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HIGH RATE ANAEROBIC DIGESTION FOR SOLID WASTE TREATMENT OF THE MUSHROOM CROP FACTORY

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ABSTRACT

The solid wastes were about 10 to 20 tons / cycle from the mushroom crop factories that were released into the wilderness areas, canal, public swamps or wetlands of the community. The survey to preliminary problems in the Pakthongchai district found that the quality of water in canal near the mushroom crop factories was over the industry wastewater standards. A review of anaerobic treatment of wastewater in high rate anaerobic digestion reactors was presented. Solid wastes of the mushroom crop factories were discharged to be a collection of animal breeding and disease and also have bad smell. Dust and smoke from the burning of wood used as fuel to make the mushroom. As well as problem was global climate changing from greenhouse gases emissions for energy using in the mushroom crop factories. Therefore the any problems should be studied to find solutions to control solid waste treatment, renewable energy to fuel production facility of the mushroom crop factories and the economy evaluation of the biogas plants was a renewable fuel. This study had the four conditions of hydraulic retention times were 3 days, 5 days, 7 days, and 9 days following which the all conditions were controlled system in the range of pH 7.5 ± 0.5 and 25 - 40 ºC. The influence of temperature, nutrients and pH upon process performance was evaluated. A pilot-scale of the high rate anaerobic digestion reactor with vertically arranged PVC tubes as biomass carrier, treating the solid wastes of the mushroom crop factories was started-up in 31 days at ambient temperatures between 25 - 40 ºC. The start-up process consisted of a long acclimatization phase followed by a low loaded growth phase at which total COD removal efficiencies of 80-90% were achieved. The results showed that the high rate anaerobic digestion reactor could be effective in removing COD are highest were 80.00%. The pH was 7.00 - 7.67 at outlet in the four hydraulic retention times. The ratio of COD: BOD was high as shown that the anaerobic biological process has the potential to eliminate the organic matter in the solid wastes. Most organic compounds containing carbon was the main component to be easily digested by microorganisms. There was a significant organic removal efficiency of the high rate anaerobic digestion tested in terms of TS, DO, COD, N, P, and K ($p < 0.05$). The maximum biogas production was 4.00 cm^3 / day in the hydraulic retention time as 9 days. A summary of this research could to solve problems many aspects of the community. The high rate anaerobic digestion technology reduced to solid wastes and air pollution such as dust, smoke and greenhouse gases from the biogas using as fuel to the mushroom crop factories. Therefore, the factories should reduce emissions from energy consumption such as reduce electricity utilization in factories and reduce the use of firewood for heating in production. The economics evaluation of solid wastes to produce biogas showed that the internal rate of return of this project (IRR) was 17% per year, PI was 1.51, which was greater than 1, this project should be invest and the payback period was 1.33 years.

Keywords: high rate anaerobic digestion, mushroom crop, biogas.

INTRODUCTION

The solid wastes were about 10 to 20 tons / cycle from the mushroom crop factories that were released into the wilderness areas, canal, public swamps or wetlands of the community. The survey to preliminary problems in the Pakthongchai district found that the quality of water in canal near the mushroom crop factories was over the industry wastewater standards. A review of anaerobic treatment of wastewater in high rate anaerobic digestion reactors was presented. Solid wastes of the mushroom crop factories were discharged to be a collection of animal breeding and disease and also have bad smell. Dust and smoke from the burning of wood used as fuel to make the mushroom. As well as problem was global climate changing from greenhouse gases emissions for energy using in factories (Intergovernmental Panel on Climate Change, 1996). Therefore the any problems should be studied to find solutions to control solid waste treatment,

renewable energy to fuel production facility of the mushroom crop factories and the economy evaluation of the biogas plants was a renewable fuel.

Investment analysis was the planning of value-adding, long-term corporate financial projects relating to investments funded through and affecting the project of capital structure Campbell and Stephen (1997). This project used payback period, PI, and IRR were index for the feasibility study.

The internal rate of return (IRR) of a project was the rate of return which equates the net present value of the projects cash flows to zero; or equivalently the rate of return which equates the present value of inflows to the present value of cash outflows. The internal rate of return (IRR) solves the following equation:

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$$\sum_{t=1}^{X} \frac{X_t}{(1+IRR)^t} - I = 0 \qquad (1)$$

In determining whether to accept or reject a particular project, the IRR decision rule was

- Accept a project if IRR > r_p
- Reject a project if IRR < r_p
- Indifferent if IRR = r_p
- For Mutually exclusive projects accept the project with highest IRR if IRR > r_p

Where; r_p was the required return on the project.

Payback Period was the period of time required for the return on an investment to "repay" the sum of the original investment. Payback period intuitively measures how long something takes to "pay for itself." All else being equal, shorter payback periods are preferable to longer payback periods. To calculate a more exact payback period (Williams, *et al*, 2012):

Payback Period = Amount to be Invested /
　　　　　　　　Annual Net Cash Flow　　　(2)

Campbell and Stephen (1997) according to apply the payback period criterion, it was necessary for management to establish a maximum acceptable payback value PP*. In practice, PP* was usually between 2 and 4 years. In determining whether to accept or reject a particular project, the payback period decision rule was:

- Accept if PP < PP*
- Reject if PP > PP*
- Indifferent where PP = PP*
- For mutually exclusive alternatives accept the project with the lowest PP if PP < PP*

The profitability index, was used when projects had only a limited supply of capital with which to invest in positive NPV projects. This type of problem was referred to as a capital rationing problem. Given that the objective was to maximize shareholder wealth, the objective in the capital rationing problem was to identify that subset of projects that collectively had the highest aggregate net present value. To assist in that evaluation, this method required that we computed each projects profitability index PI.

$$PI = \frac{NPV}{I} \qquad (3)$$

Then ranked the projects PI from highest to lowest, and then selected from the top of the list until the capital budget was exhausted. The idea behind the profitability index method was that this would provide the
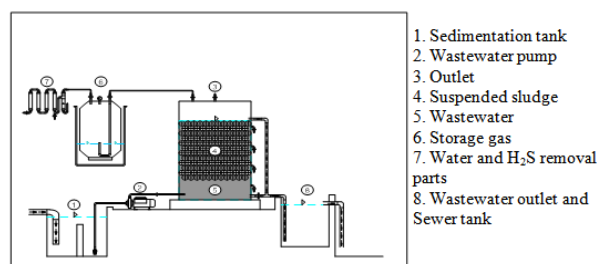
subset of projects that maximize the aggregate net present value (Campbell and Stephen, 1997).

RESEARCH METHOD

Equipment used in operations research

The high rate anaerobic digestion reactor was attempted to achieve contact between microorganism and nutrients or sewage sludge by circulate of wastewater sludge in system. The high rate anaerobic digestion include reactor has 880 litres in a cylindrical shape, 75 cm in diameter, and 2 meters high as shown in Figure-1. The components of the high rate anaerobic digestion reactor were as follows.

- Circulation pumps to the sewage sludge of the high rate anaerobic digestion reactor
- Section for exhaust biogas of the high rate anaerobic digestion reactor

1. Sedimentation tank
2. Wastewater pump
3. Outlet
4. Suspended sludge
5. Wastewater
6. Storage gas
7. Water and H_2S removal parts
8. Wastewater outlet and Sewer tank

Figure-1. Section of the high rate anaerobic digestion reactor.

METHODOLOGY

The mushroom crop factories were in the Pakthongchai district, Nakhon Ratchasima province, Thailand. This study took solid wastes from mushroom crop, were dissolved in the liquid state as wastewater. The solid wastes from the mushroom crop were crushed and sifted into small pieces. Then, they were put into the reactor and mixed with water in a ratio of 50:50, respectively. This study had the four conditions of hydraulic retention times were 3 days, 5 days, 7 days, and 9 days following which the all conditions were controlled system in the range of pH 7.5 ± 0.5 and 25 - 40 ℃, The influence of temperature, nutrients and pH upon process performance was evaluated. A pilot-scale of the high rate anaerobic digestion reactor with vertically arranged PVC tubes as biomass carrier, treating the solid wastes of the mushroom crop factories was started-up in 31 days at ambient temperatures between 25 - 40 ℃. The start-up process consisted of a long acclimatization phase followed by a low loaded growth phase at which total COD removal efficiencies of 80-90% were achieved. The system went into steady state. The percentage average of COD removal in 10 days had standard deviation less than 10%. The wastewater samples were collected at inlet and

outlet of the high rate anaerobic digestion reactor. The parameters were analysed with the Standard method (APHA, AWWA, WEF, 1992).

Statistical data analysis

　　　　The data were analysed with descriptive statistics and statistical analysis as follows:

　　　　a) To describe the characteristics of the wastewater, performance of the high rate anaerobic digestion reactor, and the volume of biogases each day in mean, standard deviation, and percentages of efficiency (Cavana *et al*., 2001, Yamane, 1973).

　　　　b) Performance testing of the high rate anaerobic digestion reactor and the difference of before and after treatment of the temperature, DO, pH, TS, COD, N, P, and K as shown in equation 4 that they were tested at 95% confidence level (Keeratiurai and Polprasert, 2004, Keeratiurai, 2012).

$$\% \text{ Removal efficiency} = \frac{(in - out)}{in} \times 100 \qquad (4)$$

RESULTS AND DISCUSSION

　　　　The study analysed wastewater samples from the solid wastes of the mushroom crop factories in the community of the Pakthongchai district, Nakhon Ratchasima province, Thailand. Wastewater was treated using the high rate anaerobic digestion technology. Hydraulic retention times (HRTs) were 3 days, 5 days, 7 days, and 9 days to provide overview of this study. Changes of basic parameters, including, temperature, pH, DO of wastewater inputs to the system and wastewater out of the system, and volume of biogases were analyzed by standard method. The results of the analysis of pH DO from wastewater out of the system, and the volume of biogases as shown in Table-1, Figure-2 and Figure-3, respectively. Table-1 showed that hydraulic retention times (HRTs) influenced slightly to the pH. The rise of HRTs made the anaerobic digestion system to adjust to neutrality.

Table-1. The results of the analysis of pH and temperature on HRTs.

HRTs (days)	State	pH	Temp (°C)
3	In	8.00	29.50
	Out	7.67	29.70
5	In	8.00	28.90
	Out	7.67	29.20
7	In	8.00	29.0
	Out	7.33	30.0
9	In	8.00	28.4
	Out	7.00	30.0

	3	5	7	9
Output	6	6	6	6
Input	2	2	1.67	1.67

HRTs (days)
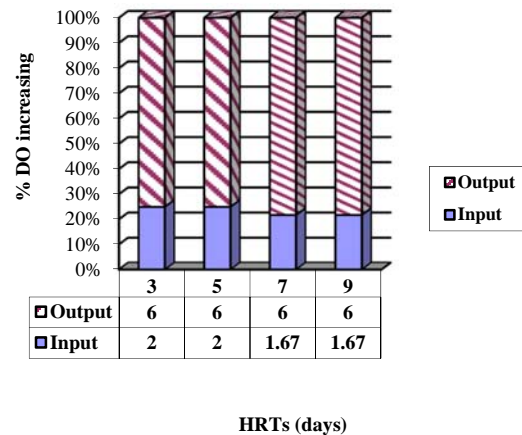
Figure-2. DO concentration (mg/L) and percentage of DO increasing on HRTs.

　　　　The hydraulic retention times (HRTs) of wastewater were controlled in the high rate anaerobic digestion reactors. The 7 days and 9 days of HRTs were highest efficiency in increasing of DO as shown in Figure-2. Figure-2 showed the increasing of dissolved oxygen depended on the increasing of HRTs.


$$y = 0.0665x + 3.2685$$
$$R^2 = 0.394$$
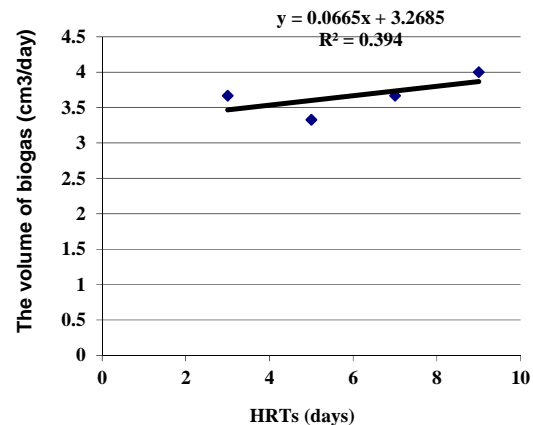
Figure-3. The volume of biogases on HRTs (cm³/day).

　　　　The condition control of wastewater into the system, the results of this study showed pH was 7.5 ± 0.5, temperature was 28.4-30 °C and hydraulic retention times was 9 days, were the condition with the highest efficiency in the biogas production as shown in Figure-3. These ranges of pH value did not have any effects to the performance of the high rate anaerobic digestion. In the other hand, they provide the optimum condition for acidogenesis bacteria and methanogens (Keeratiurai, 2012). The organic compound in the high rate anaerobic digestion reactors was assumed to be converted

to organic acids and later to acetic acid, and finally to methane and carbon dioxide gas. Figure-3 showed that the increasing of biogas production depended on the increasing of HRTs of the high rate anaerobic digestion as equation $y = 0.0665(X) + 3.2685$ with $R^2 = 0.394$.

There was a significant organic removal efficiency of the high rate anaerobic digestion system tested in terms of TS, BOD, COD, N, P, and K ($p < 0.05$). Total solids could cause turbidity in water, affect the growth and propagation of aquatic species. The hydraulic retention times (HRTs) of wastewater were controlled in the reactors, were efficiency in treating of TS, BOD, and COD, N, P, and K. The result showed that the high rate anaerobic digestion reactor could be effective in removing COD was highest as 80.00%. The efficiency of the COD removal depended on the HRTs. The results of this study showed the 7 days and 9 days of HRTs had the highest efficiency of COD removal as shown in Figure-4. The equation showed the relation of the COD removal and HRTs was $y = 13.5(X) – 28.5$ with $R^2 = 0.8526$. The concentration ratio of COD: BOD was high. The anaerobic biological process has the potential to eliminate the organic matter in the wastewater. Most organic compounds containing carbon was the main component to be easily digested by microorganisms (Keeratiurai, 2012).
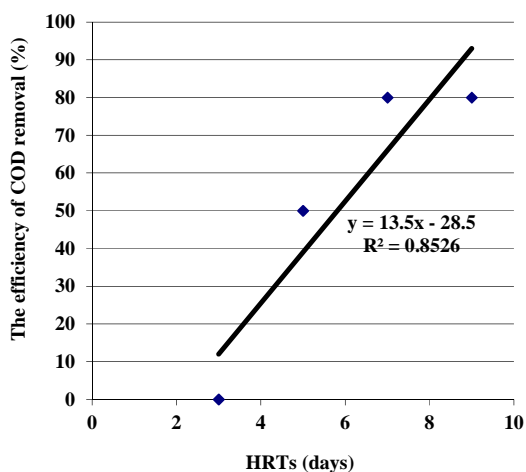

Figure-4. The percentage of COD removal on HRTs.

Total solids removal efficiency was proportional to HRTs. The results showed the 9 days of HRT had the highest efficiency of total solids removal was 70% as shown in Figure-5. The equation showed the relation of the total solid removal and HRTs was $y = 12.5(X) - 47.5$ with $R^2 = 0.8993$.
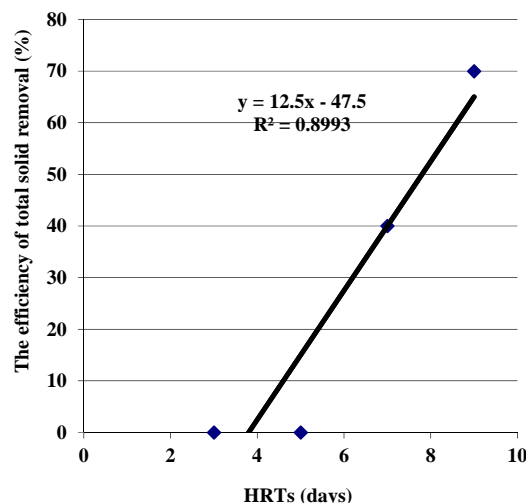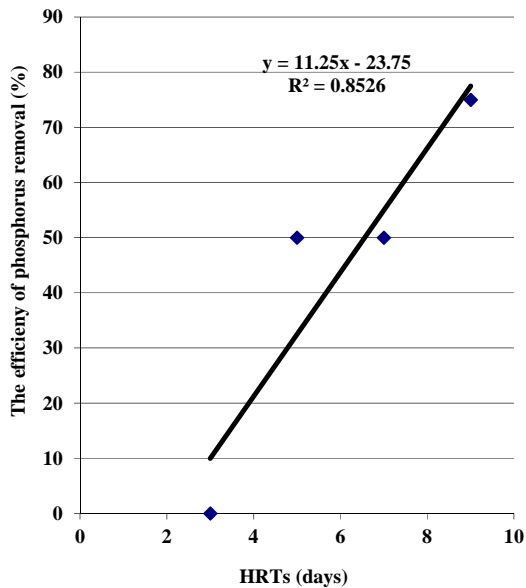

Figure-5. The relation of the efficiency of total solid removal on HRTs.

Macronutrient fertilizers were generally labeled with an N, P, K analysis, based on the relative content of the chemical elements nitrogen (N), phosphorus (P), and potassium (K) that were commonly used in fertilizers. The results of this study also showed the efficiency of removal of nitrogen (N), phosphorus (P), and potassium (K) on HRTs as shown in Figure 6-8. The efficiency of removal of nitrogen, phosphorus, and potassium were proportional to the HRTs. Figure-6 showed the relationship of the efficiency of nitrogen removal (%) and HRTs (days) that the increasing of the efficiency of nitrogen removal was proportional to the increasing of the HRTs as the equation was $y = 4.167 (X) – 12.502$ with $R^2 = 1$. The results of this study also showed the highest efficiency of nitrogen removal was 25% on HRT was 9 days. Figure-7 showed the relationship of the efficiency of phosphorus removal (%) and HRTs (days) that the increasing of the efficiency of phosphorus removal was proportional to the increasing of the HRTs as the equation was $y = 11.25 (X) - 23.75$ with $R^2 = 0.8526$. The results of this study also showed the highest efficiency of phosphorus removal was 75% on HRT was 9 days. Figure-8 showed the relationship of the efficiency of potassium removal (%) and HRTs (days) that the increasing of the efficiency of potassium removal was proportional to the increasing of the HRTs as the equation was $y = 2.222 (X) - 7.777$ with $R^2 = 0.8$. The results of this study also showed the highest efficiency of potassium removal was 11.11% on HRTs were 7 and 9 days.
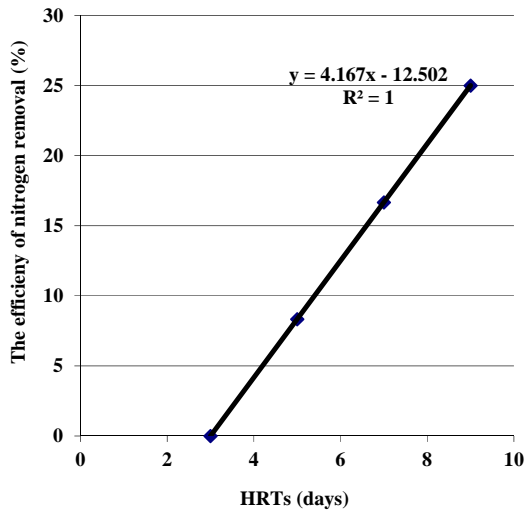
Figure-6. The relation of the efficiency of nitrogen removal on HRTs.

Figure-7. The relation of the efficiency of phosphorus removal on HRTs.
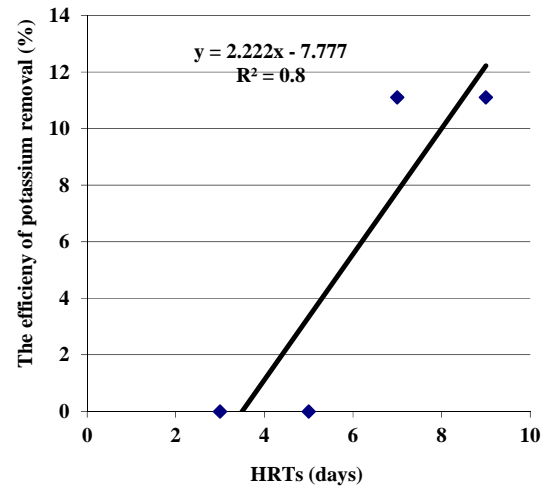
Figure-8. The relation of the efficiency of potassium removal on HRTs.

Analysis of the economic values

This research also studied the economic values of the high rate anaerobic digestion reactor that treated wastewater from the solid wastes of the mushroom crop factories and produced biogas from process for using as fuel to make mushroom. Therefore, the factories could reduce energy consumption such as reduced electricity utilization in factories for lighting by lamplight and reduced the using of firewood for heating in mushroom crop production. In addition results indicated that this high rate anaerobic digestion system was less expensive when the cost of this system was compared to the commercially available wastewater treatment tanks. The economic values were the costs of construction and energy used per unit. The results showed the IRR was 17% per year, the PI was 1.51, and the payback period was 1.33 years as shown in Table-2.

Table-2. The economic values of the high rate anaerobic digestion reactor that treated solid wastes and produced biogas from process for using as fuel to make the mushroom.

The economic values	Performance of the high rate anaerobic digestion reactor
Internal rate of return (IRR)	17% per year
PI	1.51
Payback Period	1.33 years

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SUMMARY AND CONCLUDING REMARKS

The mushroom crop factories were in the Pakthongchai district, Nakhon Ratchasima province, Thailand. This study took solid wastes from mushroom crop, were dissolved in the liquid state as wastewater. This study had the hydraulic retention times were 3 days, 5 days, 7 days, and 9 days following which the all conditions were controlled system in the range of pH 7.5 ± 0.5 and 28.4 - 30 ℃, The influence of temperature, nutrients and pH upon process performance was evaluated. The results of this study showed hydraulic retention times was 9 days, were the condition with the highest efficiency in the DO increasing and biogas production. The results showed that the high rate anaerobic digestion reactor could be effective in the removing the COD and the total solids were highest as 80% and 70%, respectively. The results of this study showed the highest efficiency of nitrogen and phosphorus removal was 25% and 75%; respectively on HRT was 9 days. The results of this study also showed the highest efficiency of potassium removal was 11.11% on 7 and 9 days of HRTs.

A summary of this research could to solve problems many aspects of the community. The high rate anaerobic digestion technology reduced to solid wastes and air pollution such as dust, smoke and greenhouse gases from the biogas using as fuel to the mushroom crop factories. Therefore, the factories should reduce emissions from energy consumption such as reduced the use of firewood for heating in mushroom production. It was suggested that the use of firewood for heating should be reduced because it creates the highest carbon emission (Keeratiurai, 2012). The economics evaluation of solid wastes to produce biogas showed that the internal rate of return of this project (IRR) was 17% per year, PI was 1.51, which is greater than 1 this project should invest and the payback period was 1.33 years.

ACKNOWLEDGEMENTS

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