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NITRIFICATION, PHYTOBENTHOS OVERGROWTH AND TECHNICAL PROBLEMS IN TERTIARY SEWAGE WATER TREATMENT PLANT.

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Abstract

Algal mats and scum were removed monthly (Jan. 2004-Dec.2004) from three tanks walls (oxidation, settling and effluent tanks) of tertiary sewage water treatment plant at El-Katameya city near Cairo. Phytobenthic algae were not detected in the collector tank during the annual course of the present investigation, thus it was examined only in the other three tanks of the sewage water treatment system. Phytobenthos community was represented by 120 species in 47 genera belonging to 4 classes namely, Cyanophyceae (65 species), Chlorophyceae (24 species), Bacillariophyceae (26 species) and Euglenophyceae (2 species). Among the dominant phytobenthos species were *Oscillatoria amphigranulate, Oedogonium capillare, Synedra ulna* and *Nitzschia obtusa* v. *vulgaris.* The increase in nitrate concentration during the nitrification phase of the biological activated sludge treatment process was found to be the main factor contributing to the high growth of benthic algae in the treatment system, decreasing nitrification phase time and injected oxygen set point reduced nitrate levels which in turn resulted in the full disappearance of benthic algae from the treatment system. The study proved that decreasing the nitrification phase time from 20 minutes/hour to 10 minutes/hour and the injected oxygen set point from 1.5 mg/L to 1.0 mg/L was ideal for the full disappearance of benthic algae from the treatment system. The treatment system was operated under such conditions for two months (October and November 2005).

Introduction

Phytobenthos growth appears regularly causing serious problems in a tertiary sewage water treatment system established at El-Katameya city near Cairo. Growth starts as a thin layer on the walls of the oxidation tanks, increases in the settling tanks and becomes extensive in the effluent tank where the green filamentous algae form extended mats covering large areas of the tanks walls. Such filamentous forms cause

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many mechanical and operational problems within the treatment system; such as plugging of pipes where they enter with the water flow from one unit to another, they also enter with the secondary treated water into the sand filters for tertiary treatment causing rearrangement of filter's media particles by widening the interspaces between particles which results in increasing total suspended solids (TSS), biochemical oxygen demand (BOD) and chemical oxygen demand (COD) in the effluent. In addition when these algae die in the sand filters they harden and cause cracks in the media and in this case the media must be replaced which is very expensive. Benthic algae enter also with the effluent into the chlorine contact chamber; which results in decreasing the efficiency of the chlorination process.

The overgrowth of benthic algae causes serious problems in sewage water treatment systems established in different parts of the world. In Canada, Winter and Duthie (2000) analysed benthic macroalgal growth and the structure of epilithic diatom communities in four sites in a stream flowing through a cultivated field near Kintore, Ontario. The dominant epilithic diatom taxa did not differ greatly among sites. Sites downstream of agricultural inputs showed an increase in the cover of *Cladophora glomerata* and other green algae, a reduction in the cover of diatoms and dominance of Oscillatoriaceae and the red alga *Audouinella violacea*. In particular, there was a positive correlation between the cover of *Cladophora* and nitrate concentration seasonality of the studied locations.

Annachhatre (1994) examined the aerobic treatment of slaughterhouse wastewater for COD removal and nitrification; the author concluded that a high degree of nitrification and COD removal of more than 85% was obtained.

Nakhla *et al*. (2005) carried out a study on the simultaneous nitrification, denitrification and clarification in an activated sludge system. They found that the system performed reliably and consistently with respect to organics and total suspended solids (TSS) removals, achieving BOD and TSS reductions of more than 96%.

Micro-organisms use dissolved oxygen in the water to break down wastes. This consequently reduces or depletes the supply of oxygen in the water needed for aquatic life. The amount of oxygen needed by micro-organisms to break down wastes in wastewater is referred to as BOD which is directly related to the pollution status of the water (WQM, 1999). Mobius (1988) assessed the improvement of COD elimination in activated sludge treatment plant; he found that when BOD was reduced to < 25 mg/L, COD removal was in proportion to BOD removal.

Donatelle (2005) reported that nutrients are mineral compounds which can have an adverse impact on water quality because of their ability to promote plant and algal growth. Nitrogen and phosphorus compounds are considered to be the most essential for algal growth. Nutrient compounds involved are ammonia, nitrites, nitrates, phosphates and orthophosphates. Nitrogen and phosphorus compounds are always present in domestic wastewaters.

The aim of this work is to find a solution for this overgrowth of benthic algae, especially the filamentous green forms (which mainly bloomed in the effluent tank of El-Katameya plant throughout the year round) by lowering nitrification phase time and injected oxygen set point.

Materials and Methods

Collection of phytobenthos samples

Algal mats and scum were removed monthly from oxidation, settling and affluent tanks walls using sharp blades or simply by hand. Samples were tipped into small plastic bottles and preserved in 4% buffered formalin. Phytobenthic algae were not detected in the collector tank during the annual course of the present investigation, thus examination was only carried in the other three mentioned tanks (Figure 1).

Lowering nitrification phase time and injected oxygen set point.

The two oxidation tanks are operated in a cycle under alternating aerobic [nitrification (N), oxygen present] and anoxic [denitrification (DN), oxygen absent and nitrate present] conditions, the two tanks contain a number of surface aerators (rotors) to provide the required oxygen supply with a set point of 1.5 mg/L. There are 6 cycles/day, each cycle takes 4 hours after which the biological treatment process is completed. Each cycle includes six phases; two of which are DN-N phases, each of 80 minutes operating time and four are N-N phases, each of 20 minutes operating time, the phases are arranged as follows DN-N, N-N, N-N, DN-N, N-N & N-N. In case of DN-N phase, sewage water is introduced to the first oxidation tank where anoxic conditions are present (DN); in this case certain heterotrophic bacteria are stimulated to utilize nitrates and nitrites formed in a preceding N-N phase as electron acceptors for cellular respiration in place of oxygen (Ketchum, 1988).

The present study attributed the overgrowth of benthic algae to the high concentration of nitrates produced during the nitrification (N) phase which is always the second phase carried out in the oxidation tanks, after which the water was transferred to the settling tanks with high nitrate levels.

In-order to decrease nitrate concentration in the treatment system we suggested to decrease nitrification phase time and injected oxygen set point (maximum oxygen concentration); to achieve this goal, and in cooperation with the engineer manager of the tertiary sewage water treatment plant, each N-N phase time was decreased from 20 min/hr to 10 min/hr and the injected oxygen set point was lowered from 1.5 mg/L to 1.0 mg/L. The treatment system was operated under such conditions for two months (October and November 2005).

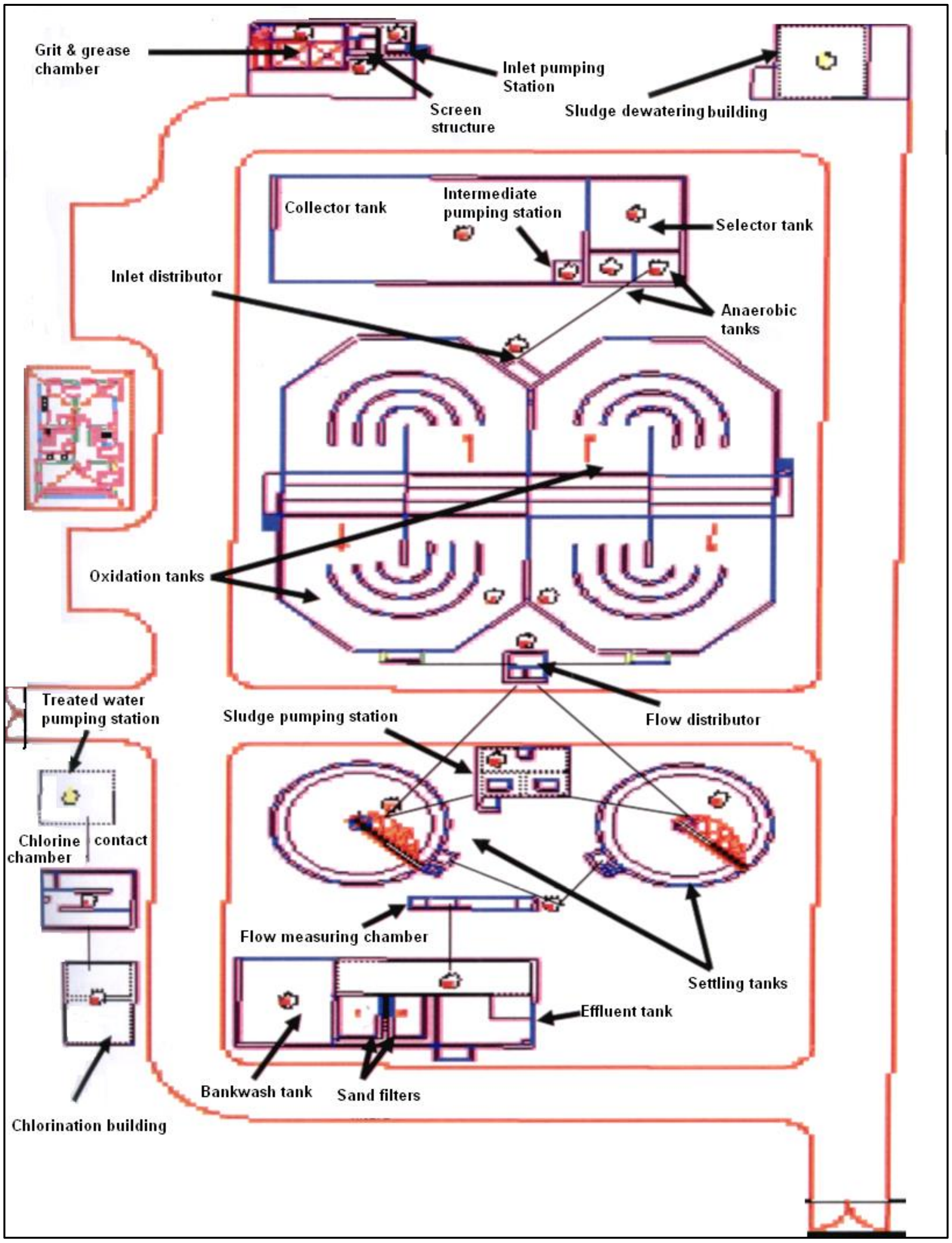

Figure (1): Tertiary sewage water treatment plant layout

Through the two months, water samples were collected from the effluent tank biweekly to determine concentrations of each of nitrate and ammonia (Ion chromatography (IC) and orthophosphate (Strickland and parsons, 1965); in addition, dissolved oxygen and biochemical oxygen demand were tested (APHA, 1992) to examine the effect of these changes on the sewage effluent quality.

Results

Phytobenthos community

The phytobenthos community in the tanks of the plant under study area during the annual cycle of the present investigation showed a diverse algal flora, where a total of 120 species belonging to 47 genera were recorded, representing four classes namely Cyanophyceae, Chlorophyceae, Bacillariophyceae and Euglenophyceae.

Genera with numerous species were *Oscillatoria* (21 species), *Nitzschia* (12), *Phormidium* (11), *Lyngbya* (7), *Scenedesmus* (5). *Chroococcus* and *Microcystis* were represented by 4 species each, where as *Chlamydomonas*, *Oedogonium*, *Stigeoclonium* and *Fragilaria* each was represented by 3 species. While only 2 species represented each of *Aphanothece*, *Gomphosphaeria*, *Nostoc*, *Spirulina*, *Chlorohormidium*, *Cyclotella*, *Melosira*, *Navicula*, *Synedra* and *Euglena.*

Phytobenthos community consisted of 65 species of Cyanophyceae representing 54.2 %, 27 species of Chlorophyceae representing 22.5%, 26 species of Bacillariophyceae representing 21.7% and 2 species of Euglenophyceae representing 1.7% (Table 1).

Table (1): Correlation of algal classes of the phytobenthos in the treatment plant.

Class	No. of species	%
Cyanophyceae	**65**	**54.2**
Chlorophyceae	**27**	**22.5**
Bacillariophyceae	**26**	**21.7**
Euglenophyceae	**2**	**1.7**
Total	**120**	**100.0**

Table (2) showed that settling tank harbored the highest number and percentage (72 species representing 37.9%) of phytobenthic species followed by effluent tank (61 species representing 32.1%); while oxidation tank recorded both lowest number and percentage of phytobenthic species (57 species representing 30.0%). The data also revealed that effluent tank recorded the highest percentage of

Cyanophyceae members (60.65%), whereas Chlorophyceae percentage recorded its maximum (28.0%) in oxidation tanks, while Bacillariophyceae highest percentage (27.8%) was observed in the settling tanks, on the other hand class Euglenophyceae highest percentage (3.3%) was detected in the effluent tank.

Table (2): Correlation of algal classes of the phytobenthos in the three tanks under investigation.

Class	Oxidation		Settling		Effluent	
	No. of sp.	%	No. of sp.	%	No. of sp.	%
Cyanophyceae	**27**	**47.4**	**36**	**50.0**	**37**	**60.65**
Chlorophyceae	**16**	**28.0**	**14**	**19.4**	**7**	**11.5**
Bacillariophyceae	**14**	**24.6**	**20**	**27.8**	**15**	**24.6**
Euglenophyceae	**0**	**0.0**	**2**	**2.8**	**2**	**3.3**
Total	**57**	**100.0**	**72**	**100.0**	**61**	**100.0**

Effect of lowering nitrification phase time and injected oxygen set point on phytobenthos growth and effluent quality.

Data given in Table (3) showed the effect of decreasing nitrification phase time from 20 min/hr to 10 min/hr and injected oxygen set point from 1.5 mg/L to 1.0 mg/L during the activated sludge treatment process on concentration of each of dissolved oxygen, biochemical oxygen demand, nitrate, ammonia and orthophosphate in the effluent. These parameters were measured once before decreasing the nitrification time phase and then every 2 weeks then after 2 months.

After lowering nitrification phase time and injected oxygen set point, the following results were obtained at the effluent:

1. Dissolved oxygen (DO) concentration ranged between 2.7 and 4.2 mgO_2/L.
2. Biochemical oxygen demand (BOD) concentration ranged between 5.0 and 8.0 mgO_2/L.
3. Nitrate (NO_3) concentration in the effluent decreased from 18.2 mg/L before the changes to become in the range of 1.5 to 3.25 mg/L after the changes.
4. Ammonia (NH_3) was not detected (ND) before and after the changes.
5. Orthophosphate (P_2O_4) concentration ranged between 0.6 and 1.2 mg/L.
6. Benthic algae disappeared completely after the 2 months; they changed from the healthy green color to dark green then to brown and finally became detached completely from the tanks walls.

7. The activated sludge still having its healthy brown color, with no appearance of black spots which act as an indicator of bacterial death, also no unpleasant odors appeared during the two months. In addition the new conditions improved activated sludge settle ability.

Table (3): Parameters measured to assess the effect of lowering nitrification phase time and injected oxygen set point on effluent quality

Parameters	Before changes	After 2 weeks	After 4 weeks	After 6 weeks	After 8 weeks
D.O (mgO_2/L)	4.1	2.7	3.2	4.2	3.8
BOD (mgO_2/L)	3.0	8.0	6.0	5.0	7.0
Nitrate(mg/L)	18.2	3.25	2.1	1.5	2.0
Ammonia (mg/L)	ND	ND	ND	ND	ND
O. phosphate (mg/L)	0.8	1.12	0.6	0.9	1.2

Discussion

The least diverse phytobenthic flora and minimum average biomass observed in the oxidation tanks could be attributed to the hyper-eutrophic conditions prevailing in these tanks which are not suitable for phytobenthos growth, and therefore only tolerant species persisted. In addition, the high concentration of suspended solids, due to the presence of activated sludge, in these tanks was another factor contributing to lowering phytobenthic growth and biomass. In this connection Sabater *et al*. (2000) recorded lower values of benthic algal biomass in sites receiving high deposition of solids.

The more diverse phytobenthic flora found in the settling tanks and the maximum biomass recorded in the effluent tank, could be attributed to the increase in nitrate concentration during the nitrification phase of the biological activated sludge treatment process, which in turn elevated the nitrate levels in settling and effluent tanks. Soltan *et al*. (2001) studied the benthic macroalgal communities of the upper rocky sub-littoral near Marseille sewage outfall after 8 years from setting up of a wastewater treatment plant and found that there is an increase in the number of taxa, compared to a previous study, and they related this to a decrease in pollution load. Our results are in agreement with the findings of Soltan *et al*. (2001), where the improvement which occurred in water quality in settling and effluent tanks, after the biological treatment process, was accompanied by an increase in phytobenthos species number. In order to decrease the diversity of phytobenthic flora and algal biomass a pilot experiment was carried out for two months to examine the effect of lowering nitrification phase time to 10 minutes/hour and the injected oxygen set point to 1 mg/L on phytobenthos growth and effluent quality. Results revealed that by decreasing nitrification phase time and injected oxygen set point, nitrate concentration in the effluent decreased from 18.2 mg/L to become in the range of 1.5 to 3.25 mg/L, no remarkable changes were observed in concentrations of each of DO, BOD and orthophosphate while ammonia was always not detected in the effluent. This indicated that oxygen injected in the nitrification phase is sufficient for autotrophic bacteria to convert ammonia into nitrate. Results also showed that phytobenthos growth disappeared completely after the two months; it changed from the healthy green color to dark green then to brown and finally it detached completely from the tanks walls. This finding ascertained that nitrate was the main factor contributing to the abundance of benthic algae in the treatment system. Supporting our findings, EPA (1988) stated that a DO in the range of 2-4 mg/L obtained at the effluent means that DO injected in the oxidation tank is sufficient for the desirable micro-organisms and to keep the quality of the activated sludge. Fried *et al*. (2003) mentioned that nitrogen levels kept below 10 mg/L maintain a healthy water system and minimize algal growth; this could explain the disappearance of benthic algae from El-Katameya treatment system after the new conditions. Collivignarelli *et al*. (1998) established conditions for good nitrogen removal efficiencies in extended aeration activated sludge plants which are not equipped with specific denitrification steps by means of controlling dissolved oxygen concentration. Drysdale *et al*. (1999) mentioned that many incomplete heterotrophic denitrifiers that reduce nitrates and nitrites slowly and weakly because of their weak nitrate and nitrite reeducates may be capable of simultaneous respiration of oxygen and nitrates thus resulting in reduction of nitrates in the aerobic zone.

During nitrification process the injected oxygen was utilized by the bacterial consortium constituting the activated sludge to degrade organic matter and converte ammonia in sewage water into nitrate. In the present study, elevated nitrate levels were among the main factors contributing to the high abundance of benthic algae in the treatment system and especially in the effluent tank where algae were present in the form of extended dense mats adhering to large areas of the tanks walls. In agreement with our suggestion; Abd El-Karim (2004) concluded that nitrate is one of the most effective parameters for periphyton abundance when he studied the periphytic algal communities in Wadi El-Raiyan Lakes. In this conecction Ciudad *et al*. (2005) mentioned that biological nitrification-denitrification is the most common process for nitrogen removal from wastewaters. During the first step, ammonia is aerobically oxidized to nitrite and then to nitrate. Subsequently, this nitrate is reduced to gaseous nitrogen by denitrifying micro-organisms that use it as final electron acceptor. Our results showed that the changes occurred in the system had no adverse effects on effluent quality or on activated sludge health where it was still having its healthy brown color, with no appearance of black spots (an indicator of bacterial death) or unpleasant odors. In addition the new conditions improved activated sludge settle ability.

Nitrite was absent throughout the whole study period, this could have resulted from the nitrification process that occurred in the second oxidation tank, where the amounts of oxygen injected in addition to the oxygen liberated during photosynthesis of algae were sufficient to oxidize nitrite into nitrate. In this connection, Abdalla *et al*. (1995) suggested that the excess of oxygen liberated during photosynthesis helps in oxidation of nitrite to nitrate.

After the two months (i.e. in Dec. 2005) the treatment system was switched once again to its usual mode of operation, which resulted in the elevation of nitrate level in the effluent to 16.0 mg/L and consequently a high growth of benthic algae developed in 7 to 10 days, revealing that nitrate is the main factor controlling phytobenthos growth.

The study proved that decreasing the nitrification phase time from 20 minutes/hour to 10 minutes/hour and lowering injected oxygen set point from 1.5 mg/L to 1.0 mg/L were the ideal conditions for the full disappearance of benthic algae from the treatment system with no adverse effects on either activated sludge health or effluent quality.

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النترتة والنمو الزائد للطحالب الملتصقة ومشاكل تقنية فى محطة معالجة ثلاثية للصرف الصحى

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أجريت الدراسة الحالية على محطة معالجة ثلاثية للصرف الصحي بمدينة القطاميه بالقرب من القاهرة حيث تم جمع عينات من البساط الطحلبى والزبد الملتصق بجدر أحواض الأكسدة و الترسيب والدفق شهريا (من يناير إلى ديسمبر2004) ولقد لوحظ عدم وجود، طحالب ملتصقة فى حوض التجميع خلال فترة الدراسة. وتبين من فحص تلك العينات وجود 120 نوعا تنتمي الى 47 جنسا تمثل 4 عائلات هى : الطحالب الخضراء المزرقة (65 نوعا)، الطحالب الخضراء (24 نوعا)، الطحالب العصوية (26 نوعا) والطحالب اليوجلينية (نوعان) وكانت الأنواع السائدة هي:

Oscillatoria amphigranulate , Oedogonium capillare , Synedra ulna , Nitzschia obtusa* var. *valgans.

وقد وجد أن زيادة تركيز النترات أثناء عملية النترتة للراسب الطيني المنشط حيويا أثناء عملية المعالجة عامل أساسي للنمو العالي والزائد للطحالب الملتصقة فى محطة المعالجة ، ولكن بتخفيض زمن طور النترتة وخفض تركيز الأكسجين المنضخ اختفت الطحالب الملتصقة بأحواض المعالجة(الأكسدة والترسيب) وحوض الدفق. وقد أثبتت الدراسة أن تخفيض زمن طور النترتة من20 دقيقة فى الساعة إلى عشرة دقائق فى الساعة مع خفض تركيز الأكسجين المنضخ من 1.5 ملجم / لتر الى 1 ملجم /لترهو الأمثل للتخلص نهائيا من تلك الطحالب فى محطة المعالجة.وقد أخضعت المحطة لتلك الظروف لمدة شهرين(اكتوبر و نوفمبر2005).