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Household Cyanobacteria Bio-reactor to Diminish Kitchen Waste Sewage Malodor and Produces Fertilizer

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Abstract: A pilot cyanobacteria bio-reactor for household usage was tested to treat kitchen sewage. The bio-reactor could efficiently reduce the sewage malodor, coagulate lipids, raise its pH and clarify sewage. The sewage treated by this bio-reactor could be in line with Taiwan EPA (Environmental Protection Administration) standard for drainage. The tap water diluted 1:50 of treated sewage had been tested for using as agricultural liquid bio-fertilizer. The fertilizer had lower fly attraction rate than untreated sewage. The treated sewage diluted 1:50 has been used to raise fish tilapia (*Oreochromis mossambicus*) successfully. For an average four member family in Taiwan, about 3.2 kg (kilograms) of kitchen waste may produce each day, and about 40% (1.3 kg) of sewage may be sieved down. If every family can prepare two sets of this easy operative and cost effective bio-reactor tanks and operate them alternately, most family kitchen sewage can be treated at home.

Keywords: household cyanobacteria bio-reactor; kitchen sewage; bio-fertilizer.

1. Introduction

Kitchen waste sewage (the liquid portion of kitchen food waste) contains carbohydrates, proteins, fats, and cellulose etc.; those are the source of nutrition for microbial metabolism [1]. Under anaerobic condition, microorganismms break down those materials into small molecules, produce organically reduced sulfur compounds, such as H_2S [2], acids [3], ammonia [4, 5] and amines ($R\text{-}NH_2$) [2], which are the most likely source of malodor [6].

In Taiwan, garbage trucks are also equipped with barrels to collect kitchen waste. Kitchen waste has high moisture content (about 70%), malodor, high oil and grease levels as well as salt. A significant portion of the kitchen waste in Taiwan was treated by landfilling or incineration. The sewage portion will lower the economic efficiency of incinerators. If treated inadequately by landfilling, the unpleasant odors, and ground-water pollution may cause residents to protest [7].

This research tested the effectiveness of a simple and cost effective cyanobacteria bio-reactor to deal with kitchen waste sewage. The bio-reactor can diminish sewage malodor, and transform sewage to liquid fertilizer for irrigating household flower plants, vegetables, community organic gardens. In case have to discharge, it can be filtered through pieces of cheese cloth then drained into the sewer system legally. This bio-reactor need not add any chemicals, operates easily, and almost every household can apply this cheap bio-reactor to treat their own kitchen sewage. This kind of

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household treatment can reduce kitchen waste weight about 40% for easier garbage truck collection. The cyanobacteria can decay organic pollutants and decreases water pollution [8]. The liquid drained solid kitchen waste can then be sent for incineration or compost.

2. Materials and Methods

2.1. Kitchen waste residue separation

Household collected kitchen waste was filtered through a 0.2 x 0.2 mm^2 pore size sieve. The filtrate was used for this study. No chemicals were needed.

2.2. Cyanobacteria source and maintenance

Lyngbya sp. was isolated from Beinan river, Taitung (a county locates in Taiwan east coast) [9]. It was maintained and expanded in 20-liter transparent covered plastic tanks contained BG-11 media [10]. An aquarium air pump (110 V, 4.5 W, 50 Hz, about 4,400 cm^3/min. air supply) was used to provide air through a sterilized cotton ball stuffed plastic tube into each tank. A CCFL (cold cathode fluorescent light) light ball (3,000 lux) was hanged on rear top 10 cm above each tank to provide the supplemental continuous illumination. Temperatures were ambient outdoor levels, ranging from 20° - 32 ℃.

2.3. Cyanobacteria quantitation

Cyanobacteria dry weight was obtained by modifying the method of Ratana et al. [11]. Each sample (1,000 mL) was filtered through a piece of Whatman filter paper (110 mm diameter, 100 circles, Advantec, Toyo Roshi Kaisha, Japan), while the sample was being filtered, they were washed with 250 mL hydrochloride acidified water (pH 4) to eliminate salt precipitate, after which the filter paper was dried in an oven at 80 ℃ for 24 h and weighed.

2.4. Select cyanobacteria with kitchen sewage treatment ability

Each 500 mL- Erlenmeyer flask was filled with 300 mL. One percent unsterilized kitchen sewage (diluted with tap water) and 0.06 g (dry weight) of *Lyngbya* sp. was added.

The flasks were stuffed with cotton balls on the necks, and set on a shaker (100 rpm). Other conditions were the same as aforementioned in "cyanobacteria source and maintenance" section.

After 30 days, dominant grown *Lyngbya* cells were collected to seed flasks with 2% unsterilized kitchen sewage (diluted with tap water). Another 30 days later, dominant grown *Lyngbya* cells were collected to seed flasks with 5% unsterilized kitchen sewage. Then repeated the similar procedure to seed flasks with 10% unsterilized kitchen sewage, and then seeded flasks with 20%, 25%, and 30% unsterilized kitchen sewage sequentially.

2.5. Experimental design

Each 20-liter transparent plastic tank was filled with four liters of kitchen waster sewage filtrate and 16 liters of tap water (1:5 diluted). The control tank was set neither aeration nor cyanobacteria added. One experimental group tank was set with aeration (as described above) but without cyanobacteria. Another experimental group tank was set with both aeration and cyanobacteria (0.2 g/L, dry weight) added. One round of test cycle was five to ten days, depended on how long the data could show the trend of the tendency. The tanks used in this study were screw tight covered. The malodor was sealed inside the tanks. But, the covers were not entirely seamless, small amount of air could effuse out from the cover aperture.

2.6. Malodor components exam

To check concentrations of ammonia, H_2S, and acids (acetic acid and butyric acid were chosen for it usually presented during sewage treatment) [1, 12] and amines. A Gastec GV-100 (GASTEC Corporation, Japan) hand sampling pump was used for sampling. For measuring each different kind of component used a specific detector tube. A small hole was punched on the side of each tank cover. When collecting the air sample, the tip of the detector tube was pierced in the hole and a full-stroke (100 mL) was pumped. The reading was adjusted by the temperature and related compensation factors as described in Gastec operation manual. All types of detector tubes were chosen to fit their sensitivities range. After sucking air into the detector tube, the specific component in the air will react with the chemical inside the tube. By reading the distance of the color change inside the tube, the concentration of the specific component was known. The hole on the cover was sealed with a piece of tape after sampling.

2.7. COD (chemical oxygen demand), DO (dissolved oxygen) and pH measurements

A Hach DR/2010 spectrophotometer was used to detect COD (followed the manual). In case of any sample COD value greater than the instrument measurement limit, de-ionized water was used to make dilutions and then the COD value was measured and calculated by multiplying the dilution coefficient. DO was measured by a dissolved oxygen meter (TECPEL DO-16098). A pH meter (Milwaukee pH 600) was used to measure sewage pH values.

2.8. Fertility comparison

Bok Choy (*Brassica chinensis* L. CV. Ching-Geeng) (seeds bought from Taitung An-Tung Company) was used to compare the fertility for cyanobacteria treated kitchen sewage with the most popular market sold household flower and vegetable fertilizer HYPONeX #2 (major components : 4% ammonium , 4% nitrate , water-soluble phosphorus anhydride 20%, water-soluble potassium 20%, and others). The HYPONeX #2 was 1:1000 (w/v) diluted in tap water by following the producer's remark. The cyanobacteria treated (10 days) kitchen sewage was again diluted 1:10 in tap water (the sewage was originally diluted 1:5 when started the treatment). The 1:50 dilution was chosen to prevent high sodium concentration which would displace the calcium and magnesium in the soil, and lead to a decrease in filtration and permeability of the soil leading to problems with crop production [13]. Another experimental group of kitchen sewage (diluted 1:50 in tap water) without cyanobacteria treatment was also used. The control group only irrigated with tap water.

In the field, each ridge planted 40 Bok Choy. Each Ridge was 50 250 cm2 in size. Bok Choy was planted approximately even distributed on the ridge. Every ridge group hand sprinkling irrigated one liter tap water each day, and groups one to four ridges every four days separately hand sprinkling irrigated one of the following fertilizers: 500 ml diluted HYPONeX #2 solution, 500 mL diluted cyanobacteria treated sewage, 500 mL tap water, or 500 mL diluted untreated sewage. Each ridge separated five meters from each other. The Bok Choy were grown for seven weeks, during the growth period, every seven days three biggest vegetables were picked from each ridge and weighed.

2.9. Test of germination rate

Bok Choy seeds were seeded on plates contained different fertilizer to check the germination rates. Group A: HYPONeX #2 (1:1000 dilution in tap water) 20 mL. Group B: Diluted (1:50) cyanobacteria treated (10 days) sewage 20 mL. Group C: Tap water 20 mL.

Group D: Diluted (1:50) untreated sewage 20 mL. For four Petri dishes, each dish placed 100 Bok Choy seeds and 20 mL fertilizer, incubated at ambient room temperature under 1,500 lux incandescent light for three days then count the germination rates.

2.10. Fly attraction test

To test if the cyanobacteria treated sewage may attract flies to the field. Sticky flypapers were used to catch flies around the Bok Choy ridges. One piece of sticky flypaper (24.7 × 45 cm^2) was placed on the center of each ridge. Every week after hand sprinkling the fertilizer, a new piece of flypaper was replaced.

2.11. Fish raise test

Cyanobacteria treated sewage again diluted 1:10 in tap water (the sewage was originally diluted 1:5 as aforementioned) was used to raise fish tilapia (*Oreochromis mossambicus*). Ten one-month-old fish bought from Guan-San Fishery (A town located in north part of Taitung County) were raised in a 100-liter open plastic container filled with 1:50 tap water diluted cyanobacteria treated sewage. Two sets of air pumps as described in the "cyanobacterium source and maintenance" section was used to pump air into the container (about 4,400 cm^3/min air supply per pump). Fish had not been fed during these three months experimental period. Fish ate the small food residuals and *Lyngbya* sp. in the container.

3. Results

3.1. Functional cyanobacteria selection

The highest concentration of kitchen sewage that *Lyngbya sp*. could grow well and form dominate strain was 20%. When the concentration was higher than 20%, the water transparency was obviously reduced and the turbidity could be noticed by the naked eye. Hence the *Lyngbya* sp. growth was inhibited.

3.2. NH_3, DO, H_2S, acetic acid, butyric acid, and R-NH_2 values

Kitchen sewage treated by cyanobacteria (with aeration) diminished the NH_3 that dispersed in the tank very fast. At the third day, the NH_3 concentration was not detectable by the Gastec detector tube. Kitchen sewage treated with aeration also could lower the NH_3 that dispersed in the tank, but, it took four days. The control group shown NH_3 lowered in the tank at the 2nd and 3rd days, then NH_3 gas raised again (figure 1). For the aerobic condition could cause NH_3 oxidized into nitrate [8].

Cyanobacteria photosynthesis could produce oxygen to increase oxidation. DO values showed the tank with cyanobacteria and aeration had higher DO values than the group of aeration without cyanobacteria added. The control group had lowest DO values (figure 2). The results might confirm cyanobacteria photosynthesis produced oxygen, and increased the dissolved oxygen concentration in the water.

H_2S showed similar results as NH_3, but it had even fast rate diminishing from the tank space. H_2S concentration diminished from the cyanobacteria treated tanks in one day, the aeration tanks took two days to get rid of the H2S. The control group did not show decline of H_2S in six days (figure 3).

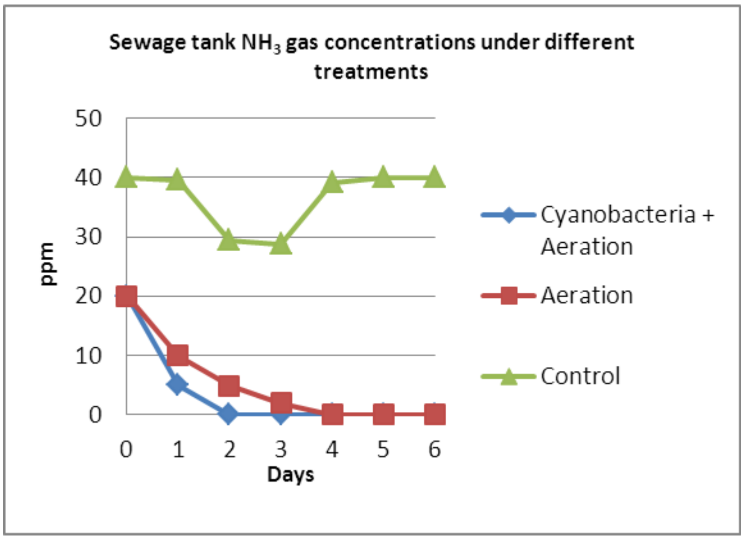

Figure1. NH_3 gas concentration values detected from different treatment tanks

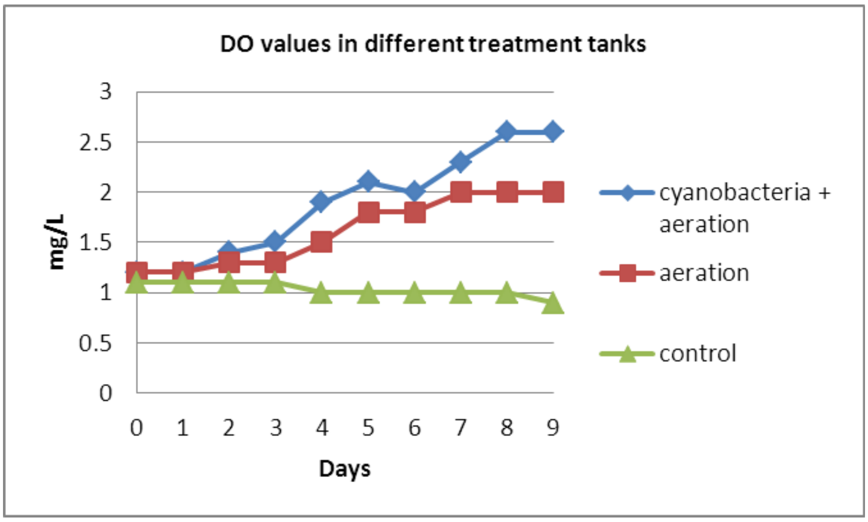

Figure 2. DO values in different treatment tanks

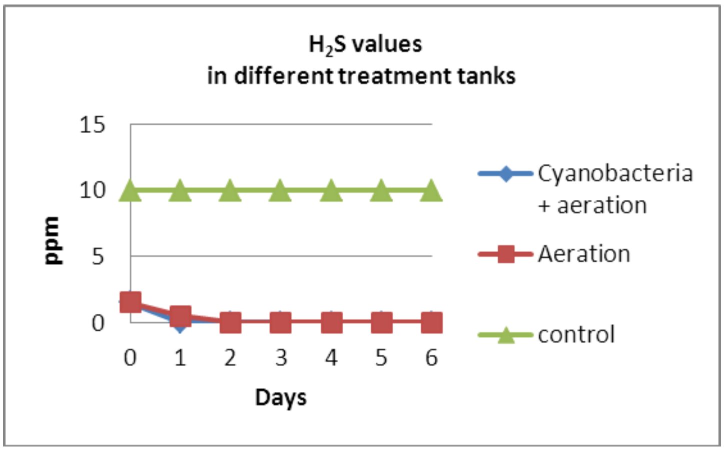

Figure 3. H_2S gas concentration values detected from different treatment tanks

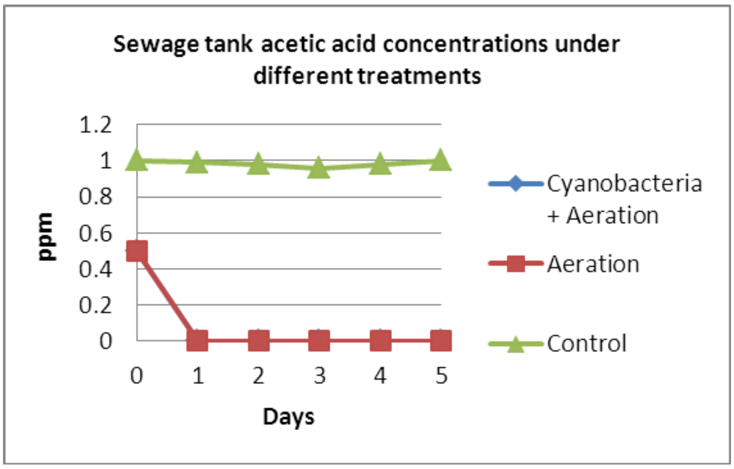

Figure 4. Acetic acid gas concentration values detected from different treatment tanks

Acetic acid and butyric acid both diminished from the cyanobacteria treated and aeration tanks at the second day, but not the control tank (figure 4). (Butyric acid had the similar results, data not shown). The line represents acetic acid values of cyanobacteria treated tank was overlaped with the acetic acid values of the aeration treated tank.

Amines were completely diminished from cyanobacteria treated tanks in one day, and diminished from aeration tanks on the third day. The control group did not show decline of amines concentration in six days (figure 5)

In fact, the cyanobacteria treated sewage tanks eliminated malodor at the second day, the sewage treated with aeration tank eliminated malodor at the 3rd day. The control tank did not eliminate malodor at the 6th day.

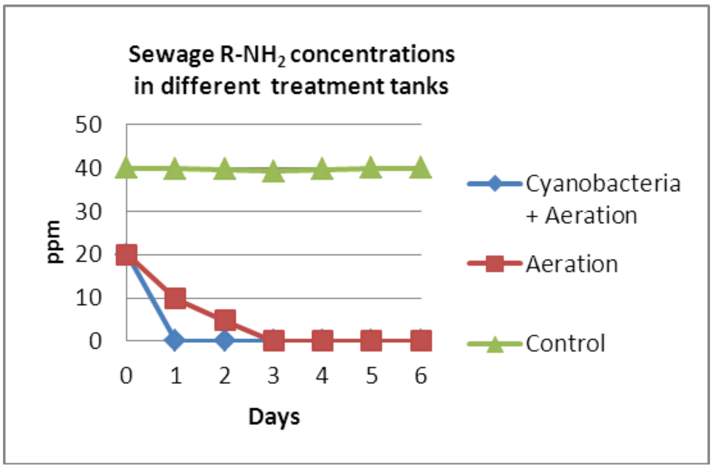

Figure 5. R-NH_2 gas concentration values detected from different treatment tanks

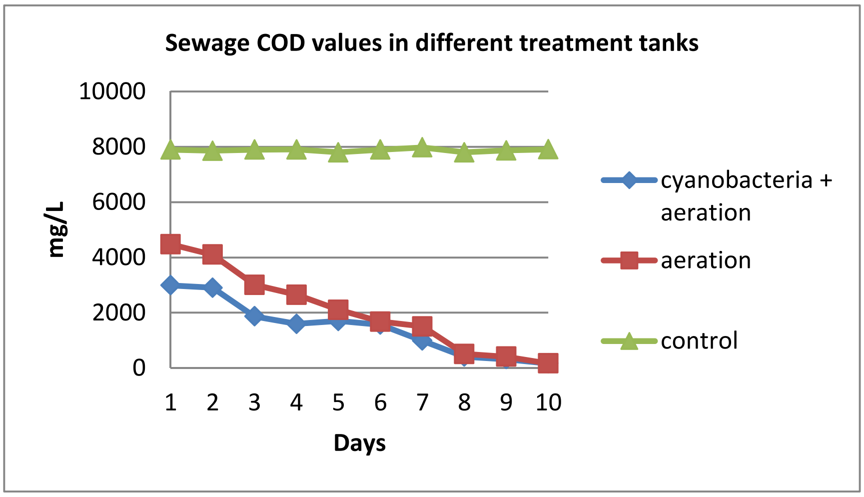

Figure 6. Sewage COD values in different treatment tanks

3.3. COD and pH values

Cyanobacteria plus aeration or aeration without cyanobacteria both treatments could lower COD values to less than 200 mg/L, the control group didn't show decline of COD values (figure 6). For cyanobacteria can produce oxygen when it photosynthesis. On the contrary, the control group without aeration, the degradation of organics was fairly low due to the lack of oxygen supply.

Cyanobacteria treated sewage, pH values changed from 4 to 9 in seven days. The aeration group took nine days raising the pH from 4 to 8. The control group did not show pH raising (figure 7). On the aerated tanks, oxygen enhanced the metabolism of the cyanobacteria, so as to the degradation of the organics (such as: acetic acid, butyric acid, etc.,) in the liquids. The pH increased with time. The pH value of original kitchen waste for each group was 4.0 without adjustment.

3.4. Bok Choy growth

Every seven days, three of the biggest plants were picked from each ridge and measured their weights and count the average. The picked plants were not re-planted back. The HYPONeX #2 fertilizer group had the heaviest weights, the cyanobacteria treated sewage fertilizer group had next, the tap water group had the 3rd, and the untreated sewage group had the last (figure8). Bok Choy grew on the ridge that used tap water as the fertilizer might use leftover nutrients in the soil, so, in short period of time the plants could grow well.

In a long run, Bok Choy should need supplement of fertilizer. Bok Choy grew on untreated sewage treated ridge shown the least growth.

3.5. Germination rate

All four group's seeds showed 100% germination rates on the 3rd day. The plate with untreated kitchen waste sewage had malodor.

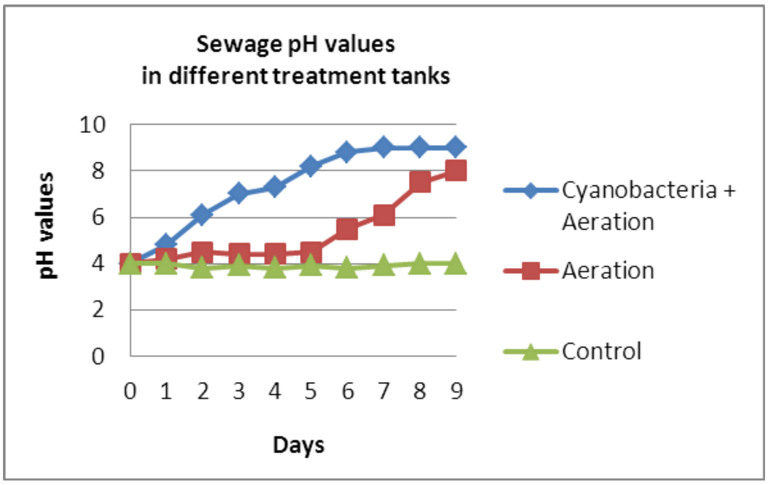

Figure 7. The pH values detected from different treatment tanks

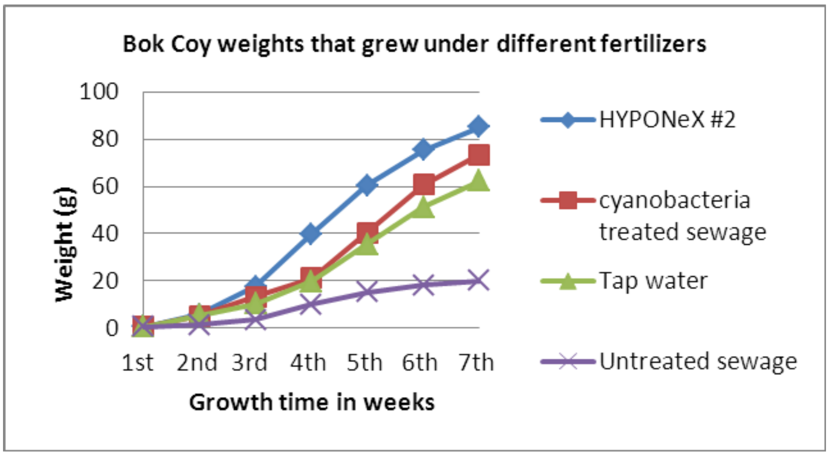

Figure 8. Averaged Bok Choy weights collected from different ridges that spread with different fertilizers

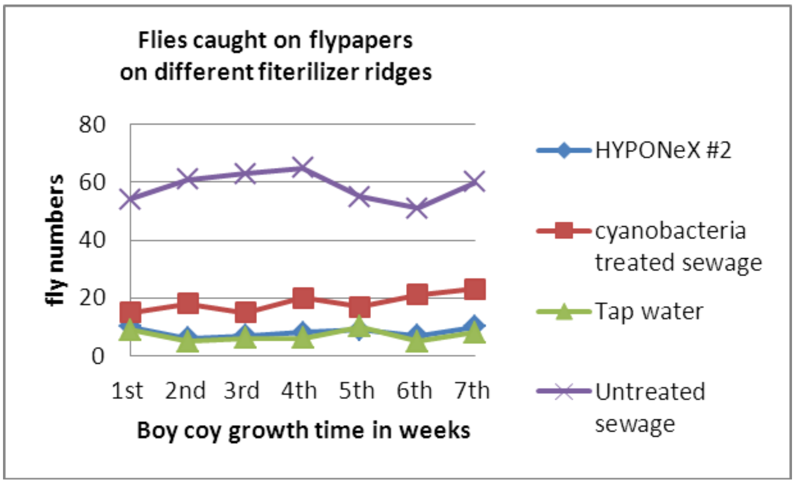

Figure 9. Fly numbers on the flypapers that collected from different fertilizer field ranges

3.6. Fly attraction test

HYPONeX #2 (1:1000 dilution in tap water) irrigated ridge and Tap water irrigated ridge had less flies attached on the flypapers. Cyanobacteria treated sewage irrigated ridge had a little more flies attached on the flypapers. The untreated sewage irrigated ridge had the most flies attached on the flypapers (figure 9).

3.7. Fish feeding

The ten tilapia fish raised in the cyanobacteria treated sewage (diluted 1:50 in tap water) kept alive after three months. No malodor could be sensed around the container. The food residues enlaced by *Lyngbya* filaments formed particles in the sewage. The cyanobacteria treated sewage was fairly clear. Fish lived in the diluted treated sewage were leisurely. Fish feces formed green threads were observed in the water. That means they ate the cyanobacteria inside the container. The diluted sewage still contained salt. That's why this experiment chose tilapia to feed for they are salt water tolerant. If fish can grow in the diluted cyanobacteria treated sewage, then it is reasonable to infer that sewage could be safely discharged into drainage.

4. Discussion

In this research, the first pilot household kitchen waste sewage bio-reactor was reported. For household usage, it should be very convenient to operators and cost effective. For the cyanobacteria bio-reactor no chemicals were needed to treat kitchen sewage. Tanks were covered, barely any tiny malodor could be sensed around the tanks by operators, and odor was reasonably tolerable. Each set of the bio-reactor, includes a 20-liter transparent plastic tank and an air pump, total cost no more than 30 USD. The nutrition in the sewage adsorbed and/or decomposed by dominate *Lyngbya* cells accompanied with other bacteria, eliminated the malodor, decreased COD.

According to Cheunbarn and Peerapornpisal [8], they speculated whether using cyanobacteria in the fertilizer, after the cyanobacteria treated sewage fertilizer spread in the field, the cyanobacteria gradually died and decomposed and released nutrients into the environment. So, the bio-reactor treated sewage could be used as bio-fertilizer. If the household doesn't want to use the treated sewage, the treated sewage can also be filtered through pieces of cheese cloth and drained. This bio-reactor took only one day to completely diminish the malodor and coagulate lipids of the sewage. Coagulated lipids floated on the sewage surface and could be picked up by a net and trashed for compost. This design is quite fast for treatment of kitchen sewage and convenient for converting sewage to a bio-fertilizer producer. The optimum cyanobacterium seeding concentration was 0.2 g/L dry weight, and the sewage concentration was 20% (1:5 diluted in tap water). *Lyngbya* cells could not form dominate strain in the bio-reactor if the seeding concentration was lower than 0.2 g/L. In Taiwan, about 0.8 kg (kilograms) of kitchen waste per person is produced each day [14, 15], and about 40% (0.3 kg) of sewage may be sieved down (by our lab operation records, data not shown). If every family can prepare 2 sets of this cyanobacteria bio-reactor and use each set alternately, then most of the time, kitchen sewage can be treated at home. This kind of bio-reactor is adequate to promote in tropical and sub-tropical areas. It occupies only 50 100 cm^2 area. When the cyanobacteria concentration is high, *Lyngbya* cells can be collected for composting or direct use for fertilizer.

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