EUTROPHICATION CONTROL IN ECOSYSTEMS

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ABSTRACT

INTRODUCTION

The pervasiveness of human impact on the environment limits the certainty with which naturally occurring nutrients and pollution source can be differentiated quantitatively. Measurements of naturally occurring baseline nutrient levels are best made in more remote, undeveloped and pristine areas; yet interpretation of these data should still be considered uncertain to some degree.

PROBLEM STATEMENT

Nutrients Discharges may accelerate the Eutrophication of lakes and reservoirs. Eutrophication defined as an excessive plant growth and/or algae “blooms” resulting from over-fertilization of rivers, lakes, and estuaries / water bodies. Eutrophication can result in deterioration the appearance of previously clear waters, odor problems from decomposing plant growth, and a lower DO level, which can adversely affect the respiration of fish, benthic aquatic animals, and attached bottom plant growth. The removal of nutrients may be undertaken to limit algal growth and Eutrophication control. Thus, it is critical to understand a wastewater treatment plant’s contribution to the overall nutrients load and its significance before considering the imposition of specific nutrients controls.

METHODOLOGY

Over the last decade, there has been an increased emphasis on limiting nutrients in municipal wastewater effluents. The main purpose of this methodology done in this study is to investigate the potential of using an enhanced biological nutrients removal process system aiming to enhance the final treated effluent quality, and reduce the impact on the environment. The methodology was implemented in such technique to predict the amount of nutrients that can removed from a particular wastewater biological treatment process system and estimating the final effluent nutrients concentration.

CONCLUSION

- The methodology is provided for nutrients parameters determination will allow municipal wastewater treatment systems or industries to evaluate the feasibility of implementation of the biological nutrients removal physical trains with a minimum cost.
- Nitrogen and phosphorus are typically the two key targets for the control Eutrophication problems. After determining which nutrient, if either are growth limiting, one must determine if and how the amount of the limiting substance entering the receiving water can be controlled. Under some circumstances, removal of both nitrogen and phosphorus may be undertaken to limit algal growth.

KEYWORDS: Eutrophication, Nutrients, Nitrogen, Phosphorus, Algae, phytoplankton.

1. INTRODUCTION

The pervasiveness of human impact on the environment limits the certainty with which naturally occurring nutrients and pollution source can be differentiated quantitatively. Measurements of naturally occurring baseline nutrient levels are best made in more remote, undeveloped and pristine areas; yet interpretation of these data should still be considered uncertain to some degree.

2. PROBLEM STATEMENT

Nutrients Discharges may accelerate the Eutrophication of lakes and reservoirs. Eutrophication defined as an excessive plant growth and/or algae “blooms” resulting from over-fertilization of rivers, lakes, and estuaries / water bodies. Eutrophication can result in deterioration the appearance of previously clear waters, odor problems from decomposing plant growth, and a lower DO level, which can adversely affect the respiration of fish, benthic aquatic animals, and attached bottom plant growth as shown in Figure (1).

The removal of nutrients may be undertaken to limit algal growth and Eutrophication control. Thus, it is critical to understand a wastewater treatment plant’s contribution to the overall nutrients load and its significance before considering the imposition of specific nutrients controls.Factors supporting this process can be divided into two categories depending on whether they are linked to the nutrient dispersion and the phytoplankton growth, or to the oxygen cycle near the bottom of the water body (for example, containment, light and water movements). Various effects can be observed depending upon the severity of the eutrophication. In addition to carbon, oxygen and hydrogen that plants can find directly from water and carbon dioxide in the atmosphere, two major nutrients are necessary for the development of aquatic life: Nitrogen (N) and phosphorus (P).

A third one, silica (Si), is necessary for the development of diatoms. During eutrophication, the concentration of nutrients in the water changes. In some cases one out of the three nutrients may be totally bound to the aquatic life and will not be available for further growth of algae. This nutrient is then called the limiting factor. The ratio of nitrogen to phosphorus compounds in a water body is an important factor determining which of the two elements will be the limiting factor, and consequently which one has to be controlled in order to reduce a bloom (Table 1). [WHO, Eutrophication and Health, 40]

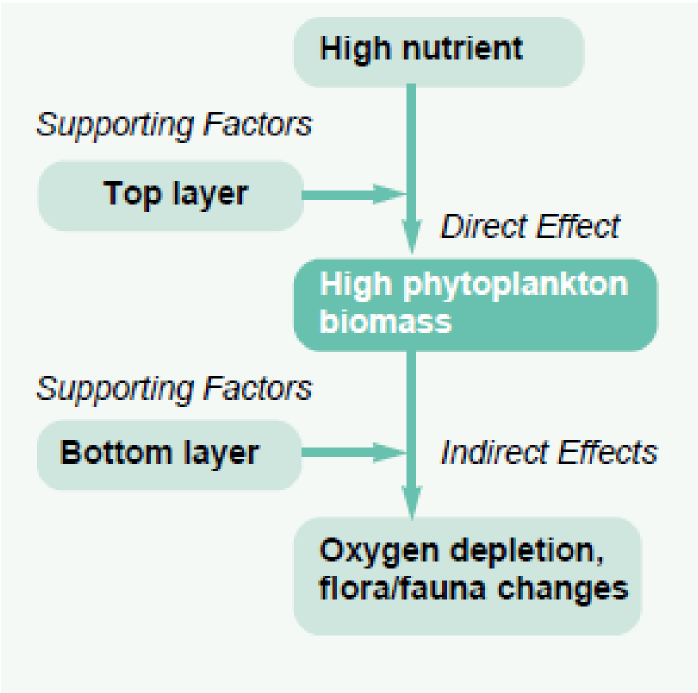

Figure (1) Eutrophication Process (Source: WHO)

Table (1) Nitrogen / Phosphorus ration (expressed in weight) for various Limiting conditions in freshwater and estuarine/coastal area

	N-limiting (Ratio N/P)	Intermediate (Ratio N/P)	P-limiting (Ratio N/P)
Freshwater	≤ 4.5	4.5-6	≥ 6
Estuarine/ coastal water[4]	≤ 5	5-10	≥ 10

Source: WHO

3. Effects of Eutrophication

The effects of eutrophication on the environment may, have deleterious consequences for the health of exposed animal and human populations, through various pathways. Specific health risks appear when fresh water, extracted from eutrophic areas, is used for the production of drinking water. Severe impacts can also occur during animal watering in eutrophic waters. Algae display varying degrees of complexity depending on the organization of their cells. Macroalgae, phytoplankton and cyanobacteria may colonize marine, brackish or fresh waters wherever conditions of light, temperature and nutrients are favourable. Some cyanobacteria have the capacity to produce toxins dangerous to human beings. Toxins can be found either free in the water where the bloom occurs or bound to the algal or cyanobacterial cell. When the cells are young (during the growth phase), 70 to 90% of the toxins are cell bound, whereas when the cells are ageing, free toxins can reach 70% of the total. It is difficult to remove free toxins in the water by the normal processes used in treating water for drinking purposes. It is usually much easier to remove cyanobacterial cells than free toxins. [WHO, Eutrophication and Health, 40]

4. Experimental Work

The Pollutant Discharge Elimination System permit for each municipal treatment plant dictates effluent limitations and monitoring requirements for that particular plant. For evaluating plant performance regardless of size, biochemical oxygen demand (BOD), total suspended solids (TSS), pH, and flow should be routinely monitored. Secondary analyses may include total coliform, fecal coliform, temperature, dissolved oxygen, total volatile solids, total solids, settleable solids, nitrogen, phosphorus, chlorine residual, dissolved solids, alkalinity, metals, COD, oil and grease, and organic priority pollutants as required. Since COD is a better energy measurement than BOD_5 for monitoring carbonaceous energy removal, it is recommended that COD be analyzed on a routine basis in plants designed to remove phosphorus, if the plant is designed to remove phosphorus, phosphorus (total phosphorus and orthophosphate) and nitrogen (ammonium, nitrite, and nitrate nitrogen). The recommended routine analytical methods are summarized in Table 2.

The **soluble readily biodegradable fraction, S_{bsi}**, plays an important role in biological phosphorus removal because phosphorus-removing microorganisms sequester volatile fatty acids (VFAs) in the S_{bsi} fraction using the energy obtained from cleavage of a phosphate bond of the polyphosphates stored within the biomass. In the anaerobic zone of a BPR process, only the readily biodegradable soluble COD (S_{bsi}) component is susceptible to fermentation to form VFAs within the short detention time (1-2 hours). Biodegradable COD (S_{bi}) may be determined using the total biological demand (T_bOD) concept of Mullis and Schroeder. The T_bOD concept assumes that particulate organic materials are hydrolyzed when the biological oxidation process is completed (normally after 24 hours).

This was true in tests performed on wastewaters from several times during the seasons for more than one year. Thus, T_bOD is conceptually equal to the biodegradable COD including the soluble readily degradable COD (S_{bsi}) and the particulate slowly degradable COD (S_{bpi}). Using T_bOD as the value for S_{bi} is thought to be adequate for design. T_bOD can be determined in a batch test. The batch test should be conducted under similar operational conditions of the actual existing wastewater treatment plant of interest, including sludge age, food to microorganism ratio (F/M), mixed liquor suspended solid (MLSS) concentration, etc.

We proposed a batch experiment for a simulation of the Biological Phosphorus Removal Process in an actual plant to show the feasibility of BPR under varying wastewater compositions. The BPR Test offers a rapid, low-cost alternative for assessing BPR feasibility and predicting the effluent soluble phosphorus concentration. The batch reactor experiment (BPR Test) developed in this study was used for dynamic simulation modeling by conducting the BPR Test at the location where a PAO-containing sludge is available (from an operating full-scale BPR plant) to simulate similar operational conditions of the actual existing wastewater treatment plant of interest, including sludge age, food to microorganism ratio (F/M), mixed liquor suspended solid (MLSS) concentration, etc.

In order to evaluate BPR feasibility of the wastewater of interest to meet with the total effluent phosphorus concentration in compliance with Treated Effluent to Water Bodies.

The operational conditions and procedure developed for the BPR Test was conducted using the Dynamic Simulation Modelling Technique, whereas the enhanced culture must depend on influent wastewater characteristics and PAO-containing activated sludge of an actual existing plant under operation and analyze the total phosphate (TP) and COD every 30 minutes for a period of time corresponding to both of the anaerobic and aerobic retention time. Experimental Work has conducted based on yearly seasonal change actual intrinsic wastewater characteristics from sewage treatment plant under operation as shown in Table (3) and figure (2). The phosphorus release rates are comparable with reported values ranging from 0.042 to- 0.056 mg-P/g VSS/min (Kang et al. 1991) as shown in Table (3)

Table (2) Recommended Routine Analytical Methods

Parameter	Method
BOD_5	Standard Methods 5210
COD	Standard Methods 5220
Total Phosphorus	Standard Methods 4500-P
Orthophosphate	Ascorbic Acid Reduction Method / Standard Methods 4500-P
NH_3+NH_4^+-N	Preliminary Distillation; Titrimetic Method / Standard Methods 4500-NH_3
NO_2^-+NO_3^-N	Devarda's Alloy Reduction Method, Standard Methods 4500
TKN	Semi-Micro Kjeldahl / Standard Methods 4500-Nitrogen (organic)
Total Suspended Solids (TSS)	Standard Methods 2540-D
Volatile Suspended Solids (VSS)	Standard Methods 2540-E
Alkalinity	Standard Methods 2320
pH	Standard Methods 4500-H^+

Source: Standard Methods refers to Standard Methods for the Examination of Water and Wastewater (American Public Health Association 1995).

Table (2): Phosphorus Results from BPR Batch Experiment

Zone	Time, Hours	22-Jun-07		
		$TP_{(test)}$	$COD_{(test)}$	$S_{bsi\ (test)}$

Anaerobic	0	12.20	645.00	185.00
	1/2	14.03	516.00	148.00
	1	24.40	451.50	129.50
	1 1/2	28.06	430.22	123.40
	2	28.95	408.29	117.11
Aerobic	2 1/2	25.01	161.25	46.25
	3	16.26	90.30	25.90
	3 1/2	12.57	83.85	24.05
	4	8.54	64.50	18.50
	4 1/2	4.88	61.28	17.58
	5	3.66	51.60	14.80
	5 1/2	1.95	43.86	12.58
	6	1.14	41.93	12.03
Test Efficiency		**90.7%**		

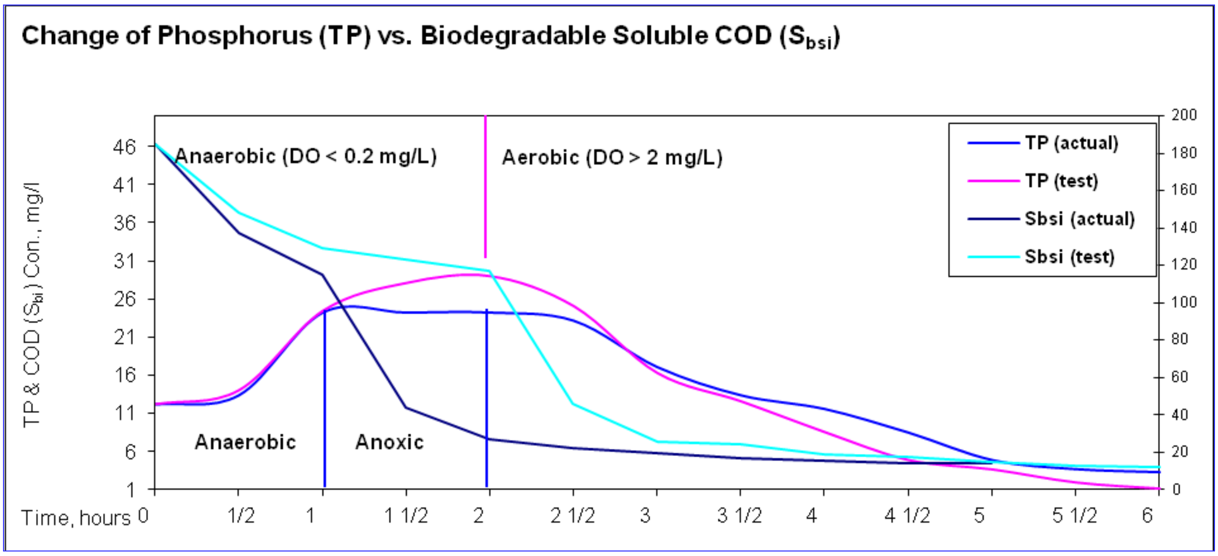

Figure (2): Effluent Phosphorus Results from BPR Batch Experiment

Table (3): Specific Phosphorus Release & Uptake Rate from BPR Batch Experiment

Specific Phosphorus Release & Uptake Rate	Value
Influent Total-P, mg/L	12.20
Influent Ortho-P, mg/L	7.08
MLVSS, mg/L	2,500
P release concentration @ end of anaerobic stage, mg/L (test)	29.0
P release concentration @ end of anaerobic stage, mg/L (actual)	24.28
Specific Phosphorus Release Rate, mg-P /g VSS .min (test)	0.056

Specific Phosphorus Release Rate, mg-P /g VSS .min (actual)	0.081
P uptake concentration @ end of aerobic stage, mg/L (effluent test)	1.14
P uptake concentration @ end of aerobic stage, mg/L (effluent actual)	3.30
Specific Phosphorus Uptake Rate, mg-P /g VSS .min (actual)	0.035
Specific Phosphorus Uptake Rate, mg-P /g VSS .min (test)	0.046
Ratio of phosphorus uptake to phosphorus release (actual)	2.30
Ratio of phosphorus uptake to phosphorus release (test)	1.20

5. FINDING OUTS

a) A simple COD fractionation method was developed in this study to characterize the wastewater; specifically aimed at biological phosphorus removal design.

b) These kinetic parameters and the detailed fractionation results of raw wastewater COD, nitrogen, and phosphorus can be used in biological nutrient removal process to obtain optimum design information for wastewater treatment.

c) The methods provided for parameter determination will allow wastewater treatment plants or industries to evaluate the feasibility of biological phosphorus removal of their wastewater with minimum cost.

d) The proposed batch experiment representing BPR test seems to be a good procedure to evaluate the feasibility of BPR if the phosphorus release rates of the wastewater of interest. The test using a constant ratio between phosphorus uptake and phosphorus release, appears to properly determine the feasibility of BPR for a specific wastewater.

e) The rates of phosphorus release and uptake are simply expressed by the increase or decrease in phosphorus concentration per unit biomass per unit time (mg-P/g VSS/min). The specific phosphorus release average values (0.053 to– 0.054 mg-P/gVSS/min), the specific phosphorus uptake average values (0.044 to– 0.046 mg-P/gVSS/min), the total phosphorus released was obtained from the difference between the initial phosphorus concentration and the phosphorus concentration at the end of anaerobic stage, and the phosphorus release are comparable with reported values (0.042 to– 0.056 mg-P/g VSS/min) [Kang et al. 1991].

6. CONCLUSION

f) The methodology is provided for nutrients parameters determination will allow municipal wastewater treatment systems or industries to evaluate the feasibility of implementation of the biological nutrients removal physical trains with a minimum cost.

g) Nitrogen and phosphorus are typically the two key targets for the control Eutrophication problems. After determining which nutrient, if either are growth limiting, one must determine if and how the amount of the limiting substance entering the receiving water can be controlled. Under some circumstances, removal of both nitrogen and phosphorus may be undertaken to limit algal growth.

h) The main purpose of this study is to develop a simple procedure for determining whether the biological phosphorus elimination can be feasible for any wastewater treatment plant of interest. Biological phosphorus removal techniques offer a number of advantages over chemical addition, including enhanced treatment, reduced energy consumption, and reduced sludge production. A rapid, low-cost method for determining the feasibility of biological phosphorus removal should allow these techniques to be more widely used.

i) The operational conditions and procedure developed for the BPR Test was conducted using the Dynamic Simulation Modeling Technique, whereas the enhanced culture must depend on influent wastewater characteristics and PAO-containing activated sludge of an actual existing plant under operation and analyze the total phosphate (TP) and COD every 30 minutes for a period of time corresponding to both of the anaerobic and aerobic retention time.