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EFFICIENCY OF WASTEWATER TREATMENT WITH HYDROPONICS

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ABSTRACT

This study used the wastewater from the fish pond for hydroponics. It was combined the benefits in terms of crop production and wastewater treatment. The assumption of this research expected that plants could use the nutrients that contained in the wastewater. The wastewater was treated using the aerobic technology with hydroponic reactor on hydraulic retention times (HRTs) 1, 3, 5, and 7 days. The collected wastewater samples at inlet and outlet of hydroponic reactor. The parameters were analyzed with the standard methods. The parameters were temperature, pH, DO, TKN, TP, TK, TS, SS, VSS, TDS, and COD. They were used to evaluate the performance of the wastewater treatment with a hydroponic. The results of parameter analysis showed that the pH values of effluent were in the ranges of 7.33-8.0 with the temperature of 27ºC-29ºC. These ranges of pH and temperature value have litter effects or did not effect in significant to the performance of hydroponic. The total reductions on 1, 3, 5, and 7 days of hydraulics retention times of TDS, COD, TKN, TP and TK ranged from 20.4% to 70.0%, 52.0% to 79.0%, 12.23% to 50.56%, 8.33% to 33.33%, and 0% to 44.44%, respectively. The result of this study showed that hydroponic could treat wastewater from fish pond. The result also showed the increasing of dissolved oxygen in wastewater of 1, 3, 5, and 7 days of hydraulics retention times in DO ranged from 33.33% to 66.67%. The results obtained in these investigations show that it was possible to recover nutritious substances from fish processing wastewater by hydroponics. Hydroponic production systems have potential for the treatment and reuse of wastewater in intensive aquaculture systems.

Keywords: hydroponics, wastewater treatment.

INTRODUCTION

Currently, the environmental problems intensify steadily increased. They are rain isn't seasonal, outbreak and insect pests, soil degradation and climate change. They have impact on the manufacturing agriculture. Environment problems have two aspects; the reduction of natural resources and degradation of environmental quality from the activities of human. Pollutions caused by human action were in air, water, and soil. Water in the rivers was more polluted. Water pollution was due to chemical, fertilizer and animal waste that human dumped them into canal and rivers. Wastewater was important problem since a large quantity of water was used for product addition and utensil cleaning. Such huge amount of organic pollutants in wastewater makes problems with its treatment when they are combined with municipal wastewater. The discharged volume of wastewater depends on the size of activities. The treatment of wastewater with less area requirement should be appropriate. Wastewater from fish processing can be treated in different ways: mechanically, chemically or biologically (Usydus and Bykowski, 1999). The hydroponic is another alternative that can resolve these problems and a new technology to revolutionize the cultivation system. Because it will help increase productivity, reduce the use of chemical fertilizers, and can cropping up anywhere. The focus of this study was evaluating the performance of wastewater treatment from fish pond with hydroponic. And evaluate ways to reduce household expenditure by aerobic wastewater treatment from the fish pond to fill it back into the pond for reducing the costs of water. And wastewater would be used instead of chemical fertilizer for growing vegetables.

The hydroponic is a way of cropping to imitate the cropping above ground. It was cropping on material that is not soil or cultivated into the nutrient solution. Hydroponics can be divided according to giving the nutrient solution around the roots as follows:

a) Model of cropping in nutrient solution is bringing roots of plant immersion in a solution directly. This can be done both recirculation and non-recirculation of solvents. Non-recirculation of solvents has two types as aerobic and anaerobic. Recirculation of solvents has two types as deep flow technique (DFT) and nutrient film technique (NFT). They increases oxygen to the plant roots and keep them from elements precipitate. The plant receives fully nutrients.
b) Aeroponics are cropping by the roots are in air and nutrients were sprayed directly on the root plant at the time.
c) Substrate culture is the cultivation by using the plant material to replace soil for support the plant roots. Plant material popular is usually a neutral, not nutrients, harmless to the growth of plants and readily available in the local such as husk, coconut shell, sawdust, bark, sand, gravel, asbestos. The advantage of this system is that even if the water system was damaged, the plant material can act as a reservoir for water plants, the system was very simple, while grown was no problem, Plants were growing well. Substrate culture was divided into two styles according to the nutrient solution to the plants. They were how to provide the solution of grown plants flooded container for a time then drain off and provide the solution by dripping.

Technical crops of hydroponic can be available for almost any type of plant such as vegetables, fruits, flowers, garden tree, herbs, ivy, and perennial. The growing popularity with this method was in vegetable and fruit that crops were harvested during the short-lived. The disadvantages of hydroponics were that this system has a higher initial costs than planting in soil, and in the case of planting with recirculation systems, the disease will spread to the other plants root easily and difficult to control. While hydroponic has several advantages as follows; this method could plant up anywhere. It controls various environments easily as nutrients, pH, temperature, oxygen, etc. Crop yield and quality was stable and consistent than growing in soil. Water and fertilizer were used decreased by about 10 times and 40% of the cropping in the ground, respectively. Plants grow faster and yield more than planted on a soil and hydroponic methods could provide proportion and sufficient nutrient content to balance the needs of the plant. It saved time, because it could reduce harvest age shorter than planting in the ground, costs savings of labor in planting and maintenance, saved transportation costs due to select crop production areas closer to the market. It could control the disease and pest problems were easier because the main problem of pest was mainly caused from the soils. Growing area was used most effectively. That was the same plant in the same area throughout the year and had continued to grow. This method could have crops density than plants grown in soil because it did not have to compete for food and water. Products were clean and safe for both the consumer and the environment because they had been contaminated by microbes in the soil less.

Important environmental factors affected the plant growth were temperature, humidity, light, air, pH, various organisms are in the air, on the ground and in the soil, nutrients, and water. The optimum temperature was between 15-40 degrees Celsius for higher plants. Temperatures were higher or lower than 15-40 degrees Celsius; the growth of plants will decrease rapidly. Temperature had a direct impact on the photosynthesis, respiration, mineral nutrition, dehydration, and the activity of various enzymes. High humidity or too low would have a direct effect on the growth of plants. If the roots couldn't absorb water to keep up with the rate of dehydration of the plant, the growth of the plant halted and cells of plants were not turgidity as expected. Light quality, light intensity and duration of light that the plants receive were influence the growth of plants. Plants use sunlight as an energy source to cause the photosynthesis to the leaves or green parts of plants. Plants used air in the breathing. Oxygen content in the plant material would have an inverse relationship with the amount of moisture or water. Water culture and liquid culture system in hydroponics method often lead to root hypoxia. It was necessary to provide a sufficient amount of oxygen. By providing was the form of bubbles inserted in the solution with the air compressor or the use of recirculation systems. Alkalinity, acidity, and pH had an indirect effect on the growth of plants. The range of pH 5.5-6.5 was useful for plant that absorbs nutrients every element. Various organisms are in the air, on the ground and in the soil such as insects, diseases, microorganisms in soil, small animals and weeds. They would influence the plant growth both directly and indirectly. Direct results were the crop destruction, the spoiling of water and nutrients. The indirect effects were weak plants that diseases destroy crops to easier. Nutrients that plants need have total of 16 elements. They could be divided into two groups. The first group was nutrients that plants need a large quantity. They were carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium and sulfur. The second group was nutrients that plants need smaller than the first group. They were zinc, copper, iron, manganese, boron, molybdenum and chlorine. The expense of most important of planting in hydroponics was the plant nutrients. Because they were costs which continuous on planting period. The nutrients in hydroponics were found in new features that were cheaper than the chemical fertilizers were used for growing crops. Quantity and quality of water which was used in hydroponics must be suitable and sufficient. Poor water quality would not be able to grow plants with hydroponics at all. Therefore, this study adopted an experimental method of growing plants in hydroponics for the pretreatment of wastewater.

METHODOLOGY

This study used the wastewater from the fish pond for hydroponics. The lettuce was planted in hydroponic reactor. It combined the benefits in terms of crop production and wastewater treatment. The assumption of this research expected that plants could use the nutrients contained in the wastewater. In addition, it could save the costs of the fertilizer that used to grow the plants, and also made it possible to treat wastewater as well. Return to the wastewater treatment plant has been in the productivity of the plant.

Equipment used in operations research

The wastewater was treated using the aerobic technology with hydroponic reactor on hydraulic retention times (HRTs) 1, 3, 5, and 7 days to provide an overview of this study. Water from the fish pond was pumped into the hydroponic reactor for treatment as shown in Figure-1 and circulating through the treated water into the fish pond. They were saving water and crops to utilize nutrients contained in wastewater.

Figure-1. The wastewater treatment plant with a hydroponic.

The system went into steady state. The percentage average of COD removal on 10 days had standard deviation less than 10%. The collected

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wastewater samples at inlet and outlet of hydroponic reactor. The parameters were analyzed with the standard method. The parameters were temperature, pH, DO, TKN, TP, TK, TS, SS, VSS, TDS, and COD. They were used to evaluate the performance of the wastewater treatment plant with a hydroponic.

Statistical data analysis

The data were analyzed with descriptive statistics and statistical analysis that described the characteristics of the wastewater, performance of hydroponic reactor in mean, standard deviation, and percentages of efficiency. Performance testing of the reactor and the difference of before and after treatment of the temperature, pH, DO, TKN, TP, TK, TS, SS, VSS, TDS, COD were tested at 95% confidence level as follow:

$$\% \text{ Removal efficiency} = \frac{(in - out)}{in} \times 100 \quad (1)$$

RESULTS AND DISCUSSIONS

The performance of hydroponic reactor

The main components of the fish pond wastewater are proteins and fats, substances of nutritious value, and the load of these pollutants may be extremely high depending on the production type. Characteristic of wastewater from fish pond included temperature, pH, TKN, TP, TS, SS, VSS, TDS, COD, DO of wastewater inputs to the hydroponic system and wastewater out of the hydroponic system. They were analyzed with standard methods. The results of the analysis of wastewater inputs to the system from the laboratory were shown in Table-1. As it could be seen from Table-1 that the pond had the low fish density and the fish were of young age. Water in the pond was not very dirty.

Table-1. The Characteristics of fish pond wastewater used to hydroponic reactor.

Parameters	Unit	Average ± S.D.
Temp.	ºC	28.42±0.67
pH	-	8.0±0.4
TKN	mg/L	75.0±4.43
TP	mg/L	11.5±0.69
TK	mg/L	75.5±4.69
TS	mg/L	457.5±17.49
SS	mg/L	104.25±30.09
VSS	mg/L	100±27.08
TDS	mg/L	348.25±28.72
DO	mg/L	6.0±0.4
COD	mg/L	100.07±9.67

The fish pond wastewater was treated using the aerobic hydroponic technology on hydraulic retention times (HRTs) 1, 3, 5, and 7 days to provide an overview of this study. There was a significant total dissolved solid removal efficiency of TS on HRTs ($p < 0.05$) as shown in Figure-2. Suspended solids could cause turbidity in water, affect the growth and propagation of aquatic species.

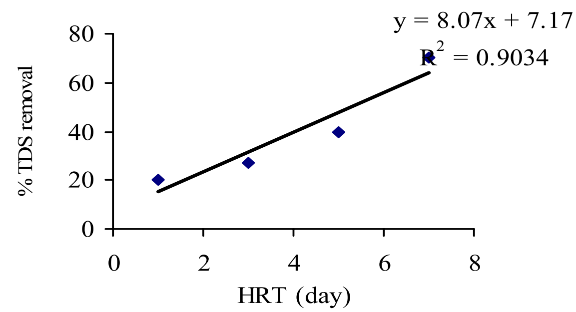

Figure-2. The total dissolved solid removal efficiency on HRTs of hydroponic reactor.

The pH values of effluent were in the ranges of 7.33-8.0 with the temperature of 27ºC-29ºC. These ranges of pH and temperature value have litter effects or did not have effect to the performance of hydroponic. Although the range of pH 5.5-6.5 useful plants that absorb all the nutrients. On the other hand, they provided the optimum condition for hydroponic was used to treat wastewater from fish pond.

The total COD removals of 1, 3, 5, and 7 days of hydraulics retention times were in the ranges of 52% to 79% as shown in Figure-3. The COD removal efficiency of 7 day of HRT was slightly higher than that of 5 day and decreased at 3 day and 1 day of hydraulics retention times, respectively. In this study, it could be observed that total COD removal was clearly dropped at 1.0 day HRT due to the increase of up-flow velocity and organic loading rates. The up-flow velocity was the main limiting factor for design of hydroponic reactor for treated fish pond wastewater. Gloger *et al.* (1995) compared the COD removal rate of hydroponic tanks that had lettuce plants with aerated tanks that had no plants in treating fish wastewater. They reported 54% higher COD removal rate for lettuce tanks compared with tanks with no plants. The COD removal rate of hydroponic reactor depended on the type and quantity of plants used.

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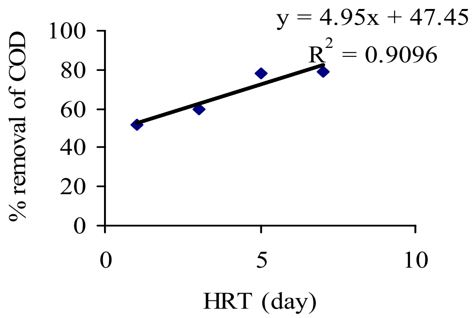

Figure-3. The total COD removal efficiency on HRTs of hydroponic reactor.

Fish were farmed and the waste products were used to feed plants. The waste produced by the fish, was turned into a plant usable nitrate source with the help of nitrifying bacteria belonging to the genus nitrosomonas and nitrobacter. Nitrosomonas remove the ammonia from the water that was excreted by the fish and nitrobacter oxidize toxic "nitrite" to non-toxic "nitrate". This nutrient rich solution feeds the plants and once they had extracted what they need it returns to the fish tanks. It took about one month for the establishment of the nitrifying bacteria so it was important that the feeding rates was kept low in this period and that the nitrite and ammonia levels were monitored. The major contents of nitrogen constituents in fish pond wastewater were organic-nitrogen with 80.5±3.2% and the remaining was nitrate-nitrogen. The ammonia-nitrogen in the influent was found for all HRTs; and it could be monitored at the effluent with the percentage was 36±6.1%. The results showed that plants could absorb ammonia from the fish pond wastewater to some degree. Almost of organic-nitrogen in fish pond wastewater were converted to ammonia-nitrogen due to bacterial composition and hydrolysis as shown in reaction and later assimilate to organic-nitrogen in bacterial cells.

Organic-nitrogen in fish pond wastewater+bacteria→NH_3

Moreover, organic-nitrogen in bacterial cells was also converted to ammonia-nitrogen according to the death and hydrolysis of cell. Regarding to nitrate-nitrogen, it was reduced to nitrite-nitrogen form and later assimilative reduced to ammonia-nitrogen as so-called ammonification by the action of bacteria under anaerobic condition as shown in chemical reaction. Some nitrite-nitrogen was reduced to nitrogen gas due to denitrification reaction.

NO_3^- (reduction) → NO_2^- (assimilate reduction) → NH_3

Because the system was aerated continuously, the ammonium is oxidized into nitrite and then into nitrate as follows:

$NH^+_4 + 1.5O_2$ (nitrosomonas)→ $NO_2^- + H_2O + 2H^+$

$NO_2^- + 1/2O_2$ (nitrobacter) → NO_3^-

The TKN removals on 1, 3, 5, and 7 days of hydraulics retention times were in the ranges of 12.23% to 50.56% as shown in Figure-4. The TKN removal efficiency of 7 day of HRT was highest and decreased at 5 day, 3 day and 1 day of hydraulics retention times, respectively. Gloger *et al*. (1995) attributed the reduction in ammonium ions (NH^+_4) to both direct plant uptake and nitrification.

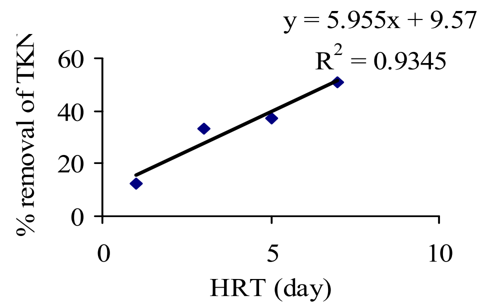

Figure-4. The TKN removal efficiency on HRTs of hydroponic reactor.

Wastewater from fish pond contains mostly organic. Phosphorus is a nutrient used by organisms for growth. It occurs in wastewater bound to oxygen to form phosphates. Phosphates come from a variety of sources including agricultural fertilizers, domestic wastewater, detergents, and geological formations that water of fish pond came from domestic wastewater. The discharge of wastewater containing phosphorus may cause algae growth in quantities sufficient to cause problems in fishing process. Dead and decaying algae could cause oxygen depletion problems which in turn could kill fish and other aquatic organisms in fish pond. The contents of fish pond wastewater consist of ortho-phosphate and organic-phosphorus with the ranges of 50-60% and 30-40%, respectively. Regarding to the treated wastewater, the minor content was organic-phosphorus. It could be concluded that organic-phosphorus was converted to ortho-phosphate in acid digestion step and some organic-phosphorus were used by microorganisms for cell synthesis and energy transport. Phosphorus was not only utilized by microorganism for cell maintenance, photosynthesis, and energy transport but also stored for subsequent use (Metcalf and eddy, 1991). The total phosphorus removals of 1, 3, 5, and 7 days of hydraulics retention times were in the ranges of 8.33% to 33.33% as shown in Figure-5.

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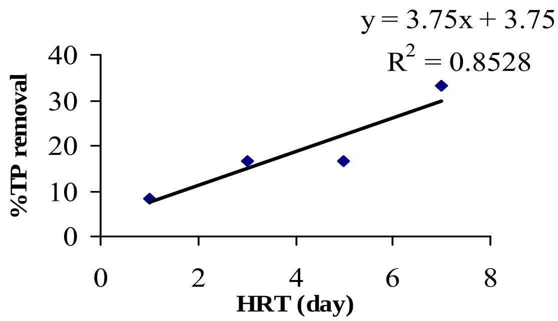

Figure-5. The total phosphorus removal efficiency on HRTs of hydroponic reactor.

The potassium concentration in each compartment decreased with time during the growth period and was dependent on the quantity and type of plants. About 0- 44.44% of the potassium in the fish pond wastewater was removed from the system as showed in Figure-6. Mant *et al*. (2003) achieved 24.9% potassium removal using S. viminalis grown in gravel hydroponic system to treat primary settled sewage wastewater. The removal efficiency of potassium observed in this study could be attributed to plant uptake, as well as to the precipitation of potassium in the form of K_2S. The wastewater was rich in potassium and the application rate was based on phosphorous requirement by plant, which resulted in potassium over fertilization for all plants.

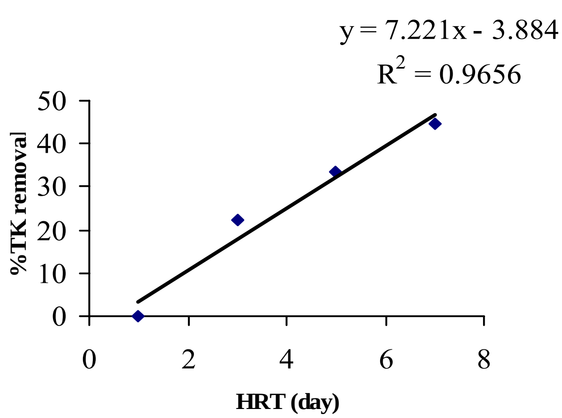

Figure-6. The total potassium removal efficiency on HRTs of hydroponic reactor.

Cropping need fertilizer to grow crops more efficiently and completely. This study did not used chemical fertilizers, in order to reduce the costs of cultivation and the good health of farmers and consumers. This study used fertilizer from wastewater of fish pond that fishes were fed with manure's chicken. Wastewater from fish farming with chicken manure were important variables related to the fertilizer application of plants, including N, P, and K as showed in Figures 4-6. The results of this study showed that plants in the hydroponic reactor could extract the nutrients in the wastewater to take advantage. They were shown with the percentage of TKN, TP, and TK removal. The results of this study also showed that the potassium was most eliminated, more than nitrogen and phosphorus, respectively. The removal of nutrients could be observed from the slope of the graph.

The result of this study also showed that plants in the hydroponic reactor could treat wastewater of fish pond. The dissolved oxygen (DO) in wastewater increased with the increasing of HRTs as showed in Figure-7.

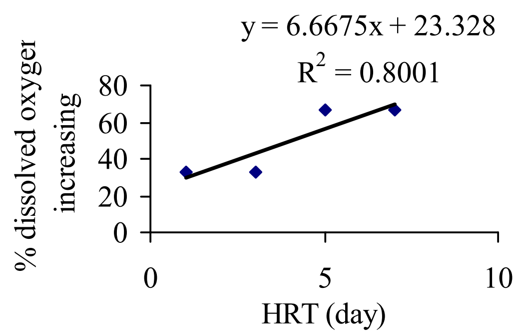

Figure-7. The percentage of dissolved oxygen increasing on HRTs of hydroponic reactor.

Although substantial amounts of soluble and insoluble substances were released by the seeds during the germination period, the plants were able to remove all the pollutants in wastewater and significant portions of those released substances. The total reductions in total solids, COD, NO_3–N, NO_2–N, phosphate and potassium ranged from 54.7% to 91.0%, 56.0% to 91.5%, 82.9% to 98.1%, 95.9% to 99.5%, 54.5% to 93.6% and 99.6% to 99.8%, respectively (Ghaly *et al*., 2005). The results of this study showed that hydroponic could treat wastewater from fish pond. Hydroponic production systems have potential for the treatment and reuse of wastewater in intensive aquaculture systems. Combining aquaculture with the hydroculture technique may serve the double purpose of reducing the pollution caused by fish farming and the demand for commercial fertilizers, thereby helping to preserve surface and ground water quality (Pettersen, 1987).

CONCLUSIONS

The total reductions on 1, 3, 5, and 7 days of hydraulics retention times of TDS, COD, TKN, TP and TK ranged from 20.4% to 70.0%, 52.0% to 79.0%, 12.23% to 50.56%, 8.33% to 33.33%, and 0% to 44.44%, respectively. The results of this study showed that hydroponic could treat wastewater from fish pond. The results also showed the increasing of dissolved oxygen in wastewater on 1, 3, 5, and 7 days of hydraulics retention times of DO ranged from 33.33% to 66.67%. Hydroponic production systems have potential for the treatment and reuse of wastewater in intensive aquaculture systems.

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