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# Novel Two Stage Vertical Flow Biofilter System for Efficiency Treatment of Restaurant Wastewater.

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**ABSTRACT**

Restaurant wastewater treatment with combination method of Grease Trap and Multi Soil Layering (MSL) has been studied. The aimed of this research are to use some material in the our environment for removal of nitrite, nitrate, phosphate, oil and grease from restaurant wastewater. The grease trap was made of Poly Vinyl Chloride (PVC) has dimensions of 45x25x35cm. MSL system made of an acrylic box has dimensions of 50x15x50cm. MSL containing permeable layers (PL) and soil mixture layers (SML). PL consists of a zeolite 3-5 mm particle size, SML consists of volcanic soil, coconut shell charcoal, iron powder and corn cob powder with a ratio of 75:10:10:5 in weigh with molds resembling brick wrapped in gunnysacks. PL and SML were arranged in an acrylic box like the brick pattern. Variations of the wastewater flow rate in the system were 25, 50, 75, 100 mL/min with two processes aeration and non-aeration. Grease trap could decreased levels of nitrite, nitrate, phosphate, oil and grease while the pH of restaurant wastewater was increased. The highest efficiency for removal grease, nitrite, phosphate, nitrate on grease trap at flow rate of 25 mL/min were equal to 95.40%, 12.91%, 8.65%, 8.02% respectively and MSL could decreased of grease 100% both with aeration and non-aeration for all flow rate. At a flow rate of 25 mL/min with aeration, removal efficiency of nitrite 86.44%, nitrate 92.53%, phosphate 97.75%, whereas in the non-aeration 64.21% nitrite, 83.98% nitrate and 79,75% phosphate.
**Keywords:** Combination Method, MSL, Grease Trap, Restaurant Wastewater

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## INTRODUCTION

Nowdays, restaurant is a kind of business that growing rapidly along with population growth and the neccesary of people to eat. The growth of a variety of restaurants so rapidly have an impact to environment due to its activity producing wastewater in a big scale. Untreatment restaurant wastewater and directly discharged into environmental water body will lead to make pollution. In addition, the organic material which are contained in restaurant wastewater can cause unpleasant odor [1]. Type of Indonesian restaurant assortment, ranging from outlets to large scale restaurant. the restaurant is located in West Sumatra Generally that is a specific restaurant serving typical cuisine of West Sumatra such as rendang, chicken curry, fish curry, meat soup, chicken and grilled fish, fried chicken, fried fish etc [2]. Most of that typical cuisine rich in coconut milk and oil in its processing. The processing of foodstuffs in the kitchen or from the cleaning process cutlery produce organic pollutant load is quite big, especially oil and grease. Remaining of oil and grease in the processing of the foodstuff and the sticking of tableware is directly discharged into the sewer, over time can cause a blockage (clogging) on the pipe due to the nature of the oil and grease that are insoluble in water and susceptible to stick on the wall of the pipe. Ideally, every restaurant would have to have a wastewater treatment system before being discharged into environmetal water body.

Oil and grease content in domestic wastewater should be handled in special treatment before the wastewater is treated further. Chen [3] conducted a municipal waste water treatment with a contact aeration method using activated sludge. Before processed by such a method, the content of oils and grease separated by grease trap. Grease Trap is a device specifically designed to catch oil and grease from kitchen waste. The main principle of this tool is to catch the oil and grease in wastewater flow into a wire porous filter so that grease expected to be retained on the filter [4]. Wastewater containing minimum levels of oil and grease can be streamed into the next processing system to lower levels of other pollutants such as phosphate, nitrite, nitrate and neutralize the pH of waste water.

Domestic wastewater treatment to reduce levels of pollutants such as BOD, COD, TSS, Nitrite, Nitrate and Phosphate had been common practice in countries such as Japan, China and Taiwan. The method involves wastewater treatment biologically, chemically and physically in a system called Multi Soil Layering (MSL). Chun-Ho [5] studied variation PL using zeolites, granular activated carbon, oyster shells and expanded clay aggregates. SML mixture composed by soil, carbon, rice husks and iron powder. Zeolite as a PL provides optimum results with TSS removal efficiency of 83.4%, 76.9% COD, $NH_3$-N 99.7% and 98.5% phosphate at a flow rate of 0.5 $m^3/m^2/d$. MSL system is a method of wastewater treatment by utilizing the volcanic soil as main medium mixed with various other materials such as charcoal, iron powder and biomaterials (corncorb, rice husk, and rice straw) formed into blocks called Soil Mixture Layer (SML). MSL containing of permeable layers (PL) and soil mixture layers (SML). PL was a material that has a high porosity such as zeolite, perlite, gravel and pumice [6]. PL and SML were arranged in an acrylic box like brick pattern.

Biological treatment by utilizing soil microorganisms contained in Soil Mixture Layer (SML) has nitrification and denitrification process, physical treatment involves filtration in Permeable Layer (PL) for total suspended solids (Total Suspended Solid, TSS), chemical treatment includes reactions such as oxidation of iron metal powder in SML to bind the phosphate ions be form a precipitate of iron (III) phosphate insoluble [7]. The addition of phosporous as phosphate ion is one of the most serious environmental problems because of its contribution to the increased eutrophication process of lakes and other natural waters. It occurs in natural water, wastewater, sediments and sludges [8].

Song Ying [9] also using zeolite as PL and varying the addition of activated sludge 5%, 10% and 20% into the SML for turtle farm wastewater treatment. Efficiency of its system does not vary much with various additions of activated sludge into the SML.

Zein R [10] Corn cobs was used for improvement the quality of used palm cooking oil, that the quantity of cholesterol (12.810%), trygliserides (20.519%), LDL (12.199%), MDA (14.906%) could decreased (submitted for publication). Mohammed [11] corn cobs was used also for removal of heavy metal Cu(II), Pb(II), Zn(II), Ni(II), Cr(VI). Nowdays, that agriculture by product was used as biosorbent, in this case corncob included as biosorbent for above explaining.

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Zein R [12] used sugar palm *Arenga pinnata Merr (*Magnollophyta) fruit shell as biomaterial to remove Cr(III), Cr(VI), Cd(II) and Zn(II) from aqueous solution, this biomaterial can use also as carbon source for microorganism nutrient.

The present study is constructing the grease trap combine with MSL for removal of nitrite, nitrate, phosphate, oil and grease of restaurant wastewater, using some material has in the our environment. The grease trap was made of Poly Vinyl Chloride (PVC) has dimensions of 45x25x35cm. MSL system in the form of an acrylic box has dimensions of 50x15x50cm. Corn cobs was used as carbon source for microorganism nutrient.

## MATERIAL AND METHODS

### Structure and components of grease trap

Grease trap (GT) has dimensions of 45x25x35cm. Materials for the assembly of grease trap is jerrycan, silicone rubber, PVC pipe, and wire porous filter with 0,1 mm diameter. GT is assembled from two pieces of jerrycan capacity 20 L cutting about 10 cm upper. Both of jerrycan glued with silicone rubber on one side to form a GT with two rooms. Figure 1 shows the grease trap assembled.

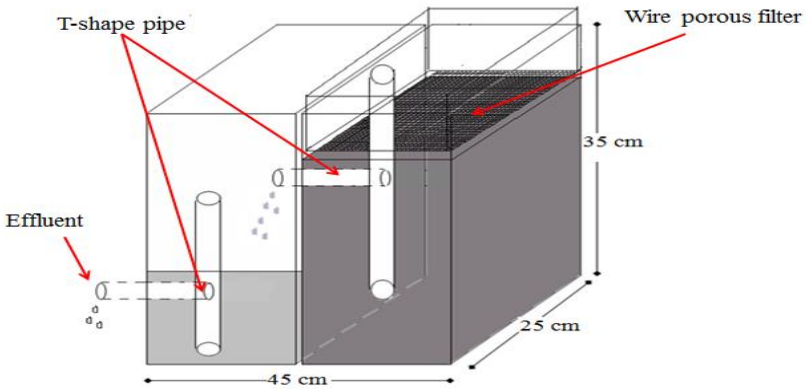


**Figure 1. Grease trap**

### Structure and components of multi soil layering (MSL) system

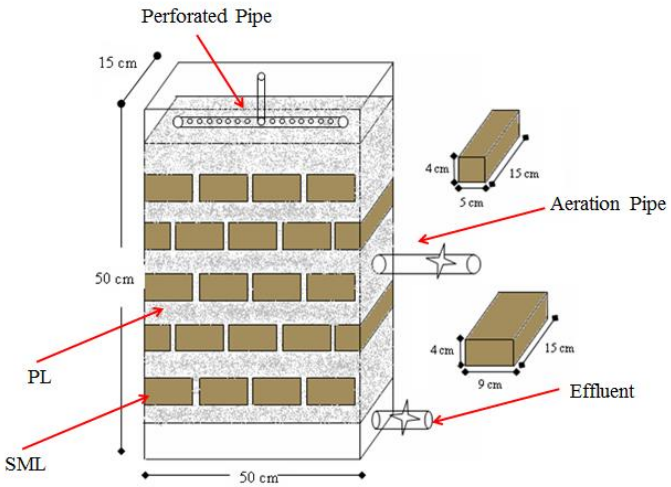


**Figure 2. MSL system**

MSL in the form of an acrylic box with dimensions of 50x15x50cm. PL was a zeolite 3-5 mm particle size. SML was composed of volcanic soil, coconut shell charcoal, iron powder and corn cob powder with a ratio of 75:10:10:5 by weigth with molds resembling brick wrapped in gunnysacks. PL and SML were arranged in acrylic

box like the brick pattern. Materials for the system installation of MSL is a zeolite, burlap, volcanic soil (andisol soil), coconut shell charcoal, powdered corn cobs, and iron powder. MSL system are equipped by perforated distribution pipe and aeration pipe. Perforated pipe (waste water distribution) with 48 cm in length equipped with small holes along the pipe with a diameter of 0.5 cm. It is purposed in order to waste water flowing from the GT spread evenly in layers MSL system and not concentrated in one direction only. Aeration pipe useful for air flow into the MSL system to support the aeration process, it is connected to the pump. MSL construction scheme shown in Figure 2.

**Installation of combination method of grease trap and MSL**

The installation of the method by combining GT & MSL to form wastewater treatment system, it is given in figure 3:

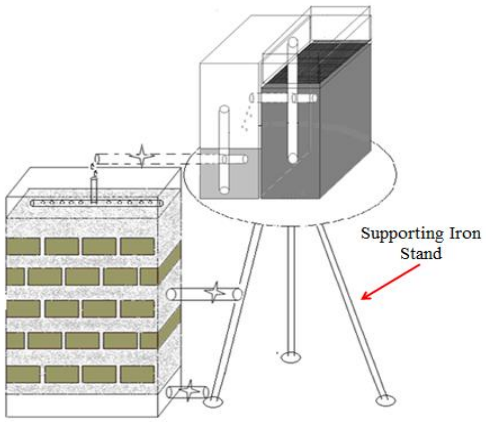


**Figure 3. The combination method of grease trap and MSL**

The combination of GT & MSL were equipped by influent and effluent tank. Influent tank as chamber to put the waste water discharged into GT; Effluent tank as a place to accommodate the waste water that has been through the MSL system. Streaming of wastewater into GT & MSL system was done by flow rate (25, 50, 75, 100) mL/min. While for the variation of aeration and non aeration performed on the MSL system for any flow rate.

**Parameter analysis and data collection**

Parameters tested were: Nitrite, Nitrate, Oil & Grease, Phospate, pH and analyzed by standar method for wastewater APHA [13]. The parameters analysis were performed in initial samples before treatment, samples that have passed the GT tools and samples that have been through the combination system. The data obtained are converted into efficiency value and curve to study the effect of flow rate variations and influence the process of aeration and non-aeration to the efficiency removal of each pollutant parameters.

## RESULT AND DISCUSSION

**Analysis of restaurant wastewater characteristics**

Restaurant wastewater characteristics before processed by the combination method of GT and MSL shown in Table 1:

**Table 1. Characteristics of restaurant wastewater**

| No | Parameters | Unit | *Restaurant wastewater* |
|---|---|---|---|
| 1 | pH | - | 5,3 |
| 2 | Oil & Grease | mg/L | 165,2 |
| 3 | Nitrite | mg/L | 1,208 |
| 4 | Nitrate | mg/L | 1,553 |
| 5 | Phosphate | mg/L | 9,440 |

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Restaurant wastewater has pH value is 5.3, it is mean that if the water flowing in the pipe, it will faster the pipe be corrosive [14]. Oil and grease causes clogging of pipes in treatment units that need cleaning and sometimes replacement of pipes, this lead to increase maintenance and inspection cost [4]. Oil is liquid while grease is solid at room temperature, if entering MSL system can cause clogging due to oil and grease including organic molecules that require a longer time to be decomposed by microorganism [15]. Nitrites and nitrates content can be generated from the decomposition of organic compounds containing N (Org-N) [7]. Phosphate can be generated from the degradation of household detergent [16].

**Efficiency of combination method of grease trap and MSL system**

**Oil and grease removal efficiency**

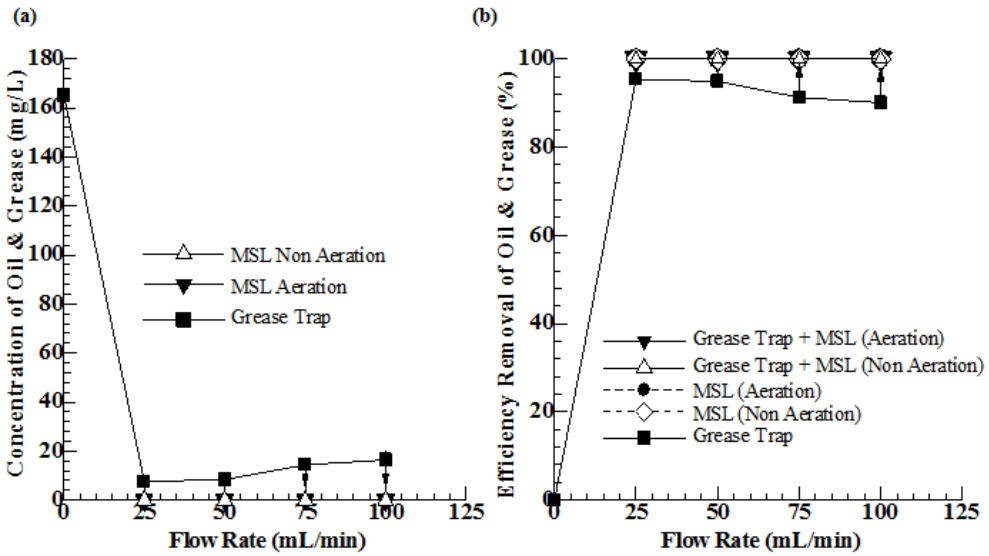


**Figure 4. Effect of flow rate on grease trap and MSL system (aeration and non aeration) process**
**(a) concentration of oil and grease from grease trap to MSL, (b) removal efficiency of oil and grease**

Oil and grease removal efficiency is very significant on the grease trap. The efficiency obtained at all flow rate are >90%. The highest removal efficiency was at a flow rate of 25 mL/min at 95.40%. It is due to grease trap apparatus has two rooms connected by a T-shaped pipe is mounted horizontally, it is mean the wastewater entering the first room will collected in advance and provide an opportunity for the oil and grease to float. Wastewater streams flowing from the bottom of the T pipe so that the oils and grease could minimized to get into the second room. In the second room of grease trap also allows the re-floatation oils and grease that are still carried over into the second room. In addition, the first chamber of grease trap apparatus is also equipped with a wire porous filter allows the solid fat filtered and does not carry over into the MSL system. Overall, oil and grease separation process that occurs in grease trap make the levels of oil and grease is decreased before entering the MSL system. Using of grease traps is very beneficial caused it can prevent clogging on the MSL system.

Oil and grease removal efficiency in the combination system of grease trap and MSL system for all flow rate on the aeration and non-aeration process were 100%. Although oil and grease in wastewater has been filtered in grease trap, oil and grease still remains before entering MSL system, it will degraded by microorganism has in the brick soil mixture.

Gawad [4] studied new approach to degrade oil and grease industrial wastewater, the work presented lipase hydrolysis stage using *Pseudomonas* strains as a producer of lipase and assess their degradation capabilities. This approach included enzyme unit coupling with adsorbent materials as efficient method to complete removal. Adsorption technique used zeolite as easily and cheaply available adsorbent, removal efficiency of oil and grease reached to 99%.

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**Nitrite and nitrate removal efficiency**

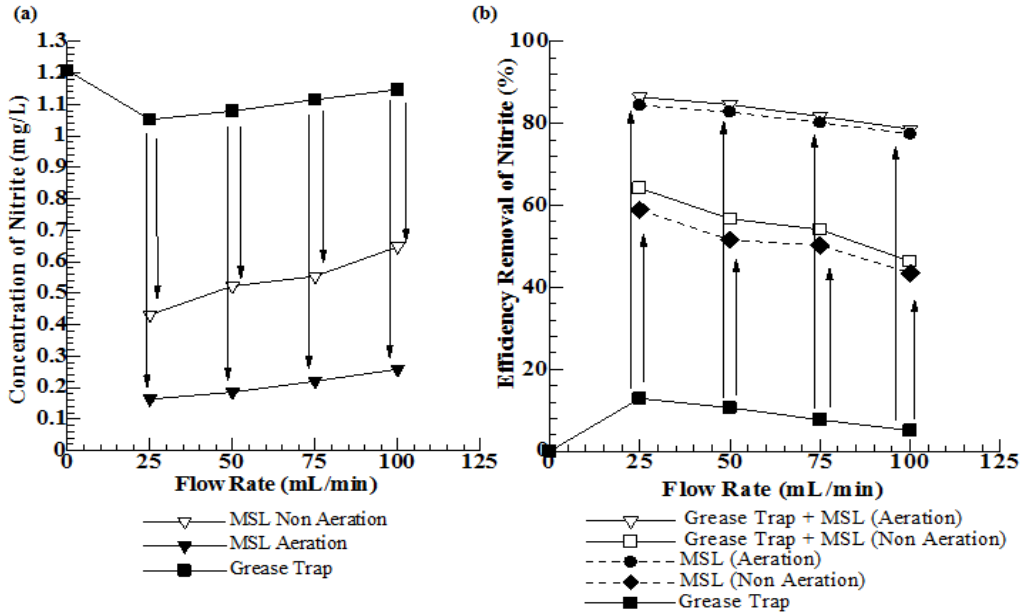


**Figure 5. Effect of flow rate on grease trap and MSL system (aeration and non aeration) process**
**(a) concentration of nitrite from grease trap to MSL, (b) removal efficiency of nitrite from grease trap to MSL**

At flow rate 25 mL/min, removal efficiency of nitrite in the effluent grease trap was 12.91% while in the combination system of grease trap and MSL was 86.44% on the aeration and 64.21% on the non aeration process. At flow rate 100 mL/min, it was 78.59% on the aeration and 46.34% on the non aeration process. The faster of flow rate, removal efficiency become decreasing related to the fast interaction between organic subtances and material in the MSL system, it makes the process of nitrification and denitrification become not optimum.

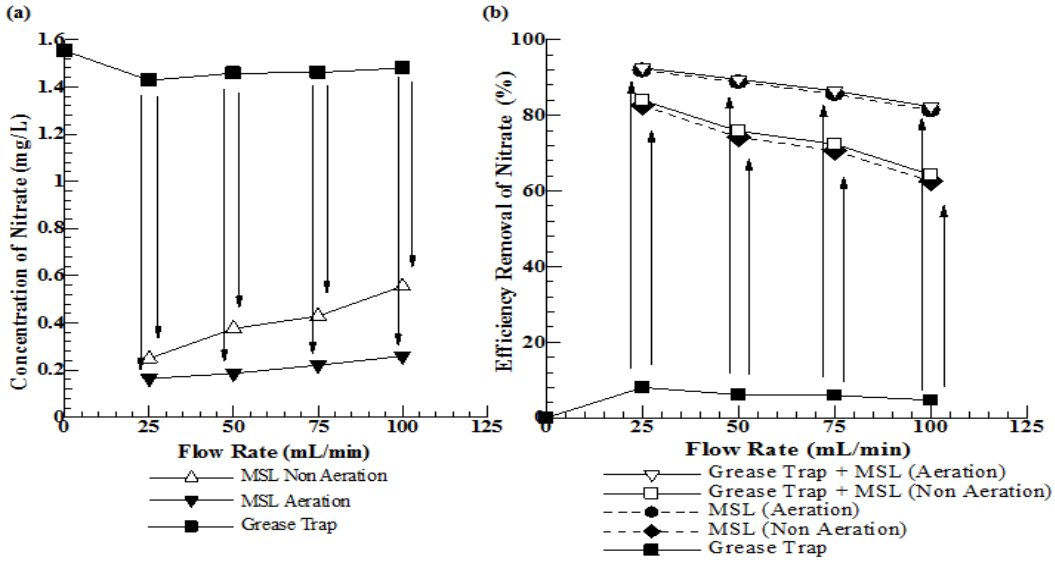


**Figure 6. Effect of flow rate on grease trap and MSL system (aeration and non aeration) process**
**(a) concentration of nitrate from grease trap to MSL, (b) removal efficiency of nitrate from grease trap to MSL**

At flow rate 25 mL/min, removal efficiency of nitrate in the effluent grease trap was 8.02%. Decreasing level of nitrite and nitrate related to the possibility of nitrification and denitrification occured in the grease trap. The highest removal efficiency of the combination system in decreasing level of nitrate was 92.53% on the aeration and 83.98% on the non-aeration process at this flow rate.

Nitrites and nitrates content in the wastewater can be generated from the decomposition of organic

compounds containing N (Org-N). Org-N is converted into $NH_3$-N through the ammonification process. $NH_3$-N is oxidized into $NO_2$-N and $NO_3$-N on the nitrification process by aerobic bacteria. $NO_2$-N and $NO_3$-N are reduced into $N_2$ gas on the denitrification process by anaerobic bacteria [5,7,17]. It can be concluded that the decomposition of nitrites and nitrates in wastewater related to each other. Such of these two processes could have been taking place at the grease trap because wastewater may containing decomposer microorganisms.

In MSL system, nitrification subsequently occurs in zeolite layer. Zeolite adsorbs $NH_3$-N in the wastewater through ion exchange mechanism and as a nitrifying bacteria carrier because zeolites has high porosity and large surface area [5,7,17]. The availability of sufficient carbon source is required in MSL as a nutrient for the growth of microorganisms [9]. In this study, corncob powder and coconut shell charcoal was mixed together into soil mixture brick as nutrients sources for the growth of microorganisms.

Combination system of grease trap and MSL on the aeration process could decreasing nitrite and nitrate levels with higher removal efficiency compared to the non-aeration process at all flow rates. However, if aeration process is too dominant in the MSL system can reducing the efficiency of MSL in decreasing the levels of nitrites and nitrates due to nitrification process occurs in aerobic environment and continued by denitrification process in anaerobic environment [6]. Attanandana [7] studied about the cafeteria wastewater treatment obtained total nitrogen removal efficiency of 90.8% on the aeration process and 68.1% on the non-aeration process.

**Phospate removal efficiency**

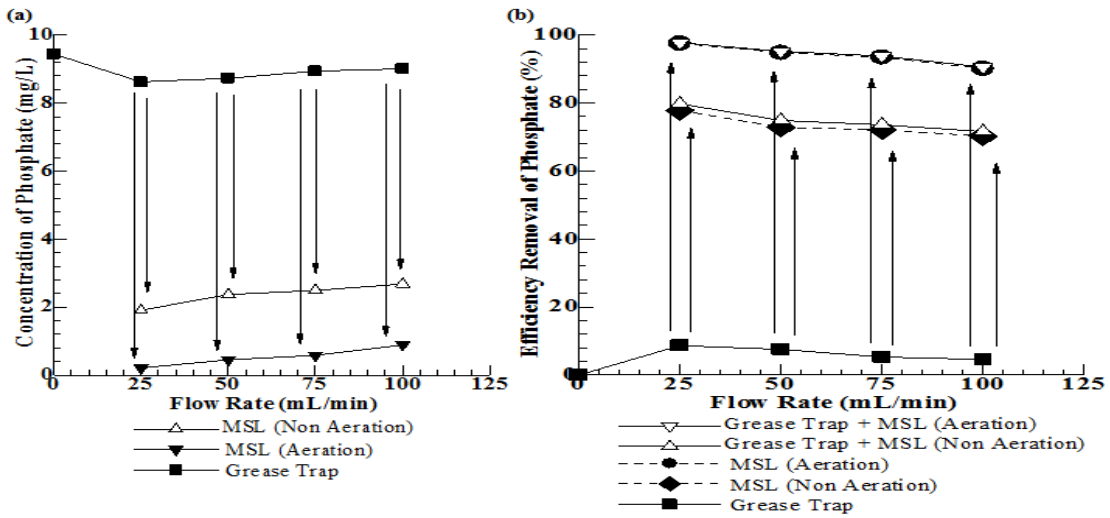


**Figure 7. Effect of flow rate on grease trap and MSL system (aeration and non aeration) process**
**(a) concentration of phosphate from grease trap to MSL, (b) removal efficiency of phosphate from grease trap to MSL**

At flow rate 25 mL/min, removal efficiency of phosphate in the effluent grease trap was 8.65%. It is due to phosphate ions has been degraded by microorganisms contained in wastewater. Krishnaswamy [8] studied about the microrganisms degrading phosphate such as *Bacillus* sp, *Pseudomonas* sp and *Enterobacter* sp, and obtained removal efficiency by three bacteria as 92.5%. Phosporous is used by microorganism for their cellular maintenance, synthesis of nucleic acids, construction of cell membranes (as phospholipids) and chemical energy transfer reactions within cells (as ATP molecules). Some phosporous is also stored for future use by the cells.

At all flow rates, removal efficiency of phosphate by combination system grease trap and MSL on the aeration process was above 90% and about 70% on the non-aeration process. Decreasing level of phosphate ions can be explained by the binding mechanism of it by iron powder contained in soil mixture brick.

The removal of phosphate primarily relies on the iron powder in soil mixture brick. The reactions occur on the aeration process where oxygen was blown into the system MSL, Fe metal will be oxidized into ferrous ions ($Fe^{2+}$). Ferrous ion then be carried away by the flow of waste water in the system to the zeolite layer. In this

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layer, ferrous ion will be oxidized into ferric ions ($Fe^{3+}$). Ferric ions will bind phosphate ion ($PO_4^{3-}$) contained in the waste water to form insoluble compounds $FePO_4$ [5,6,18]. However, continuous aeration process can also reduce the efficiency of the MSL system in lowering phosphate ion because it allows the formation of $Fe_2O_3$ [19]. Microorganism in the MSL system also absorbed phosphate ion as their nutrient [6].

In this study, combination system with aeration process is more efficient than non-aeration process in reducing level of phosphate in restaurant wastewater. Attanandana [7] studied about the cafeteria wastewater treatment obtained phosphate removal efficiency of 90.1% on the aeration and 51.9% on the non-aeration process.

The possible entry of phosphate ions into aquatic environment is through household sewage water and industrial effluent particularly fertilizer and detergent. One of phospate source is from the decomposition of detergent containing Sodium Tripolyphospate [8]. In the process of cleaning the glassware in restaurants may use detergent. Ion phosphate is not a toxic species in water, but excess of phosphate ions can lead of eutrophication. Eutrophication is the proliferation of aquatic plants due to the presence of phosphor, which becomes fertilizer agent for the plants, the presence of abundance aquatic plants can inhibit sunlight or oxygen into the water body so could damage aquatic ecosystems [16].

**Neutralization degree of acidity (pH)**

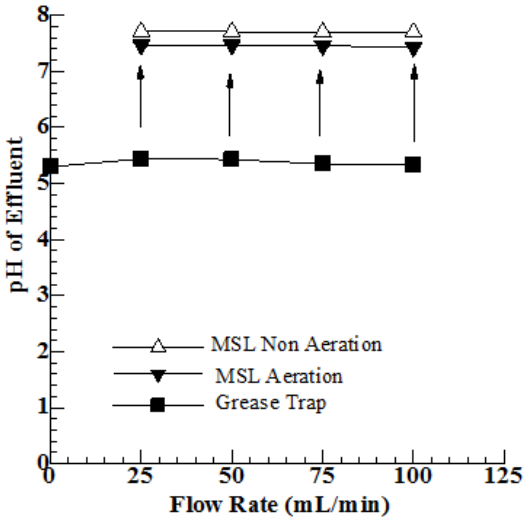


**Figure 8. Effect of flow rate on grease trap and MSL system (aeration and non aeration) process**

Restaurant wastewater has pH value is 5.3 (flow rate 0 mL/min), it is mean that if the water flowing in the pipe, it will faster the pipe be corrosive [14]. pH in the grease trap slightly increased, it is related to the denitrification process that occurs in grease traps, oil and grease collected in the grease trap could containing microorganisms cause denitrification. Denitrification is the reduction process of nitrite and nitrate to $N_2$ gas by releasing $OH^-$ ions participate in raising the pH of the wastewater.

The pH of the effluent combination system of grease trap and MSL on the aeration slightly lower than non-aeration process due to nitrification posibility is greater than denitrification. Nitrification is the process of oxidation organic compounds containing N (org-N) into $NH_3$-N, $NH_3$-N is then oxidized into $NO_2$-N and $NO_3$-N by aerobic bacteria. This process release of $H^+$ ions that caused the pH of the effluent being lower than non-aeration process. While in the non-aeration process, pH of the effluent becomes greater than the effluent aeration, due to in the denitrification process $NO_2$-N and $NO_3$-N were reduced into $N_2$ gas by releasing $OH^-$ ions [17].

## CONCLUSIONS

The high content of the various pollutants in the wastewater require proper processing before it is discharged into the environmental water. Grease trap contributed in decreasing levels of all pollutant, otherwise raising the pH of the wastewater. The highest efficiency grease trap was at a flow rate of 25 mL/min

were equal to 95.40% oil & grease, 12.91% nitrite, 8.02% nitrate and 8.65% phosphate. Variation of the flow rate of 25-100 mL/min in the combination system provided significant efficiency for the parameter nitrite, nitrate and phosphate on the aeration and non aeration process. Novel two stage vertical flow biofilter system of grease trap and MSL is very effective for restaurant wastewater treatment.

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