Determination of Levels of Phosphate, Ammonia and Chlorine from Indoor and Outdoor Nano Tank System

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Abstract Fresh water, as well as river water quality and pollution control has worsened year after year due to rapid development that produce large amounts of waste which inevitably end up in the water bodies. Presence of ions such as phosphates, ammonia and chlorine in the water body determine the survivability of organisms and water quality in the aquatic ecosystem. Excessive or less ions will affect the balance of the ecosystem involved. For example phosphate stimulates the production of aquatic plants and phytoplankton as the food sources for other organisms. Excess present in the water body will cause eutrophication that caused algae bloom which will block sunlight from penetrating into the water body and also reduce the amount of dissolved oxygen. Another example, ammonia is enriching source of nutrient for fertilizer necessary in increasing yield of crops. However, excessive amount would lead to eutrophication. Even in low concentration, ammonia is toxic to aquatic organisms which can pose threat to the aquatic populations. Hence, the main objective of this study is to determine the levels of ions such as phosphate, ammonia and chlorine in different water bodies using colorimetric analysis. This will provide data on the health of the water bodies that can be used to sustain the larger ecosystem health and human population involved.

Keywords Phosphate; Ammonia; Chlorine; Aquaponic

Background

Fresh water quality and pollution control has worsened year after year due to rapid development in Malaysia. Large amounts of waste were produced, which includes industrial, commercial, domestic, and transportation waste which inevitably end up in the water bodies has led to higher rate of water pollution in Malaysia. These pollutants were mostly contributed by untreated or partially treated sewage from the manufacturing or agriculture industries, and generally came from the sources, including livestock farming, earthworks and land clearing activities, domestic sewage and other liquid organic waste products. Surrounding ecosystems and the ecological health of water bodies could be degraded as the level of pollution increases. Therefore, several water quality monitoring or prediction programs (artificial neural networks, ANNS) and sustainable use of water were actively launched and promoted (Huang et al., 2015).

The Environmental Monitoring and Assessment Program (EMAP) were started in South Dakota with US Environmental Protection Agency (USEPA) to monitor the surface water condition in waded perennial streams in 2000-2004. The objectives of EMAP were to develop monitoring tools in producing unbiased estimate of ecological status and trend of surface water across large geographic areas and to demonstrate effectiveness of the developed tools in a large scale assessment. Monitoring tools used were bio-indicators, stream survey design and estimation of reference condition. USEPA also provided a complete set of core ecological indicators that can be used to measure at each assessment stream sites. The ecological indicators included physical habitat, instream characteristics, aquatic vertebrate assemblages, periphyton assemblages, benthic macroinvertebrate assemblages, field properties, water chemistry and fish tissue contaminants.

The quality of a certain water system is usually assessed by measuring concentration of targeted pollutants presence inside the water system. In view of this, the sources of pollutants can be identified and the way to reduce
or remove the sources of pollutants offer several advantages including developing a sustainability environment. In a close aquaculture system, source of pollutants are included but not limited to fecal waste of fish and uneaten fish feed. Presence of phosphates, ammonia and chlorine in the water body are important for survivability of organisms and determination of water quality in the aquatic ecosystem. Phosphate is an important element for growth of plants and animals. It stimulates the production of aquatic plants and phytoplankton which are the food sources for other organisms. However excessive phosphates present in the water body would cause eutrophication other than algae bloom on the surface of water (Yanamadala, 2005). This occurrence would affect the water body as the bloom of algae will block sunlight from penetrating into the water thus light depending aquatic organisms and invertebrates will slowly deteriorate due to insufficient light available to carry out necessary photosynthesis process. The excessive presence of the micro algae also will compete with other aerobic aquatic organisms for the limited supply of oxygen available hence will cause reduction of the amount of dissolved oxygen available in the water system.

Ammonia, through nitrification process, can be break down into different agricultural beneficial nitrogen elements such as nitrate and nitrite. Nitrate is one of the major source used in fertilizer for agriculture to increase crops yield. However, excessive amount of nitrates would lead to eutrophication and decrease of water quality. Ammonia is toxic to fish and other aquatic organisms even in low concentration and thus when present in high amount it is very potent in drastically declining the aquatic organisms population in the affected water system. This is all due to toxic buildup in internal tissues and blood of the aquatic organisms when the aquatic organisms have difficulty in excreting out the toxicant efficiently from their body under the present of high amount of ammonia. These will eventually lead to death. Amount of ammonia concentration in water body depends on environmental factors such as water temperature, pH, dissolved oxygen and also carbon dioxide levels.

Chlorine or chloramine though is an excellent chemical used as disinfectant in treating water body for human consumption and usage, it can also cause harm to aquatic organisms in similar efficiency. Chlorine kills various microbial waterborne pathogens such as bacteria, viruses, protozoa and fungi which can grow on the walls of tanks or reservoirs. These pathogens might cause health problems to human such as cholera, typhoid and many more. Yet, exposing to high levels of chlorine in water can also cause health diseases and alter the physical condition of water which gave the water bad taste and odor (Global Health Center, 2017). Both chlorine and chloramine are highly toxic to all fish and invertebrates. Any fish or aquatic invertebrates expose to any measurable amount of chlorine will suffered from chemical burns. Fish gills are sensitive organ and are exposed directly to the aquatic environment in order to assist the respiration process. Thus gills necrosis due to chlorine or chloramine chemical burn can lead to respiratory difficulty and asphyxiation. At the same time, if chlorine absorbs into the fish body, this will causes burns throughout the fish as chlorine or chloramine spread inside the fish body through the blood system. Aquatic invertebrates also suffered the similar effect if expose to any measurable amount of chlorine or chloramine as they can absorb it through their body surfaces.

Aquaponic is a combination of traditional aquaculture (raising aquatic animals such as fish and prawns in tanks) and hydroponics (cultivating plants in water) in a symbiotic environment. The nitrogenous waste including feed waste and faecal waste excreted by the fish in the form of ammonia will be converted to nitrate or nitrite by the nitrifying bacteria. Fish feed waste dissolved in the water could provide necessary nutrients directly for plant, where these dissolved waste nutrients were assimilated by the plants after decomposed by the nitrifying bacteria, reducing discharge to the environment and extending the water use (Rakocy et al., 2006).

Hence, determination levels of phosphate, ammonia and chlorine in water bodies is important to sustain ecosystem health and human population. One of the methods of monitoring the levels of phosphate, ammonia and chlorine is by using colorimetric analysis. Colorimetric analysis is a method of determining the chemical compounds concentration in a solution with the aid of color reagent. It measures the color of the water sample by adding chemical reagent which forms a colored product and evaluates the colored product through comparator disc. But this method is not suitable if the water sources are turbid.
1 Methodology

Tanks for indoor and outdoor freshwater were constructed from fiberglass, each filled with 55 L (approximately 15 gallon) water and located in UCSI University. For outdoor freshwater tank with plants, 14 days basil seedlings (30 seedling for each tanks) were located on the filtration system to form a hydroponic or aquaponic system, respectively. All tanks were uniformly aerated and were filled with freshwater every 7 day after water samples were collected. Phosphates, ammonia and chlorine were determined following the methodology listed below. Water samples were collected from indoor and outdoor tanks, respectively in a duration of 4 sampling (one per week, a total of 4 weeks) between April and May 2018. The water temperature of indoor tanks is 21°C-32°C while the water temperature of outdoor tanks is 24°C-35°C. The quantity of feed given to a tank each day based on the total weight of fishes. The feeding rate is fixed to be 2.5% per day. pH for all the tanks were standardized at pH 7 and were recorded using LAQUA Twin pH meter.

Colorimetric analysis is measured by the Lovibond Tintometer. The method involves the matching of the color of light transmitted through a specified depth of sample with color transmitted from the same source through a set of colored glass slides.

1.1 Phosphates

Two 13.5 mm/10 mL molded cells were filled with water samples to the 10 mL mark. One of the molded cells was place in the left hand compartment of the comparator. One Lovibond Phosphate HR Tablet was added into another molded cell and it was crushed and mixed to dissolve. The molded cell was left to stand for 10 minutes and placed in the right hand compartment of the Lovibond tintometer with standard comparator discs 3/136. The comparator was held against a standard light source (not fluorescent) and the color produced was match against the disc by rotating the disc until a color match obtained. Phosphate concentration (mg/L) was displayed in the bottom right aperture of the comparator.

1.2 Ammonia

A total of 10 mL of water samples was poured into each 13.5 mm/10 mL molded cells. One cell was placed in the left hand side of the Lovibond tintometer with standard comparator disc 3/125. One Lovibond Ammonia No.1 tablet and one Lovibond Ammonia No.2 tablet were added into another cell. The tablets were crushed and mixed until fully dissolved. The cell was placed in the right hand side of the comparator and allowed to stand for 10 minutes. After 10 minutes, the color produced was match against the standards by holding the comparator against a light source of white light. The disc was rotated until the nearest color match was found, the ammonia concentration (mg/L) was displayed in the indicator window.

1.3 Chlorine

One 40 mm/20 mL molded cell containing the sample was placed in the left hand compartment of the Lovibond tintometer with standard comparator disc 3/2APH. Another 40 mm/20 mL cell was rinsed out with sample and filled to the 20 mL mark. One Chlorine HR tablet was added into the cell. It was crushed with a clean stirring rod and mixed thoroughly until dissolved. One acidifying GP tablet was added into the cell, crushed and mixed thoroughly until dissolved. The cell was placed in the right hand compartment of the comparator and the comparator was held facing a standard white light source. The disc was rotated until the nearest color match was obtained. The concentration of total chlorine (mg/L) was displayed at the bottom right hand aperture of the comparator.

2 Results

The concentration of phosphate, ammonia and chlorine from different water sample sources with different conditions, outdoor tank, indoor tank and planted tanks were recorded and tabulated in Table 1.

3 Discussion

Based on the results, the phosphate concentration in both indoor (4.0 ± 0.5 mg/L) and outdoor fish tanks (4.0 ± 0.5 mg/L) has higher concentration compared to planted tank (0 mg/L) (Table 1). This is due to the uneaten fish feeds, faeces, dead matter or the water itself in the tanks contribute in the increasing of phosphate level. Therefore,
increased phosphate level in fresh water may due to the higher phosphorus load to the fresh water during the nutrient mineralization process from this supplemented fish feed (Kibria, 2014). Furthermore, higher phosphorus load to the fresh water could lead to water pollution and turned water cloudy (Sharip and Suratman, 2017). The phosphate level in aquaponic tanks (Outdoor fish tanks with plant) is lower compare to the tank without plant. The possible reason for phosphate level decreased in aquaponic tank with growing basil was due to the phosphorus present in the fresh water have been taken up by plants, since phosphorus was an essential macronutrient for enhancing plant growth and development.

Table 1 The concentration of phosphate, ammonia and chlorine of water samples (Mean ± Standard Deviation, n=3) from outdoor tank, indoor tank and planted tanks

| Water sample sources                  | Concentration (mg/L) | pH     |
|---------------------------------------|----------------------|--------|
|                                       | Phosphate            | Ammonia| Chlorine|        |
| Outdoor fish tank                     | 4.0±0.5              | 1.0±0.0| <2.0±0.0| 7.2±0.2|
| Outdoor fish tank with plant          | 1.0±0.5              | 0.2±0.0| <2.0±0.0| 7.0±0.3|
| Indoor fish tank                      | 4.0±0.5              | 1.0±0.0| <2.0±0.0| 7.0±0.2|
| Planted tanks                         | 0.0±0.0              | 0.0±0.0| <2.0±0.0| 7.3±0.2|

Furthermore, Phosphorus is a nutrient source for growth of aquatic plants and animals in marine ecosystem. Excessive phosphorus concentration can lead to nutrient pollution and eventually caused eutrophication. Methods to manage phosphate pollution in a fish pond are mechanical dredging for removal of polluted sediments and pond aeration that facilitate the decomposition process of organic matter and prevent accumulation of excess nutrients. Besides, by adding phosphate removal additives such as Bentonite-lanthanum clay can reduce the dissolved phosphate concentration (Kurzbaum et al., 2017). It can react with phosphate and formed a permeable layer when settled out at the bottom of the pond. The layer would continue to bond with phosphorus as it released from the polluted sediment.

For ammonia concentration, both indoor and outdoor fish tanks have 1.0 ± 0.0 mg/L ammonia whereas the ammonia concentration for planted tank is 0 mg/L (Table 1). Tanks with fishes (Indoor and outdoor) have higher ammonia concentration. This is due to the breakdown of fish metabolism including respiration, by-products as well as excretion of urine and faeces. There is no fish present in the planted tank so no fish feed was provided. Most of the particulate waste from the faecal waste of fish, uneaten fish feed, some organisms such as bacteria, fungi, and algae will be accumulated in the aquaculture system (Rakocy et al., 2006). The ammonia released from particulate waste after decomposition by microorganisms was reported to be toxic to plants and fish in aquaculture system (Brito et al., 2002). These particulates waste may lower dissolved oxygen levels in water, turns water cloudy. In aquaponic system, the nutrient and water utilization efficiency were enhanced and nitrification was in place to oxidize ammonia to nitrite and followed with nitrate. Aquaponic system has been proved as an excellent method for recycling phosphorus by maximizing the phosphorus removal efficiency and enhancing nutrient utilization by fish and plants while yielding a high quality crop (Cerozi and Fitzsimmons, 2017).

Chlorine is greenish-yellow gases with a strong odour that can dissolve in the water. It combined with other chemicals as disinfectants and kills microorganisms. Most of the chlorine enters river or lake and react with other chemicals formed more stable compounds. Basically, chlorine gets into a natural water sources due to industrial development, agriculture activities and chemical spills. It is widely used in wastewater treatment plant, food processing systems and paper mill systems. One of the exposures of chlorine to natural water sources is effluent from treated water system. When treated effluent released to receiving waters, there is still some free residual chlorine present in the water. These free residual chlorines dissipate rapidly depend on the environmental factors (US EPA, 1999). As for chlorine concentration, all tanks have the same concentration which is less than 2 mg/L. Chlorine present in all tanks because of the water sources. Tank that is filled with tap water to compensate water loses through condensation, will have chlorine present in the water as disinfectants to kill the microbes. However, the concentration is acceptable up to 4 ppm (Wiant, 2010).
Based on the Table 1, phosphate and ammonia are derived from the fish feed or fecal. This can be clearly reflected by comparing all the tanks with fishes to the planted tanks (hydroponic). The complicated interactions of environmental parameters between the feeding and water quality in aquaculture such as temperature, dissolved oxygen, pH and salinity has an impact on feeding metabolism and growth of cultured species (Gabriel et al., 2007). However, the accumulation of uneaten fish feed can lead to the releasing of potentially harmful organic and inorganic materials which will causes fish death and pollution (Akinrotimi et al., 2007). High protein diet lead to high nitrogen excretion which is toxic to both of fish and water. In fact, higher faecal nitrogen and phosphorus loss at higher protein intake in fish. Uneaten fish feed, one of the main source of pollution, was lost in the tank sediments through the process of mineralization (Xu et al., 2007). Besides, abundance of nutrient loading induced by fish feed encourages bacterial growth, making water slimy, emanating offensive odours and causes water quality impaired. Improvements in feed quality and feeding techniques can result in reduction of nitrogen pollution from aquaculture. The use of high energy diets in fish can increase the utilization of nutrients and helps reducing the solid waste and nutrient load in the water (Akinrotimi et al., 2007).

According to Boyd et al. (1998), only 10-30% of phosphorus and 20-40% of nitrogen applied in feed is retained by the fish, thus lowering the amount of phosphorus and nitrogen in feed formulation can reduce the water pollution in aquaculture. A sustainable, environmental friendly aqua feed with low pollution potential has now become the prime consideration among the feed manufacturing industries (Akinrotimi et al., 2007).

Aquaponic, with the combination of aquacultures with agricultures, could enhance the nutrient and water utilization efficiency and overall environmental sustainability. Besides, implementation of aquaponic system has been proved as an excellent method for recycling phosphorus by maximizing the phosphorus removal efficiency and enhancing nutrient utilization by fish and plants while yielding a high quality crop (Cerozi and Fitzsimmons, 2017).

4 Conclusion

Determine concentration of phosphate, ammonia and chlorine in water samples are important as high level of these pollutants concentration can cause lethal effect on organism living in the water. In conclusion, phosphate and ammonia levels that contributed mainly from fish feed and fecal, are within the acceptable range. In order to maintain a sustainable aquaculture, sustainable farming methods should be encouraged to avoid overuse of fish feed and indirectly influx the nutrients into the water bodies. High levels of ammonia are highly toxic in tanks however low concentration can cause stress on fish which make them vulnerable to disease. High levels of phosphates do not directly harm to fish but it can cause nutrient pollution which can deplete the oxygen level in the water. Presence of chlorine in high volume can cause casualty in fishes as well as plants growing from the aquaponic system. The quantity of chlorine in the water source used must be determined to determine whether steps to eliminate chlorine from the water source are necessary or otherwise. This will indirectly affect the sustainability of the system through cost and managing. Thus, it is important to identify sources and types of pollutants in aquaculture system in order to achieve a sustainable system which benefits all.

Authors’ contributions

LHL did work of data collection, system design, manuscript writing; LZLR did work of data collection, manuscript writing; YTS did work of preliminary testing, manuscript writing; SST did work of System design, Experiment design. All authors read and approved the final manuscript.

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