farm wastewater. In the book it is stated that in 1 tablespoon or 10 grams of natural soil contains 11 billion microorganisms. Pollutants in wastewater can be physically and chemically absorbed by soil particles (SML: mixed soil layer) and split rock surface (PL: permeable layer). Furthermore, it is broken down by microorganisms found in mixed soil layers.

The vertical distribution of BOD in each layer of the STBM system is as high as 200 cm and helps to explain the process of movement of cattle farm wastewater in the STBM system that researchers could not previously understand (Figure 2). At a depth of 90 cm from the height of the STBM system. Removal of high BOD occurred gradually at 7 levels of mixed soil layers and 7 levels of permeable layer of split rock and local fibers. It turned out that the concentration of BOD was in accordance with the quality standards recommended by the Indonesian government. In the 15 layers of the STBM system in this study, the absorption and degradation process of BOD occurred linearly and gradually the BOD concentration continued to decrease until 96% was lost.

A somewhat similar result was reported by that in the MSL system in Japan, BOD removal occurred in the first mixed soil layer and continued in the 7 th layer until the BOD decreased to 96% with an HLR flow rate of 1008 L/m^2/day and MSL height is 73 cm.

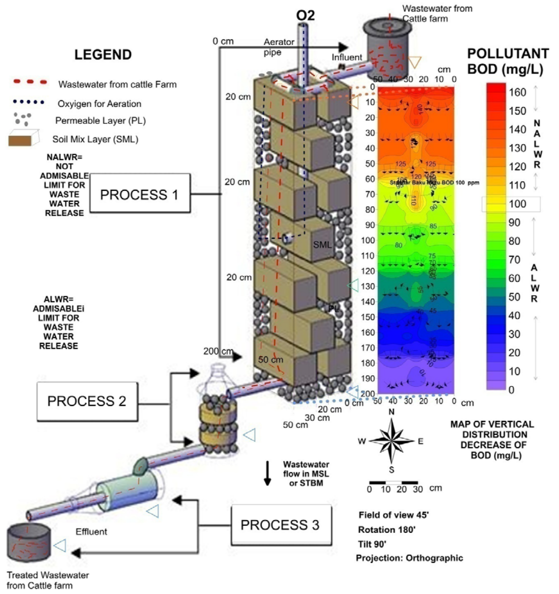

Figure 3: Vertical Distribution of Biological Oxygen Demand (BOD) in the STBM system during the purification of Cattle farm wastewater.

4 CONCLUSION

The STBM system shows high performance and adaptability in removing pollutants in cattle farm wastewater and is efficient in handling wastewater pollutant parameters, namely nutrients, organic matter, color and odor. Recommendations are given for the use of STBM to purify pollutants in cattle farm wastewater in Indonesia. In order to be cheap and easy and remain efficient and avoid operational constraints, it is better to use local Indonesian soil and materials.

ACKNOWLEDGMENT

The Research Team sincerely thanks Kemendikbud Dirjen Vokasi Indonesia for Financial support with No. Contract: / SP2H / LT / DRPM / 2022 is very much appreciated and many thanks.

REFERENCES

Rahmiana Zein, Refilda Suhaili, Heric Novrian, Syukrya Ningsih, Lidya Novita, Neneng Swesty, Mukhlis, and Hilfi Pardi. 2017. Multi Soil Layering (MSL) System for Treatment of Tofu Industry Wastewater. Research Journal of Pharmaceutical, Biological and Chemical Sciences. RJPBCS 8(6). 675-682. https://www.researchgate.net/publication/328980681

Aflizar dan Tim. 2018. Pengenalan IPAL STBM (Instalasi Pengolahan Air Limbah sistim Tanah Berlapis Melafu) dan Fakta unik dibalik IPAL Industri Milik Swasta dan Negara. Politeknik Pertanian Negeri Payakumbuh.

Aflizar. 2013. Mengatasi Pencemaran Perairan Dengan Ipal Stbm (Sistim Tanah Berlapis Melafu) Untuk Mengolah Limbah Cair Home Industri Dan Domestik Dan Air Sungai Tercemar. Politeknik Pertanian Negeri Payakumbuh. DOI: 10.13140/RG.2.2.35549.92649.

Aflizar, Muzakir, Edi Syafri. 2014. Poster thn 1 Ristek. Rekayasa IPAL STBM (Sistim Tanah Berlapis Melafu) berbasis Tempurung Sawit dan material Lokal untuk menetralisir Polutan dalam Limbah cair PKS DOI: 10.13140/RG.2.1.3835.7362

Lahbib Latrach, Tsugiyuki Masunaga, Naaila Ouazzani, Abdessamad HEJJAJ1, Mustapha MAHI and Laila MANDI. 2014. Removal of bacterial indicators and pathogens from domestic wastewater by the multi-soil-layering (MSL) system. Soil Science and Plant Nutrition (2014), 1–10. http://dx.doi.org/10.1080/00380768.2014.974480

Masunaga T, Sato K, Zennami T, Fujii S, Wakatsuki T 2003: Direct treatment of polluted river water by the multi-soillayering method. J. Water Environ. Technol., 1, 97–104. doi:10.2965/jwet.2003.97.

Sato K, Iwashima N, Wakatsuki T, Masunaga T 2011: Quantitative evaluation of treatment processes and mechanisms of organic matter, phosphorus, and nitrogen removal in a multi-soil-layering system. Soil Sci. Plant Nutr., 57, 475–486. doi:10.1080/00380768.2011.590944

Sato K, Masunaga T, Wakatsuki T 2005a: Characterization of treatment processes and mechanisms of COD, phosphorus and nitrogen removal in a multi-soil-layering system. Soil Sci. Plant Nutr., 51, 213–221. doi:10.1111/j.1747-0765.2005.tb00025.x

Sato K, Masunaga T, Wakatsuki T 2005b: Water movement characteristics in a multi-soillayering system. Soil Sci. Plant Nutr., 51, 75–82. doi:10.1111/j.1747-0765.2005.tb00009.x

Bdour AN, Hamdi MR, Tarawneh Z 2009: Perspectives on sustainable wastewater treatment technologies and reuse options in the urban areas of the Mediterranean region. Desalination, 237, 162–174. doi:10.1016/j.desal.2007.12.030

Masunaga T, Sato K, Mori J, Shirahama M, Kudo H,Wakatsuki T 2007a: Characteristics of wastewater treatmentusing a multi-soil-layering system in relation to wastewater contamination levels and hydraulic loading rates. Soil Sci. Plant Nutr., 53, 215–223. doi:10.1111/j.1747-0765.2007.00128.x

Sato K, Masunaga T, Wakatsuki T 2005a: Characterization of treatment processes and mechanisms of COD, phosphorus and nitrogen removal in a multi-soil-layering system. Soil Sci. Plant Nutr., 51, 213–221. doi:10.1111/j.1747-0765.2005.tb00025.x

Sato K, Masunaga T, Wakatsuki T 2005b: Water movement characteristics in a multi-soillayering system. Soil Sci. Plant Nutr., 51, 75–82. doi:10.1111/j.1747-0765.2005.tb00009.x

Attanandana T, Saitthiti B, Thongpae S, Kritapirom S, Luanmanee S, Wakatsuki T 2000: Multi-media-layering system for food service wastewater treatment. Ecol. Eng., 15, 133–138. doi:10.1016/S0925-8574(99)00041-5

Luanmanee S, Boonsook P, Attanandana T, Saitthiti B, Panichajakul C, Wakatsuki T 2002: Effect of intermittent aeration regulation of a multi-soil-layering system on domestic wastewater treatment in Thailand. Ecol. Eng., 18, 415–428. doi:10.1016/S0925-8574(01)00103-3

Luo W, Yang C, He H, Zeng G, Yan S, Cheng Y 2014: Novel two-stage vertical flow biofilter system for efficient treatment of decentralized domestic wastewater. Ecol. Eng., 64, 415–423. doi:10.1016/j.ecoleng.2014.01.011

Masunaga T, Sato K, Wakatsuki T 2001: Application of multisoil- layering method in wastewater treatment. APEC virtual centre for environmental technology exchange.

Chen Xin , An Cheng Luo, Kuniaki Sato, Toshiyuki Wakatsuki & Tsugiyuki Masunaga. 2008. An introduction of a multi-soil-layering system: a novel green technology for wastewater treatment in rural areas. Water and Environment Journal. Print ISSN 1747-6585. doi:10.1111/j.1747-6593.2008.00143.x

Masunaga T, Sato K, Senga Y, Seike Y, Inaishi T, Kudo H, Wakatsuki T 2007b: Characteristics of CO2, CH4 and N2O emissions from a multi-soil-layering system during wastewater treatment. Soil Sci. Plant Nutr., 53, 173–180. doi:10.1111/j.1747-0765.2007.00118.x

APHA 1992: American Public Health Association. Standard Methods for Analysis of Waste and Waste Water. APHA,Pub, Washington, DC.

Chen Xin, Kuniaki Sato, Toshiyuki Wakatsuki And Tsugiyuki Masunaga. 2007. Comparative study of soils and other adsorbents for decolorizing sewage and livestock wastewater. Soil Science and Plant Nutrition (2007) 53, 189–197. doi: 10.1111/j.1747-0765.2007.00124.x

Chen Xin, Kuniaki Sato, Toshiyuki Wakatsuki and Tsugiyuki Masunaga. 2007b. Effect of aeration and material composition in soil mixture block on the removal of colored substances and chemical oxygen demand in livestock wastewater using multi-soil-layering systems. Soil Science and Plant Nutrition (2007) 53, 509–516 doi: 10.1111/j.1747-0765.2007.00156.x

Brady, R and Weil, NC. 2007. Nature and Properties of Soils, The, 15th Edition. Pearson. https://www.pearson.com/us/higher-education/program/Weil-Nature-and-Properties-of-Soils-The-15th-Edition/PGM219427.html