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ORIGINAL ARTICLES

Phytoplankton and Nutrient Dynamics in El-Sadat Wastewater Treatment Plant (Egypt)

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ABSTRACT

Phytoplankton dynamics in El-Sadat wastewater treatment plant (WWTP) located in Egypt were studied between December 2005 to June 2007. The treatment system is waste stabilization ponds, which receive mixed domestic and industrial waste water with daily flow rate of 33000 m^3. Characterization of raw waste water showed a big variation during two years evaluation period. The maximum chlorophyll "a" concentration reached in April 2006 for the facultative pond and the maturation pond 1099 µg/L and 700 µg/L respectively. Mean chlorophyll "a" concentrations varied between 25.1-1099 µg/L and 26-700 µg/L in facultative and maturation ponds respectively. Also, the maximum counts was reached 6401 org. /ml and 3038 org./ml for facultative and maturation pond respectively in July 2006. Nutrient concentrations were 9.5 mg/L NH_4-N, 0.1 mg/L NO_2-N, 0.39 mg/L NO_3-N and 1.6 PO_4-P for maturation pond. Chlorophytes and Euglenophytes dominated phytoplankton in the facultative pond; the first group represented 63.0% to 96.7% of total phytoplankton density in July, August, September and November 2006, whereas Euglenophytes reached 92.4% of total phytoplankton density in April 2006. The species ***Ankistrodesmus acicularis*** was dominated Chlorophytes, while the species ***Euglena sanguine*** was dominated Euglenophytes. Cyanophyta in the maturation pond represented more than 92% of total phytoplankton density in February, March 2006 and March, May 2007. Dominate Cyanophyta were ***Oscillatoria agardhi , O. brevis, O. chlorine, O. limnetica and O. limosa.*** In the maturation pond, Euglenophytes represent 59.8-87.3% of total phytoplankton abundance, when Euglena accounted for 77 % of total phytoplankton density. These densities indicate that the wastewater treatment plant (WWTP) may be an optimal habitat for Cyanobacteria, and consequently, a possible source of Cyanobacterial toxins.

Key words: wastewater treatment plant-Phytoplankton-Toxicity-Mice

Inroduction

Waste stabilization ponds (WSP) or lagoons offer the simplest solution for the treatment of municipal wastewater and are widely applied in developing countries especially in rural areas. Wastewater treatment in waste stabilization pond is natural process resulting from the complex symbiosis of bacteria and algae (Munoz & Guieysse, 2006). The pond systems provide a natural sustainable process for disinfection of pathogenic bacteria in sewage (Davies. Colley *et al* 1997, 2000 and craggs *et al*., 2004) without risk of by-products.

WSP are a satisfactory solution for small communities (Racault *et al*., 1995 and Hosetti, 1995). They consist of a set of connected basins in which biological processes break down the organic matter at a natural rate tanks to forces of nature such as temperature, wind, sunlight and the biological interaction of microorganisms (Mara, 2009). WSP are considered environmentally sustainable given their low energy consumption (Muga and Mihelcic, 2008), the associated carbon dioxide emissions reduction (Shilton *et al*., 2008) and because they return nutrients to the surrounding environment (Muga and Mihelcic, 2008).WSP generates important savings on operation and maintenance costs (Tsagarakis *et al*., 2003 and Morro *et al* 2012).

Micro-algae are an important part of wastewater treatment when the WSPs are employed. Several factors, such as light intensity, ammonia and sulphide toxicity and mainly, the surface organic loading applied to the pond are reported to pose some effects on the development of algal population in the ponds (Athayde *et al*., 2000). There are microorganisms responsible for the molecular oxygen production, a vital element to the bacteria that participate in the biochemical oxidation of the organic matter. The presence of the algae in adequate levels assures the aerobic conditions in the pond. When the ecological balance is lost, there is a risk of anaerobic conditions, bringing as consequence the reduction of the system efficiency (Suetmasu, 1995). Another supplemental role of the algae in the ponds is the removal of nutrients, such as nitrogen, phosphorus and carbon (inorganic carbon CO_2 or bicarbonate) to satisfy nutritive needs. The natural selection is made in benefit of some resistant species that are generally founded in the polluted water.

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According to (König 2000), the algae found in the stabilization ponds in general, belong to Cyanobacteria (blue green algae), Chlorophyta (green algae), Euglenophyta (pigmented flagellate or Phytoflagellated) and Bacillariophyta (Diatoms) phylum. Cyanobacteria have been reported to dominate in some WWTP (Oudra, 1990). Among them, *phormidium* is typical genus in waste water treatments (Canizares-Villanueva *et al*., 1994). (Silva 1998) recorded the presence of the *Cyanobacterium planktothrix sp*. In the parade WWTP (Portugal). Although Chlorophytes were dominant.

Some studies are available examining the relationship between phytoplankton and nutrient concentration changes in wastewater treatment plants (oudra, 1990). The present paper contributes results of an investigation on the dynamics of the phytoplankton community in El-Sadat WWTP in Egypt, and their relationship to the main algal nutrients (i.e. phosphorous and nitrogen).

Material and Methods

1-Description of the study site:

El-Sadat WWTP is located at 11 km distance to the North East of the city as shown in on an area of approximately 72 feddans. The treatment plant consists of three ponds: two parallel anaerobic units, facultative and three maturation ponds (Figs. 1, 2). The total hydraulic retention time for the WWTP is 28.4 days. It was designed to receive a maximal effluent flow of 33000 m^3 and surface organic loading rate 7.5-14.2 kg/ha/day. This WWTP was planned for a population of 250.000 inhabitants.

2-Water sampling:

Sampling was monthly collected between December 2005 and June 2007 in the facultative and maturation ponds. Samples were collected at the surface of the ponds for identification and counting of phytoplankton species. Samples for physical and chemical analysis were kept refrigerated until they were analyzed in the laboratory, within 24 hours of collection.

3-Physico-chemical Analysis:

Wastewater samples were subjected to Physico-chemical Analysis according to (APHA, 2005).

4-Identification and quantification of phytoplanktonic forms:

Different algal species and groups were identified and counted under a Research microscope (300 x magnifications) using Sedgwick-Rafter cell according to standered methods (2005). For count and identified according to the key of freshwater algae (Streble & Krauter, 1978 Komárek and fott, 1983; Komárek and Anagnostidis, 2005 and Hustedt, 1976). Algae enumerated by using the Sedgwick-Rafter cell method. One milliliter of well concentrated sample was placed onto the cell chamber and a cover glass placed over it. The sample was allowed to settle for 5 min and they were analyzed in the laboratory. The numbers of algae present were calculated as follows for slandered methods

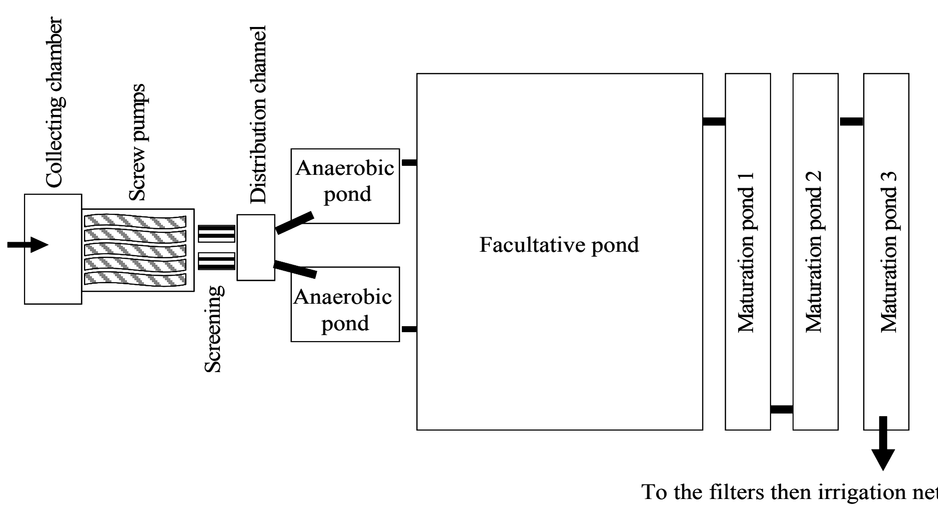

Fig. 1: Schematic Diagram of the Treatment Plant at Sadat City

Fig. 2: Google Earth Picture of the Treatment Plant at Sadat City

5-Toxin analyses and quantification:

The toxicity of *Oscillatoria spp* was measured with a mouse bioassay. The toxicity of the freeze-dried algal material is determined by using male mice weighing 20-23 gm. Toxicity is tested by intraperitoneal injection of lysate algal cells by freeze-thawing. The material dissolved in 0.9% NaCl at concentrations of 20,30,40,50, and 20 mg wet weight per ml and suspended by vortexing for 30 min followed by 30 min centrifugation at 4000 rpm (Underdal, 1984). The mice were observed during the following 24 h for any signs of poisoning.

Results And Discussion

Phytoplankton dynamics in the facultative pond:

The distribution pattern of algae in the facultative pond throughout the investigation period recording four algal groups included 24 species, (7 species of Chlorophyta, 3 species of Euglenophyta, 5 species of Cyanophyta and 9 species of Bacillariophyta). Chlorophyta was the dominant algal groups throughout the study period in facultative pond (Fig. 3). Chlorophyta represents by 66.5-96.7% of total phytoplankton abundance in June, August and September 2006, while Euglenophyta are represented by 46.2-92.4% of total phytoplankton abundance in April, May 2006 and May 2007.

The species *Ankistrodesmus acicularis* was dominated among the Chlorophytes and *Euglena sanguinea*, *Phacus longicauda* within Euglenophytes (Fig. 3). Pereira *et al.,* (2001) found that, Chlorophytes represented 80-85 % of total phytoplankton abundance in January, March, May and June, while Euglenophytes dominated (i.e. 60-96 % of total phytoplankton abundance) in April and July 2006. The genera *Oocystis* and *Pandorina* were dominant among the Chlorophytes and *Euglena* within Euglenophytes (Fig. 3).

Generally only one or two species will be dominant at any one time in the facultative pond. The most commonly recorded genera are: *Chlorella*, *Scenedesmus*, *Chlomydomonos*, *Micractinium*, *Euglena*, *Ankistrodesmus*, *Oscillatoria*, and *Microcystis*. The microorganisms observed are common on literature concerning WSP (Mara and Pearson, 1998). The dominant algal species is determined by the organic loading, with those algae able to tolerate anaerobic conditions being recorded in ponds receiving heavy organic loads, e.g. *chlamydomonos spp.* and *Euglena spp*. (Morro *et al* 2012).

Cyanophyta dominated 70-90% of total phytoplankton abundance in February, March 2006 and June 2007. Bacillariophyta represented by 82-93% of total phytoplankton abundance during December 2005 and January 2006.

In general changes in algal counts deviated from 56 to 6401 org. /ml denoting the overgrowth in algal counts at the some months of the study period. The maximum count was 6401 org./ml in July 2006 (Fig 4). This may be due to the changes in organic load which led to the disappearance of some algal species while some species are not affected. (Silva, 1982).

The Chlorophyll (a) concentrations ranged from 25.1 µg/L in January 2006 to 1099 µg/L in April 2006. The highest value of Chlorophyll (a) was recorded at April 2006, while the lowest concentration was found at January 2006. A significant relationship between algal counts and Chlorophyll (a) content was observed (Fig. 5).

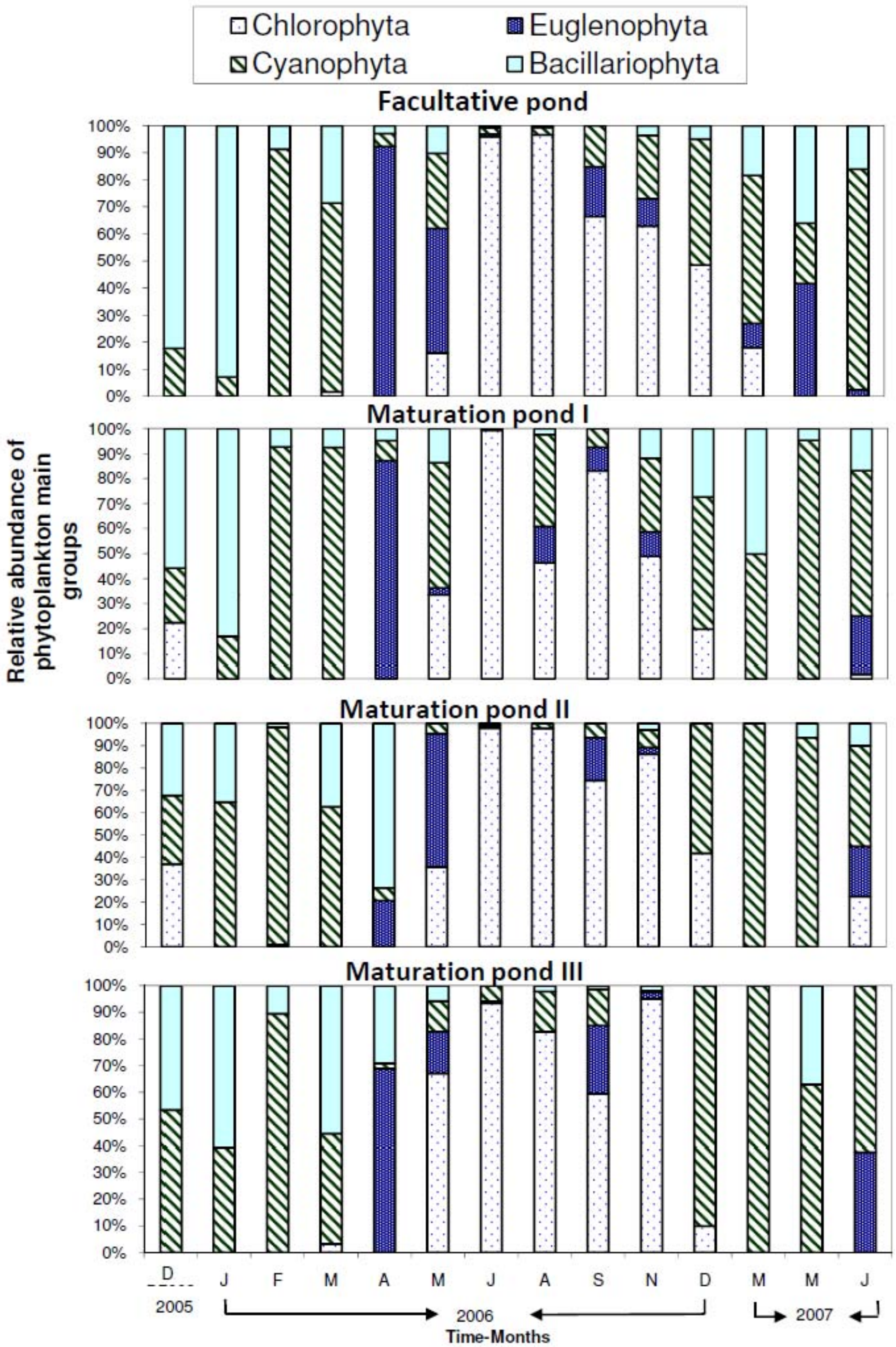

Fig. 3: Changes in the Relative Abundance of Phytoplankton Main Groups for the Facultative and Maturation Ponds

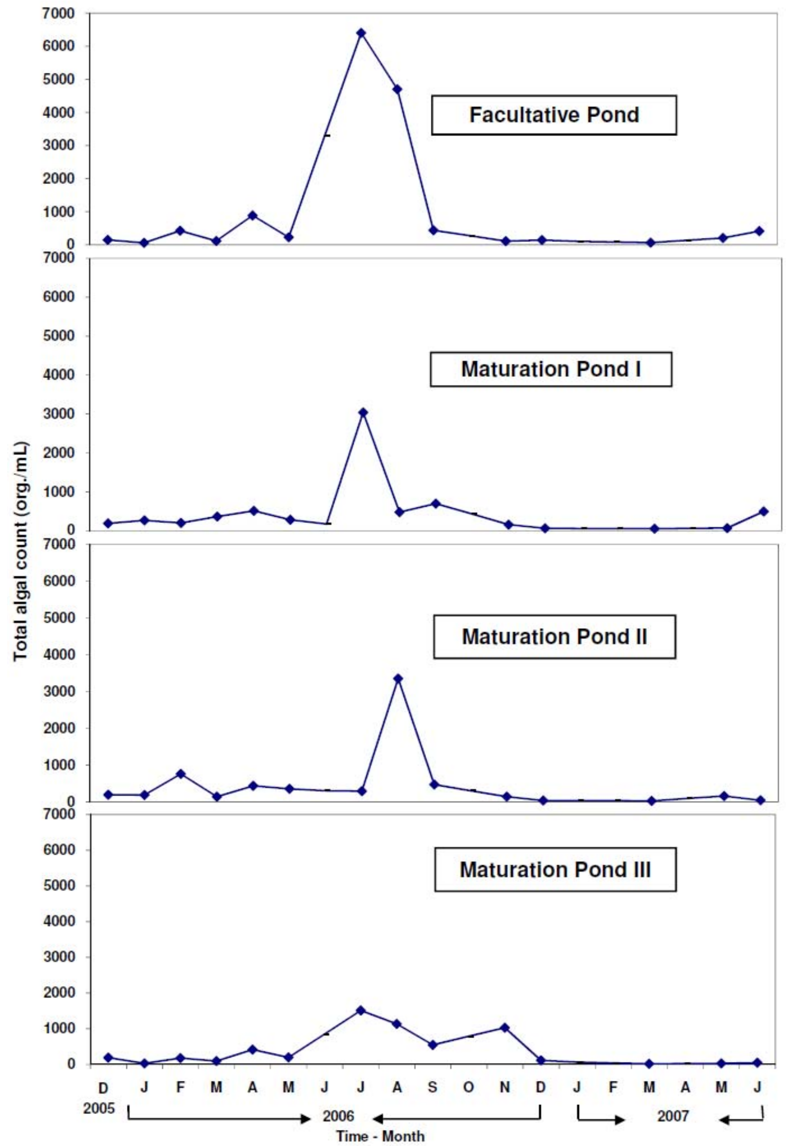

Fig. 4: Changes in Total Algal Count in Facultative and maturation pond

Content in Facultative and maturation ponds:

In agreement with data represented by Pereira *et al*., (2001) there is a good relationship between chlorophyll (a) concentrations and phytoplankton density. A positive correlation was found between chlorophyll "a" concentration, orthophosphate and nitrate concentration took place (Fig. 6).residual total phosphorus in the facultative pond effluent ranged from 1 to 9.1 mg P/L with an average value 2.9 mg p/L the corresponding values of nitrite and nitrate concentrations were ranged from 0.0 to 0.31 mgN/L with an average value 0.0825 mg N/L, and 0.11 to 1.2 mg N/L with an average value 0.48 mg N/L, respectively. A supplementary role, but a very important one, is the removal of plant nutrients such as nitrogen and phosphorus. Nutrients are also precipitated out of solution as a consequence no of the pH change brought about by photosynthesis, which reduces the concentration of carbon dioxide in the water (Morro *et al* 2012).

Phytoplankton Dynamics in the Maturation ponds:

The distribution patterns of algae in the maturation pond throughout the investigation period indicate the presence of various algal species belonging to four groups, namely. Chlorophyta, Euglenophyta, Cyanophyta and Bacillariophyta. The recorded four algal groups included 22 species, 7 species of Chlorophyta, 3 species of

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Euglenophyta 6 species of Cyanophyta and 6 species of Bacillariophyta., In the maturation ponds, the highest abundances were found in July 2006, August and November 2006. Chlorophyta, Euglenophyta and Cyanophyta were the dominant algal groups throughout the study period (Fig. 3).Maximum algal abundance was attained in August 2006 (3.4 x 10^6org. /L) (Fig. 4). Chlorophyta represented 67.2-99.3% of total phytoplankton abundance in May, July, August, September, and November 2006, *Ankistrodesmus acicularis* was the most dominant species, while Euglenophyta represent 59.8-87.3% of total phytoplankton abundance in April and May 2006, where *Euglena sanguine* was the dominant species. Cyanophyta dominated 52-95% of total phytoplankton abundance in, January, February 2006, December, and March 2007. *Oscillatoria spp. (O.agardhi, O.brevis, O.chlorina, O.limnetica and O.limosa*) were dominant. Bacillariophyta represented 55.7-83% of total phytoplankton abundance in December 2005, January and April 2006, where *Nitzshia liniaris* was the dominant species. These results are similar to those observed during Cyanobacterial bloom in freshwaters ecosystems (Vasconcelos, and Araujo 1994), but contrast with those of Oliveira (1995), who reported dominance of Chlorophytes in wastewater stabilization ponds. *Microcystis oeruginosa* is one of the most common species in freshwaters ecosystems. However, it is not common in WWTP ponds. Other Cyanobacterial species common in WWTP are *Synechoccocus* and *Synechocystis* (Oudra, 1990).

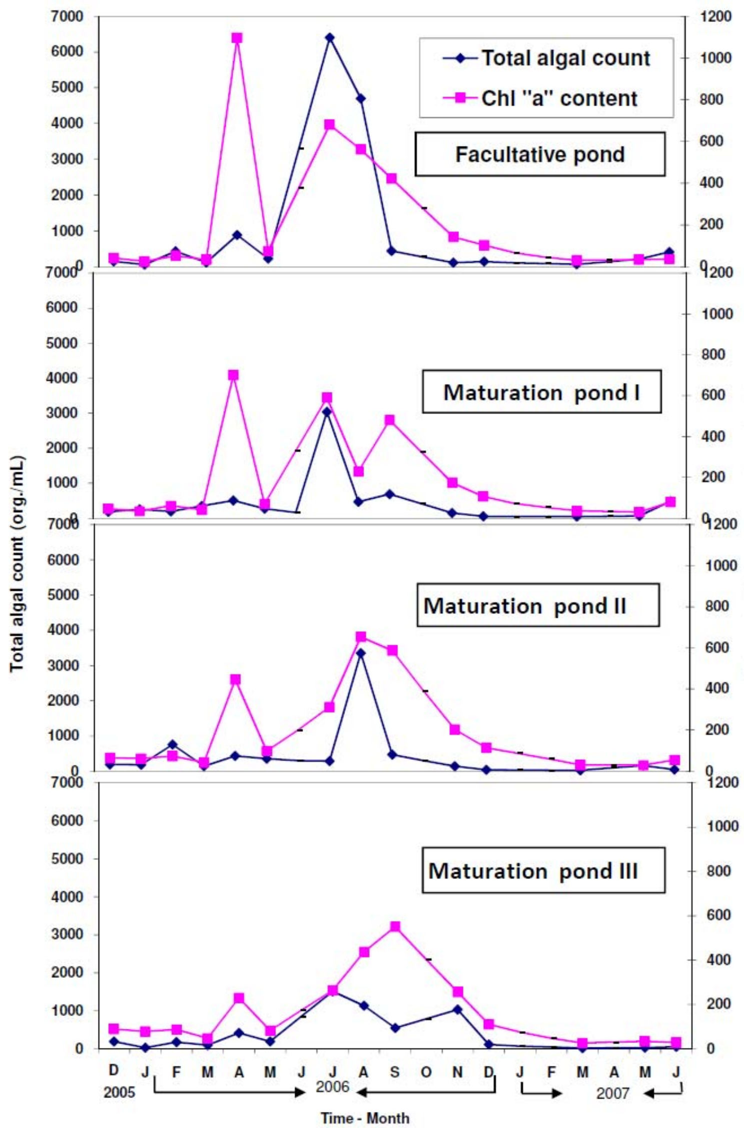

Fig. 5: Relationship between Total Algal Count and Chlorophyll (a)

In the maturation pond there was a good relationship between chlorophyll "a" concentration and phytoplankton density (Fig. 5), changes in nitrate and orthophosphate concentrations against chlorophyll "a" in the maturation pond are shown in (Fig. 6).

Toxin analysis and quantification:

Negative results for Cyanobacterial toxicity were obtained during the *Oscillatoria sp.* high density, using the mouse bioassay. Also, Pereiera *et al* (2001) obtained negative results for Cyanobacterial toxicity during the *plonktothrix mougeotii* bloom using the mouse bioassay.

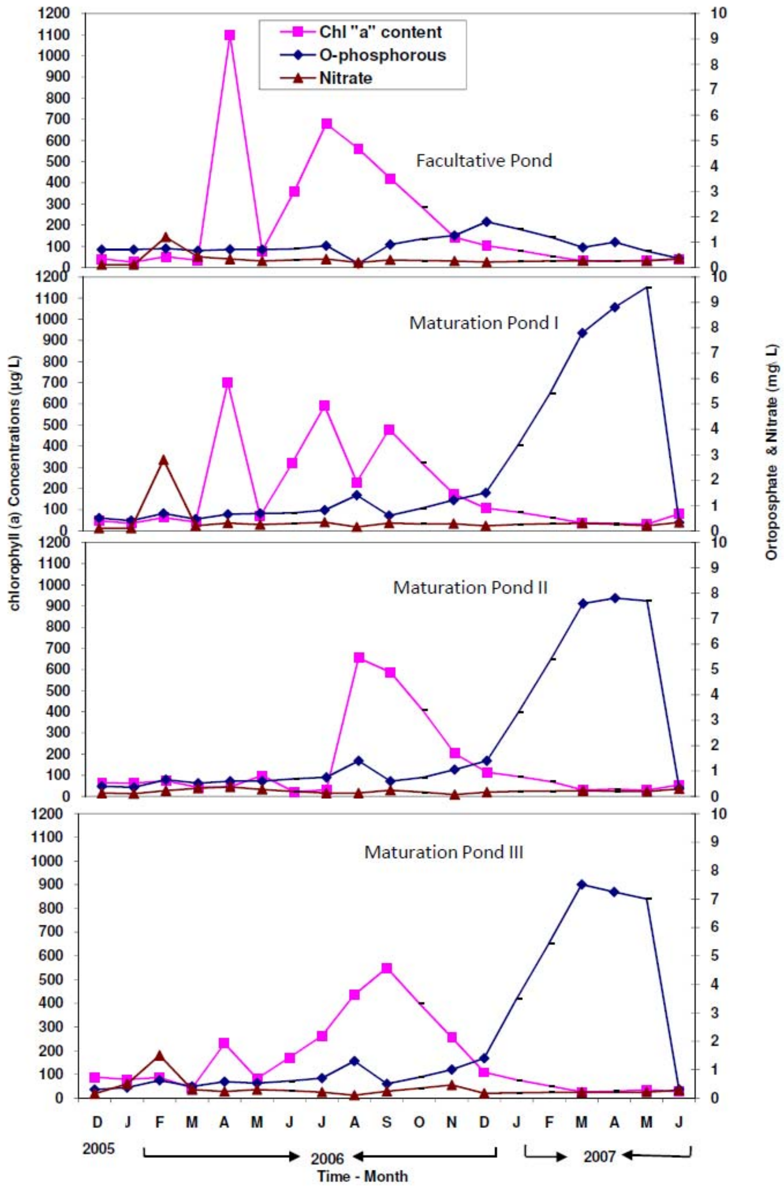

Fig. 6: Relationship between Chlorophyll (a) Concentrations with Nitrate and Orthoposphate in Facultative and Maturation Ponds

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