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REMOVAL OF NITROGEN AND PHSOPHOROUS IN A FACULTATIVE AND A WATER HYACINTH POND : A CASE STUDY

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A thesis submitted in partial fulfilment of the requirement for the degree of Master of Engineering

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Finally the author respectfully dedicates his thesis work to his beloved parents for their moral support and encouragement.

ABSTRACT

A study was carried out in facultative and water hyacinth ponds operating in parallel and receiving mainly domestic wastewater after pretreatment in an anaerobic pond. After two months of experiments on this system, the load was increased in the water hyacinth pond by sending the complete flow in this pond and the experiments were continued. During both stages, nitrogen and phosphorous were monitored at different points to observe their removal in facultative and water hyacinth ponds.

Organic, nitrite and nitrate nitrogen removal were found much better in the hyacinth pond whereas the ammonia nitrogen and phosphorous removal was comparatively better in the facultative pond. Total nitrogen removal was almost equal in both the ponds. Dissolved oxygen concentration was always much higher at every points in the facultative pond. However with double loading the nitrogen and phosphorous removal decreased further in the water hyacinth pond.

Mean percent removal based on concentrations for TKN, NH_3-N, Org-N, NO_2-N, NO_3-N and TP for the facultaive pond were 37, 43, 26, -1867, -55 and 15 % and the corresponding removal rates in the water hyacinth pond were 36, 30, 65, 14, 40 and 9 % respectively. During double loading, the percent removal rates in the water hyacinth pond for average NO_2-N, NO_3-N TKN and TP were -29, 15, 26 and 8 % respectively.

LIST OF SYMBOLS

BOD_5	=	5-day bio-chemical oxygen demand
cm	=	Centimeter
d	=	Day
Fi	=	Influent of facultative pond
F10	=	At 10 m distance in facultative pond
F30	=	At 30 m distance in facultative pond
F60	=	At 60 m distance in facultative pond
Fe	=	Effluent of facultative pond
ha	=	Hectare
Hi	=	Influent of water hyacinth pond
H10	=	At 10 m distance in water hyacinth pond
H30	=	At 30 m distance in water hyacinth pond
H60	=	At 60 m distance in water hyacinth pond
He	=	Effluent of water hyacinth pond
in.	=	Inch
kg	=	Kilogram
L	=	Liter
m	=	Meter
m^2	=	Meter square
m^3	=	Cubic meter
mg	=	Milligram
NO_2-N	=	Nitrite nitrogen
NO_3-N	=	Nitrate nitrogen
Org-N	=	Organic nitrogen
TKN	=	Total kjeldahl nitrogen
TP	=	Total phosphorous
$^{\circ}C$	=	Degree centigrade

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I INTRODUCTION

1.1 General

Waste stabilization ponds are the simplest and most economical method, if land is cheap, for wastewater treatment to reduce organic pollution and pathogenic bacterial contamination for small communities and rural area, particularly in tropical and subtropical regions. Stabilization ponds are becoming more popular in developing countries for wastewater treatment because of relatively low energy requirement and low-requirement of skilled manpower for operation and maintenance. The water quality of effluent from a properly designed pond is equally good as compared to any other conventional treatment process at low cost. But the most undesirable features for stabilization pond system is presence of large quantity of algae which causes negative impact on receiving source specially if the water is used for drinking water supply. In tropical and sub-tropical region, the solar radiation is sufficiently intense through out the year to induce and enhance the algae blooming. Due to presence of high algae concentration in the effluent of facultative pond, the treatment efficiency is adversely affected.

Nitrogen and phosphorous compounds that are introduced into receiving bodies of water as part of the effluent from water facilities, stimulate the growth of the algae. The presence of profuse algal growths in receiving water bodies is one characteristic of eutrophication. The excessive eutrophication of receiving water by adding the nitrogen and phosphorous enriched waste is merging a major water pollution problem by reducing the utility and beauty of water body and threatening its existance in course time. Ammonia nitrogen which is found in main form in domestic wastewater accelerates the eutrophication rate of receiving waters by serving as a plant nutrient and by exerting a demand on the available dissolved oxygen. Nitrate nitrogen present in effluent may also result the health hazard if the receiving waters are used for water supply. Hence the reduction of both nitrogen and phosphorous in wastewater is important in controlling the eutrophication.

The aquatic plant treatment systems are becoming more popular to overcome the effect of algal bloom and as an alternative to conventional system due to better treatment of wastewater at low cost and at less maintenance. In recent year, a number of studies have been done by several investigators and reported that water hyacinth has better nutrient removal capacity from domestic wastewater. The main function of aquatic plant is to provide support for bacterial biomass which degrade the organic pollutant present in wastewater and reduce the algal growth in pond by obstructing the sunlight penetration into the pond.

In tropical region very few study is reported on removal of nitrogen and phosphorous from full scale facultative and water hyacinth pond. To evaluate the efficiency of facultative and water hyacinth pond in removing nutrient was the main purpose of this research.

1.2 Objectives of the Research

The objectives of the study were:

1) To compare the treatment efficiency of facultative and water hyacinth pond in removing total kjeldahl nitrogen ammonia nitrogen, organic nitrogen, nitrite nitrogen, nitrate nitrogen and total phosphorous.

2) To observe and compare the efficiency of water hyacinth pond due to effect of double loading.

1.3 Scope of the Research

In this study of research, AIT waste stabilization pond consisting of a facultative and water hyacinth pond in parallel and treating domestic waste from campus was used to evaluate the efficiency of the ponds. During second stage the load was increased in the same water hyacinth pond to observe the effect of treatment efficiency of the system. The experiment was conducted continuously for five months duration, for both stages starting from October 1987 till the end of February 1988.

Parameter measured were total kjeldahl nitrogen, ammonia nitrogen, organic nitrogen, total phosphorous and BOD_5. Nitrite and nitrate nitrogen value were taken from BHAMIDIPATI (1988), to observe the removal of all form of nitrogen in pond system. Other conditions including sampling and analysis time for nitrite and nitrate nitrogen were same as ammonia, organic and total kjeldahl nitrogen.

II LITERATURE REVIEW

2.1 Previous Research

The operation of the stabilization pond system is dependent on the volumetric loading, BOD loading per unit area and concentration of organic matter in the wastewater. Consequently due to settleable solid and anaerobic breakdown there is accumulation of sludge which decreases the volume of pond and ultimately affect on volumetric loading which may cause the poor effluent quality.

Little attention has been devoted specifically for nitrogen and phosphorous reduction by pond treatment. Data are incidentally available in previous studies about nitrogen and phosphorous removal. As waste stabilization pond treatment is more effective particular for BOD and coliform removal, evaluation of pond is always expressed only in these factors.

FITZGERALD and ROHLICH (1958) reported that ammonia nitrogen and organic nitrogen removal in stabilization pond was 75 to 90 % and 60 % respectively. Nitrate and nitrite nitrogen was increased but amount present was insignificant compared to ammonia nitrogen. They also reported that phosphorous value was reduced by 96 %.

NEEL et al. (1961) reported on general observation that nitrate is not produced in ponds and nitrite is also absent significantly in lack of nitrification. Organic nitrogen in the waste is converted to ammonia which is readily used by algae and generally not oxidised further to nitrite and nitrate.

BUSH et al. (1961) reported that ammonia, organic and nitrate nitrogen removal in algae pond were 63-90 %, 32-74 % and 27-60 % respectively and phosphorous removal was 19-68 %.

LOEHR and STEPHENSON (1965) reported that a normal oxidation pond is not effective to controll the nitrogen and phosphorous from wastewater. They reported that sometimes negative removal of nitrogen was observed. However the phosphorous removal was observed during summer months and it reduced to zero in winter months.

ASSENZO and REID (1966) conducted a study on seven Oklahoma stabilization pond system and reported that total kjeldahl nitrogen and total phosphorous removal ranged from 30 to 95 percent. They also reported that nitrogen fixation was not observed in any of the ponds. The greater portion of the nitrogen in the pond was consistently in the form of ammonia which might have depressed the nitrogen fixation

ARCEIVALA (1981) reported that field ponds often show wide variations in nitrogen removal efficiencies and removal are generally expected to be greater at warmer temperature and higher loading.

GLOYNA (1971) reported that the rate of gas evolution from the sludge layer is sensitive measure of the biological activity in the bottom layer of facultative pond. Once gas production is established, loading in pond will be increased affecting the effluent quality.

The facultative pond which is most effective for wastewater treatment has limitation due to large quantity of algal growth which causes the negative impact on receiving stream. To control the algal growth in facultative pond, a number of study have been done on water hyacinth and it has been reported that water hyacinth has better nutrient removal capacity as well as to control the algal bloom compared to free facultative pond.

SHEFFIELD (1966), as reported by CORNWELL et al., (1977), reported that water hyacinth grown in secondary wastewater effluent, initially removed 40 to 50 percent of orthophosphates. However after 25 to 30 days of continuous operation, the phosphate removal efficiency decreased upto 5 to 8 percent. This was attributed to the sloughing and accumulation of detritus on the bottom of pond because of the non-harvest procedure. He also reported that 94 percent removal of nitrate and ammonia nitrogen was observed when water hyacinth were grown in a semi-continuous recirculated extended aeration effluent with a contact period of 10 days.

CLOCK (1968), as reported by CORNWELL et al., (1977), has found out that high removal of nitrogen (75% reduction in nitrate nitrogen) and phosphorous (61% reduction in Ortho-P) could be obtained when secondary sewage effluent was in contact with a dense mass of growing water hyacinth at a detention time of 5 days.

ROGER and DAVIS (1972) performed an experiment for nitrogen and phosphorous removal by water hyacinth in static water and continuous flow. They reported that phosphorous removal in continuous flow was better than static water whereas the nitrogen removal was almost same in both condition. They also reported that one hectare of water hyacinth plants under normal condition were able to absorb the average daily nitrogen and phosphorous waste production of over 800 people.

WOLVERTON and McDONALD (1975) reported that the total kjeldahl nitrogen removal by water hyacinth was 60% whereas the total phosphorous removal was 26% for the first five weeks. They suggested that water hyacinth should be harvested at five week intervals for maximum phosphorous removal.

DUNIGAN et al. (1975) conducted the experiment in greenhouse lab scale and in two farm ponds. They reported that water hyacinth was capable to remove the ammonia nitrogen from water in both greenhouse and field pond test, but nitrate nitrogen removal in field test was negligible.

CORNWELL et al. (1977) reported that the nutrient percent removal by water hyacinth is dependent on the detention time of wastewater in the pond, water depth and pond surface area. Fig. 2.1 and 2.2 show the percent removal of phosphorous and nitrogen related to pond surface area and flow. They reported that in order to remove 80 percent of the nitrogen, 2.1 hectares of water hyacinths were needed per 3800 m^3/d. The corresponding phosphorous removal was about 44 percent.

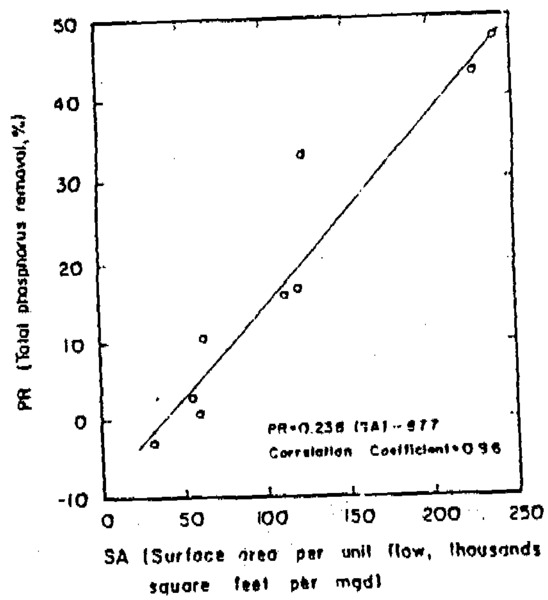


Fig. 2.1 Phosphorous Removal by Water Hyacinth Related to Pond Surface Area and Flow.

(Source: CORNWELL *et al.*, 1977)

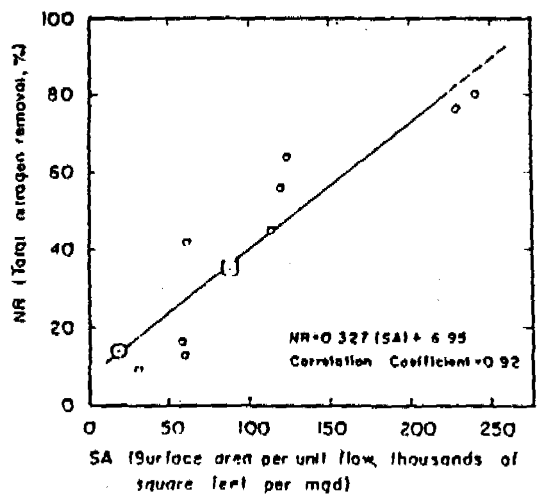


Fig. 2.2 Nitrogen Removal by Water Hyacinth Related to Pond Surface Area and Flow.

(Source: CORNWELL *et al.*, 1977)

DINGES (1978) reported that controlled culture of water hyacinths in shallow basin was effective in removing algae, other suspended particles and dissolved impurities from stabilization pond effluent. Clear high quality effluent from the system was low in nitrogen and fecal coliform bacteria. The BOD, SS and COD reduction through the plant culture were 97, 95 and 90 percent respectively. Mean effluent BOD, TSS and total nitrogen concentration were <10 mg/L, <10 mg/L and <5 mg/L respectively. He also reported that a significant reduction in total nitrogen (organic and inorganic) through the system was obtained in both the summer and winter season.

As reported by REDDY and SUTTON (1984), SWETT (1979) reported, after one year of field experiment in Coral Spring (South Florida) that water hyaçinth lagoons can provide an advanced treatment to effluent from an activated sludge plant by removing 67 % of total solids, 98% of BOD, 97 % of TKN and 79 % of total phosphorous. In Mississippi, WOLVERTON and McDONALD (1979) observed a reduction of 46 to 22 % in TKN and 28 to 52 % in TP from sewage effluent containing water hyacinth, while in Texas, DINGES (1979) measured a BOD reduction of 77 to 87 % and a TKN reduction of 63 to 69 % by water-hyacinth.

WOLVERTON et al. (1979) reported that the BOD and suspended solids removal rates in hyacinth basin are not entirely dependent on growth and harvesting rates whereas the removal of nutrients such as nitrogen and phosphorous is dependent on these variables.

The extensive works of TCHOBANOGLOUS et al., (1979), TCHOBANOGLOUS (1980), O'BRIEN (1981), STOWELL et al. (1981) and MIDDLEBROOKS (1980) may be referred for the design of wastewater treatment system using aquatic macrophytes.

TCHOBANOGLOUS et al. (1979), TCHOBANOGLOUS (1980), MIDDLEBROOKS (1980) and REED et al. (1980) have dealt with the concept, design, implication, management and use of aquatic system.

MIDDLEBROOKS (1980) reported that the sludge accumulation in water hyacinth pond was between 1.5 to $8*10^4$ m^3 of sludge/m^3 of wastewater treated compare to $1.8*10^3$ m^3 of sludge/m^3 of wastewater treated for conventional primary stabilization ponds.

Most of the studies reported above were conducted for a short period and the nutrient removal efficiency values do not include the seasonal variability. REDDY et al. (1982) reported that nutrient removal efficiency by water hyacinth shows strong seasonal dependence, because plant growth is influenced by solar radiation and ambient air temperature and biochemical transformations influenced by temperature.

STOWELL et al. (1981) studied about the treatment effectiveness of water hyacinth and emergent plant at different BOD loading and reported that aquatic system are capable of producing effluents with BOD concentration consistently below 10 mg/L.

DE BUSK et al. (1983) conducted the experiment to evaluate the removal of nitrogen and phosphorous by water hyacinth plant, with and without harvesting, in seperate pond. They found that the nitrogen and phosphorous were removed at higher rates in the harvested pond (362 and 115 $mg/m^2/d$ respectively) than in the non-harvested pond (55 and 15 $mg/m^2/d$ respectively). Mean total nitrogen and phosphorous removal from the complete system were 87 % and 10 % respectively.

REDDY (1983) performed the experiment to investigate the removal of nitrogen and phosphorous in retention reservoir with different vascular aquatic mycrophytes namely Pennywort, Water hyacinth, cattails, elodea and control (no mycrophytes). He reported that nitrogen removal was faster in Pennywort and cattails system whereas phosphorous removal was faster in Pennywort system than water hyacinth. He also reported that 34 to 40 % of inorganic nitrogen (ammonia + nitrate) was removed by plant uptake while 45 to 52 % of nitrogen was lost through ammonia volatilization and nitrification denitrification process. Plant removal of phosphorous was in range of 3 to 65 % while 7 to 87 % of phosphorous was lost through precipitation and adsorption reactions.

HAUSER (1984) reported that ammonia and total nitrogen removal in water hyacinth system with aeration were 99 and 70 % respectively compared to 70 and 55 % removal in non-aerated system.

REDDY and DE BUSK (1985) evaluated the nitrogen and phosphorous removal by eight different aquatic macrophytes namely water hyacinth, water lettuce, pennywort, duchweeds, azolla, salvinia and a submerged macrophyte egeria. They found that nitrogen removal by water hyacinth was higher than other macrophytes during summer and winter whereas phosphorous removal in summer was highest by water hyacinth and egeria system while pennywort and duckweeds showed high phosphorous removal during the winter.

ORTH and SAPKOTA (1987) reported that SS, COD, TKN and TP reduction through water hyacinth system were 81, 80, 79 and 89 % respectively compared to 9, 24, 47 and 16 % reduction respectively in facultative pond without water hyacinth.

2.2 Nature of Water Hyacinth (Eichhornia Crassipes Solms)

Water hyacinth is one of the most prominent floating aquatic plant found throughout the tropical subtropical and warm temperate regions of the world. It is also one of the most rapid growing aquatic macrophytes and is ranked eight among the world's top 10 weeds. Growth rates of hyacinth systems is a function of 1) water temperature ii) wastewater composition iii) efficiency of plant to utilize solar energy and iv) procedures used for plant harvesting. Nitrogen and Phosphorous are probably the most important plant nutrients limiting the growth of water hyacinths.The water content of water hyacinth averages about 95 % (89.3 % in leaf blades to 96.7 % in stems).

CORNWELL et al. (1977) reported that rate of growth of water hyacinth in wastewater effluent is about twice that of reported natural water values. The calculated area doubling time was found to be 6.2 days.

It is resistant to insects and disease, but very sensitive to high salinity and low temperature and does not grow in water with a temperature of 10°C or lower. The optimum temperature for water hyacinth growth ranges between 21 and 30°C. Plants die within a matter of hours when the surface water temperature approaches the freezing point.

2.3 Removal Mechanism of Nitrogen and Phosphorous in Facultative Ponds

2.3.1 Nitrogen Removal

"Biological treatment of wastewater in stabilization ponds involves several different concepts with respect to nitrogen removal. Biological oxidation mechanisms in ponds are basically similar to those found in the activated sludge and trickling filter processes. However, the cell growth nitrogen normally discharged as excess sludge from the other treatment systems but it either remains in the pond, which released again to the liquid or is discharged with pond effluent" (JOHNSON, 1968).

Organic and ammonia nitrogen (total kjeldahl nitrogen) are the principle form present in untreated wastewater. Total kjeldahl nitrogen reduction in wastewater can occur through several mechanisms.

a) gaseous ammonia stripping to the atmosphere.
b) ammonia assimilation in biomass.
c) biological nitrification.
d) biological denitrification.
e) sedimentation of insoluble nitrogen.

Ammonia nitrogen exists in aqueous solutions as ammonia (NH_3) or ammonium ion (NH_4^+) depending on the pH of the wastewater. The concentration of ammonia increases rapidly as the pH rises and this brings the loss of gaseous ammonia to the atmosphere by volatilization. With algal growth, the pH value of pond water may rise above 9.5 at noon and considerable loss of ammonia can occur. ARCEIVALA (1981) reported that an experiment in India showed about 40-60 ammonia nitrogen removal in one day when the pH had been rised earlier by lime addition to 11.0. "The rate of the gaseous ammonia losses to the atmosphere depend mainly upon the pH value, temperature, hydraulic loading rate and the mixing condition in the pond" (MIDDLEBROOKS and PANO, 1983). WILD et al. (1971) reported that the nitrification is directely related to pH and temperature of the wastewater. They suggested that optimum pH for nitrification is 8.4. Fig. 2.3 shows that 90 % of maximum nitrification rate occurs between the pH values of 8.4 to 8.9 and that outside the range of 7.0 to 9.8 less than 50 % of the optimum rate occurs. SHAMMAS (1986) reported that nitrification rate in wastewater is function of temperature within the range of 5°C to 35°C and maximum rate occurs at 30°C. WILD et al. (1971) also reported that maximum nitrification occurs at 30°C. As shown in Fig. 2.4, they found that the nitrification rate at 27°C and 17°C were 90 % and 50 % respectively of that at 30°C. Fig. 2.5 also shows the expected rate of nitrification compared to temperature for various selected pH conditions.

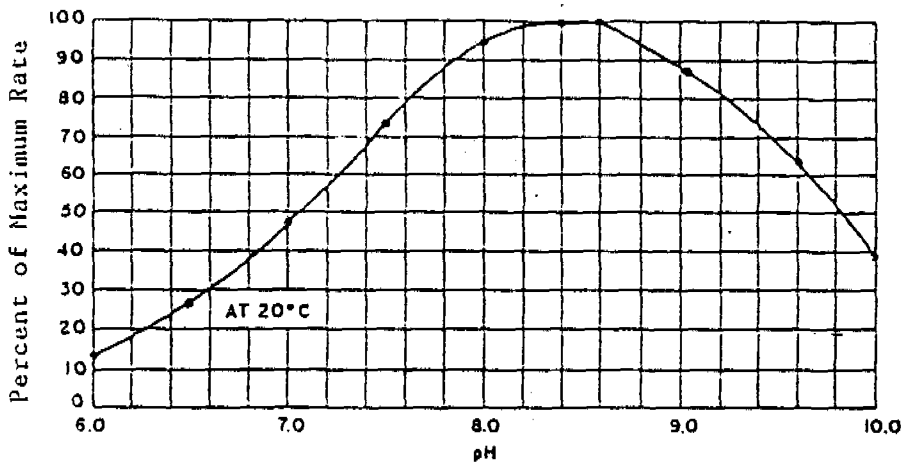


Fig. 2.3 Percent of Maximum Rate of Nitrification at Constant Temperature verses pH

(Source: WILD <u>et al.</u>, 1971)

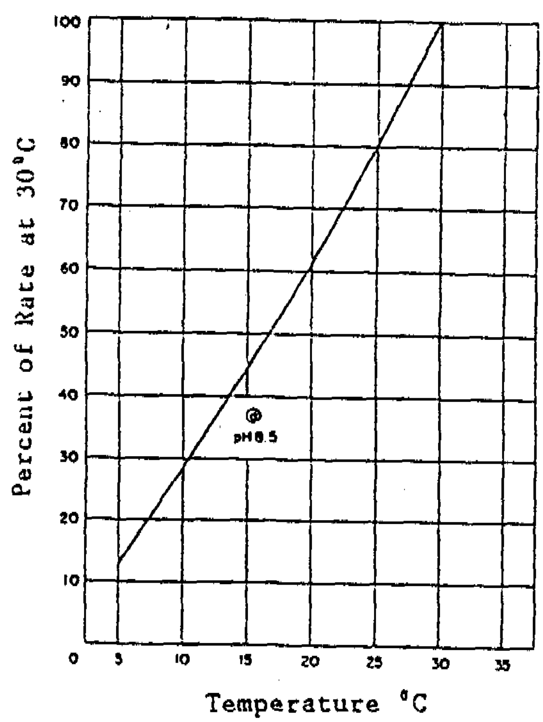


Fig. 2.4 Rate of Nitrification at all Temperatures Compared to the at 30°C

(Source: WILD <u>et al.</u>, 1971)

Organic nitrogen contained in wastewater undergoes ammonification and the resulting ammonia nitrogen is then partly used in new cell growth and partly converted to nitrite and nitrate nitrogen if conditions are favorable. Ammonia nitrogen assimilation into biomass depends upon the biological activity in the system and is affected by several factors such as temperature, organic load, detention time and wastewater characteristics (MIDDLEBROOKS and PANO, 1983). The possible mechanism of nitrogen removal in stabilization pond depends upon the growth of algae in the pond and their subsequent harvesting .

In presence of oxygen in wastewater, the ammonia nitrogen is biologically converted to nitrite and nitrate nitrogen under nitrification process. Nitrate nitrogen, the final product of nitrification, is lost partly due to algal uptake and partly to denitrification. Under anaerobic conditions nitrates and nitrites are both reduced by denitrification process. ARCEIVALA (1981) reported that less than 20 % of nitrate nitrogen is lost due to algal uptake and remaining is lost by denitrification. In absence of algal harvesting, the major mechanism for nitrogen removal from pond is denitrification.

2.3.2 Phosphorous Removal

The total phosphorous present in wastewater are in form of organic and inorganic phosphate (ortho and poly phosphate), the latter being 2 to 3 times more abundant. The main mechanism of phosphorous removal in stabilization pond are precipitation of phosphate at high pH value and absorption by the algae. Algae plays major role in both mechanism for phosphorous removal. Phosphorous removal is expected high in warmer weather when algal activity and growth are at maximum. A considerable proportion of phosphorous is reduced by the precipitation at high pH value caused by cabon di-oxide consumption by algae during the photosynthesis process. Second mechanism of reduction is directly uptaken by algae, which require phosphorous as nutrient for cell synthesis. FITZGERALD and ROHLICH (1958) reported that 96% of phosphorous is removed from pond out of which 75 % is removed by precipitation and rest by algae uptake. TOMS et al., (1975), as reported by ARCEIVALA (1981), found that phosphorous removal in the pond is directly related to pH value. Fig. 2.6 shows that precipitation begins at pH 8.2 and the soluble phosphorous concentration decreases by 10 fold for each further unit increase in pH value.

2.4 Removal Mechanism of Nitrogen and Phosphorous in Water Hyacinth Pond

The water hyacinth plants, themselves are very less involved in actual treatment of the wastewater. Their function is to provide components of aquatic environment that improve the wastewater treatment capacity of that environment. Some specific functions of water hyacinth plant in aquatic treatment system are presented in Table 2.1

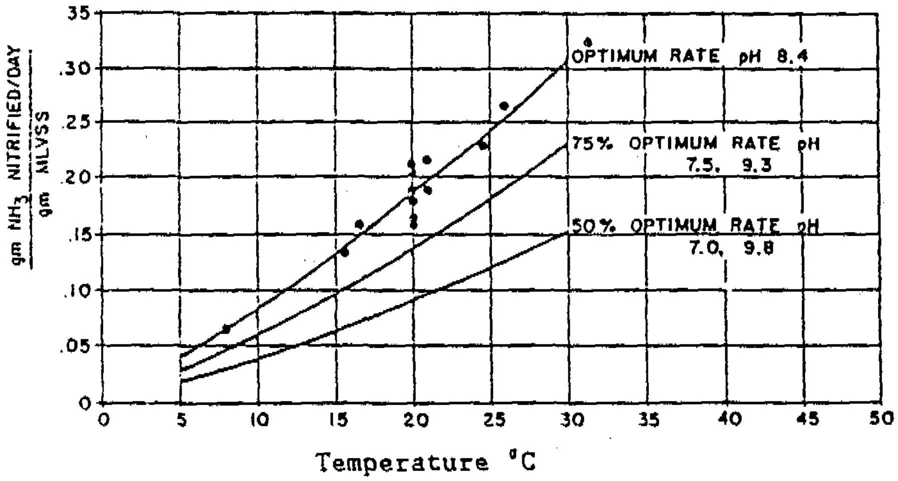


Fig. 2.5 Rate of Nitrification verses Temperature at Various pH Levels

(Source: WILD et al., 1971)

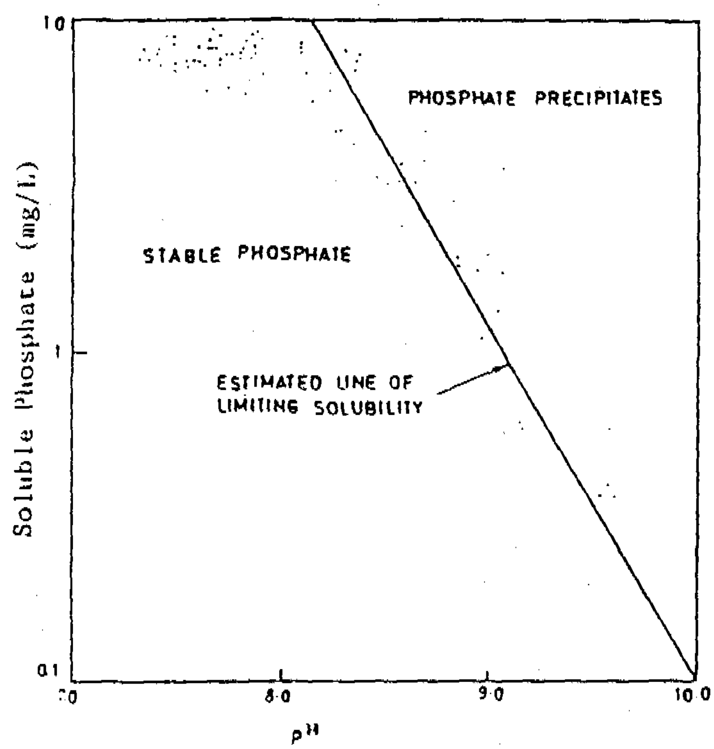


Fig. 2.6 The Effect of pH on Phosphate Precipitation

(Source: ARCEIVALA, 1981)

Table 2.1 Functions of water hyacinth plants in aquatic Treatment system (STOWELL et al.,1981)

PLANT PARTS	FUNCTION
Roots and stems in the water column	1. Surfaces on which bacteria grow. 2. Media for filtration and adsorption of solids.
Stems and leaves at or above the water surface	1. Attenuate sunlight and thus can prevent the growth of suspended algae. 2. Reduce the effects of wind on water (e.g. roiling of settled matter) 3. Reduce the transfer of gases and heat between atmosphere and water. 4. Transfer of oxygen from leaves to the root surfaces.

In aquatic systems, wastewater is treated principally by means of bacterial metabolism and physical sedimentation as is the case in conventional activated sludge and trickling filter systems. The fundamental difference between conventional and aquatic systems is that onal in conventional systems wastewater is treated rapidly in highly managed, energy intensive environments whereas in aquatic systems treatment occurs at comparatively slow rate in essentially unmanaged natural environments.

The removal mechanism for different contaminants in wastewater by water hyacinth are as the following.

2.4.1 Nitrogen Removal

The removal mechanisms of nitrogen in water hyacinth are sedimentation, volatilization, plant uptake and harvesting, microbial assimilation, and nitrification denitrification process. With the exception of denitrification and ammonia volatilization, the aforementioned mechanism do not remove nitrogen but rather convert one form of nitrogen into another that can be removed. Plant uptake and nitrification are the most significant conversion mechanisms for ammonia nitrogen in a hyacinth system treating a secondary effluent. Nitrogen removal as a result of hyacinth uptake is a function of i) water hyacinth growth rate ii) nitrogen content of hyacinths and iii) the rate of harvesting. Harvesting of hyacinth is the main to remove the nitrogen by plant uptake in hyacinth system. Nitrogen incorporated in influent solids is removed by sedimentation. Nitrogen content in hyacinth tissue is also removed by sedimentation if plants are subjected to seasonal dieback. It is important to note that at least a portion of nitrogen removed by sedimentation will be resolubilized and released to the water column. A significant amount of nitrogen is removed by bacterial nitrification and denitrification process. NICHOLS (1983) reported that nitrification coupled with denitrification, and not plant uptake, is the principal nitrogen removal mechanism. Nitrifying bacteria which is responsible for nitrification grows rapidly on submerged roots and stems of aquatic plant than other potential attachment sites. Nitrate produced through nitrification is removed by denitrification, which occurs in the sediments of aquatic system, and plant uptake.

2.4.2 Phosphorous Removal

Mechanism that may be important for phosphorous removal in water hyacinth system are plant uptake, and biological and chemical storage of phosphorous in the sediments. Chemical adsorption and precipitation reaction in sediments are the more significant mechanism compare to plant uptake. As reported in literature review the phosphorous removal in water hyacinth system is not good if hyacinth is not harvested regularly.

The principal removal mechanism for the wastewater pollutant in aquatic treatment system employing plant are summarized in Table 2.2.

2.5 Pond Efficiency

Much concern has been expressed everywhere regarding the adequancy of stabilization pond final effluent to be discharged into receiving bodies of water. This question is directly related to the gradual change that occurs in a series of ponds which show in many cases a deterioration of pond performance with time, defined as aging.

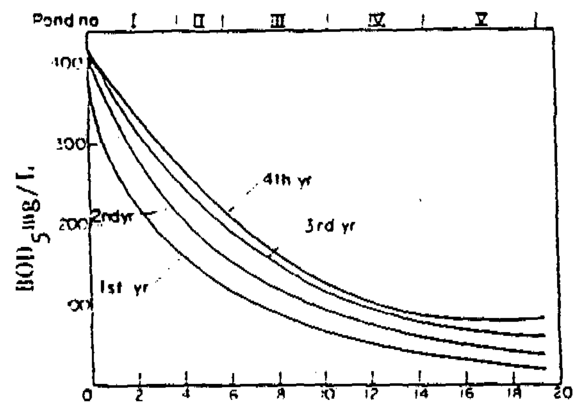
SHELEF et al. (1974) performed a experiment continuously for four years on a series of five pilot plant-scale ponds to evaluate the design of a Dan Region (Greater Tel Aviv) wastewater treatment and reclamation project. They reported that changes that occur from year to year in a series of stabilization ponds result in a gradual deterioration in removal efficiency of BOD, SS, Nitrogen and Phosphorous at each pond in series and net effect is reflected in the quality of the final effluent of the pond. They reported that increase in thickness of bottom sludges accompanied by increasing anaerobiosis of lower liquid layers in the latter ponds in the series as well as delay decomposition of accumulated sludge seem to be some of the reasons for the "Creeping" deterioration in performance. The increase of algae concentration in the latter pond of the series from year to year is a major factor responssible for the decrease in the quality of the final effluent.

Fig. 2.7 and 2.8 summarizes the results of effluent BOD of each ponds and final pond respectively for a four years period. The changes in total nitrogen and total phosphorous concentration between first two years and first three years are shown in Fig. 2.9 and 2.10 respectively.

Table 2.2- Contaminant Removal Mechanisms Operative in Aquatic Treatment Systems[a]

Mechanism	Contaminant Affected[b]								Description
	Settleable Solids	Colloidal Solids	BOD	Nitrogen	Phosphorous	Heavy metals	Bacteria and Virus	Refractory Organics	
Physical									
Sedimentation	P	S	I	I	I	I	I	I	Gravitational settling of solids (and constituent contaminants) in pond/marsh settings.
Filtration	S	S							Particulates filtered mechanically as water passes through substrate, root masses, or fish.
Adsorption		S							Interparticle attractive force (van der Waals force)
Volatilization				S					Volatilization of NH_3 from the wastewater.
Chemical									
Precipitation					P	P			Formation or co-precipitation with insoluble compounds.
Adsorption					P	P	S		Adsoption on substrate and plant surface.
Decomposition							P	P	Decomposition or alteration of less stable compounds by UV irradiation, oxidation and reduction.
Biological									
Bacterial metabolism[c]		P	P	P			P		Removal of colloidal solids and soluble organics by suspended, benthic, and plant supported bacterial. Bacterial nitrification and denitrification.
Plant metabolism[c]							S	S	Uptake and metabolism of organics by plants, Root excretions may be toxic to organisms of enteric origin.
Plant absorption				S	S	S	S		Under proper conditions significant quantities of these contaminants will be taken up by plants.
Natural die-off								P	Natural decay of organisms in an unfavorable environment.

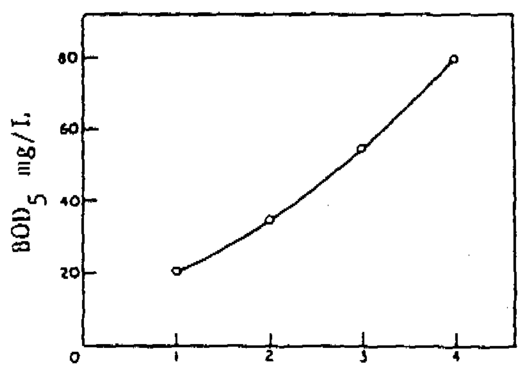
[a] Adopted from STOWELL, et al., 1980.
[b] P = primary effect, S = secondary effect, I = incidental effect (effect occurring incidental to removal of another contaminant).
[c] The term metabolism includes both biosynthesis and catabolic reactions.



Detention Time (days)

Fig. 2.7 Yearly Changes in BOD_5 as a Function of Detention Time and Sequential of Pond

(Source: SHELEF et al., 1974)



Year of Pond Operation

Fig. 2.8 Changes in the BOD_5 as a Function of Time

(Source: SHELEF et al., 1974)

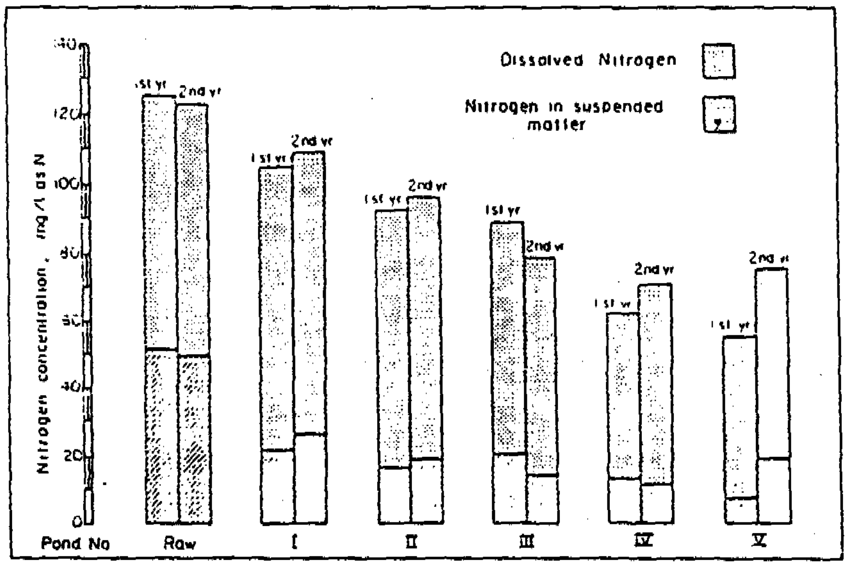


Fig. 2.9 Changes in Nitrogen Concentration in the First and Second Year of Operation along the Series of Pond

(Source: SHELEF et al., 1974)

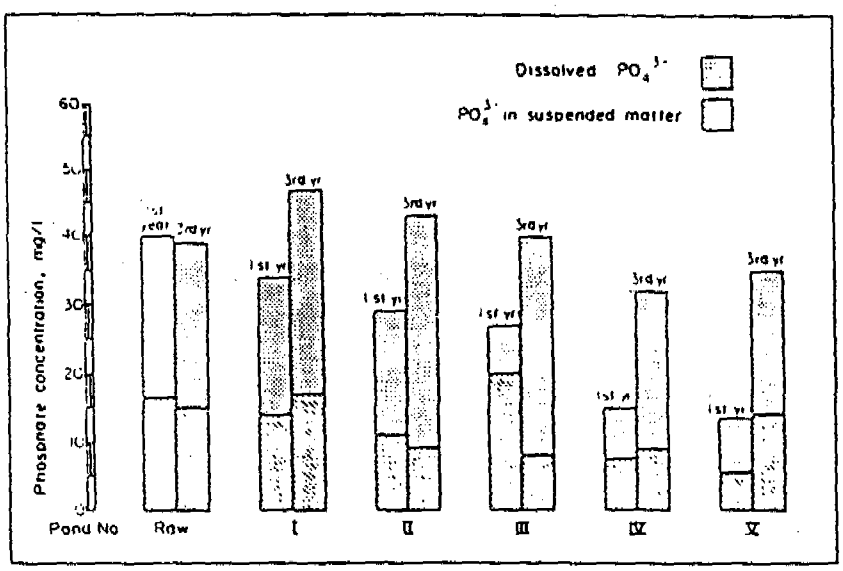


Fig. 2.10 Changes in Phosphate Concentration in the First and Third Years of Operation along the Series of Pond

(Source: SHELEF et al., 1974)

2.6 Sludge Accumulation

A certain amount of sludge accumulation occurs in stabilization ponds over a period of time. The addition depth to be provided in a pond should be sufficient to take care of the likely accumulation by the time the pond becomes due to desludging. Sludge deposits accumulate in ponds, remain anaerobic throughout their depth and are almost entirely responsible for the removal of carbon from the pond environment. The sludge deposits are a results of 1) suspended solids present in the influent wastewater, 2) bacterial solid synthesized during the metabolism of the organic wastes and 3) algal solids synthesized during photosynthesis. The mechanism responsible for sludge deposition are: 1) sedimentation of influent suspended solids, 2) bioflocculation of algal and bacterial growths in the presence of molecular oxygen and 3) autoflocculation of algae, bacteria and organic detritus enmeshed by flocs particles formed due to increases in temperature and pH.

MIDDLEBROOKS et al. (1965) studied several facultative ponds in Mississippi and found annual sludge accumulation rates of 1.5-5.1 cm (0.6-2.0 in.). GLOYNA (1971) reported that the sludge accumulation on pond is at rate of 0.03 to 0.05 m^3 per person per year. SCHNEITER et al. (1981) studied several facultative pond in Canada and Alaska and reported that sludge accumulation rates varies from 0.25 to 0.40 m^3 per 1000 people per day.

Pond cleaning interval depends on the population served by unit area of the pond and the depth provided for sludge storage. ARCEIVALA (1981) recommended the cleaning frequency of once in six year in India where pond loading are high and contains heavier grit load, but according to MEIRING et al., (1968) the pond should be cleaned out after 9 to 12 years of operation for better performance.

III METHODOLOGY

3.1 Source and treatment method of wastewater

Wastewater produced in AIT is treated by its own stabilization pond system. The pond system is designed in two parallel way, each one consisting of an anaerobic pond followed by a facultative pond as shown in Fig. 3.1. The facultative ponds recieve the wastewater from AIT, after pretreated in anaerobic ponds, and the effluents are discharged to near by canal. These both facultative ponds were selected to conduct the experiment.

In September 1986, water hyacinth was planted in one of the facultative pond to study the comparative performance of the ponds, with and without the water hyacinth. That pond was full of water hyacith in first week of January 1987. In June 1987, almost 50% of pond water hyacinth was harvested manually, from influent side. Before starting this experiment, the water hyacinth was again planted to cover the open water surface with hyacinth. In the first week of November 1978, water hyacinth was planted in one of anaerobic pond (hyacinth section). Eventhough it was beyond the scope of this study, the influent and effluent from anaerobic pond were analysed to observe the effectiveness of plants for primary treatment. That anaerobic pond was full of water hyacinth in middle of February 1988.

The flow rate of facultative pond and water hyacinth pond were controlled by V-notch (90°) weir so that the facultative and water hyacinth pond recieved almost equal hydraulic loading. The influent and effluent flow rate were measured, throughout the experiment period, with existing V-notch weir at outlet of all four ponds used with automatic level recorder.

3.2 Sampling

Grab samples were collected from influent, effluent and at 10 m, 30 m and 60 m along the pond in both systems. The sampling points in facultative and water hyacinth pond are shown in Fig. 3.2. Altogether five samples were taken from each ponds. Boat was used to collect the sample along the facultative pond whereas in water hyacinth pond temporary wooden foot path were constructed (Fig. 3.2). 1 liter sampler was used to collect the sample from the middle of the ponds, to avoid the disturbance by boating and movement on foot path. Influent and effluent samples were collected at effluent chambers of anaerobic and facultative pond respectively. Every time samples were collected about 10 to 15 cm below the wastewater surface level. The frequency of sampling was after every two or three days according to availability of time, and sampling time was kept on changing, from morning to evening, to get average daily representative data. When the facultative pond was complete dry, the composite samples of sludge were collected from three different section of facultative pond for their analysis (Fig. 4.24).

3.3 Experimental Program

To evaluate the performance of the pond, according to required objectives, the experiment was conducted in two stages as described below.

(i) First Stage :- In this stage, experiment was started from first week of October 1987 till first week of December 1987. During that period, every time ten grab samples, five from each pond, were collected and analysed immediately in Environmental Engineering Laboratory for the following parameters: 5-day biochemical oxygen demand (BOD_5), ammonia nitrogen (NH_3-N), organic nitrogen (Org-N), total kjeldahl nitrogen (TKN), and total phosphorous (TP). The physical parameters such as dissolved oxygen, temperature and pH were also measured. The dissolved oxygen and temperature were measured at situ by membrane electrode and portable DO meter whereas pH value was measured by pH meter in laboratory.

(ii) Second Stage:- After first stage, total flow was diverted toward the hyacinth pond in second week of December and experiment was continued till the end of February 1988. During that period altogether six samples, five from hyacinth system as mentioned earlier and one from anaerobic pond, were collected and analysed for the following parameters: 5-day biochemical oxygen demand, total kjeldahl nitrogen and total phosphorous. Dissolved oxygen, temperature and pH were measured by same method as in first stage. The influent and effluent of hyacinth pond was analysed for detergent, to investigate the reason of foaming in water hyacinth pond.

During second stage there was no flow in facultative pond. After one week, the wastewater from facultative pond was pumped out and after two weeks of drying, the sludge depth was measured at differnt points in the pond and sludge samples were collected from three different section, i.e. 10 m, 60 m 95 m and 115 m along the pond, and analysed for total phosphorous, total kjeldahl nitrogen and volatile solid content in sludge.

3.4 Analytical Method

All parameters mentioned above, except TP and TKN analysis in sludge, were analysed according to Standard Methods for Water and Wastewater (APHA, AWWA and WPCF, 1985). Total phosphorous and total kjeldahl nitrogen content of sludge were measured by AOAC (1985) and EPA (1973) method respectively. For wastewater, all the parameters were analysed unfilter. The detail of methods adopted for wastewater and sludge analysis are given in Table 3.1.

Table 3.1 Parameters and Analysis Method.

Parameters	Method of analysis
<u>Wastewater</u>	
BOD_5	Incubation at 20°C for 5-days
NH_3-N	Titrimetric method
Org-N	Macro-kjeldahl method
TKN	Macro-kjeldahl method
TP	Stannous chloride method
Detergent	Methylene blue method
<u>Sludge</u>	
TP	Molybdovanadophosphate method (AOAC)
TKN	Macro-kjeldahl method (EPA)
Volatile solid	Igniting at 550°C for one hour

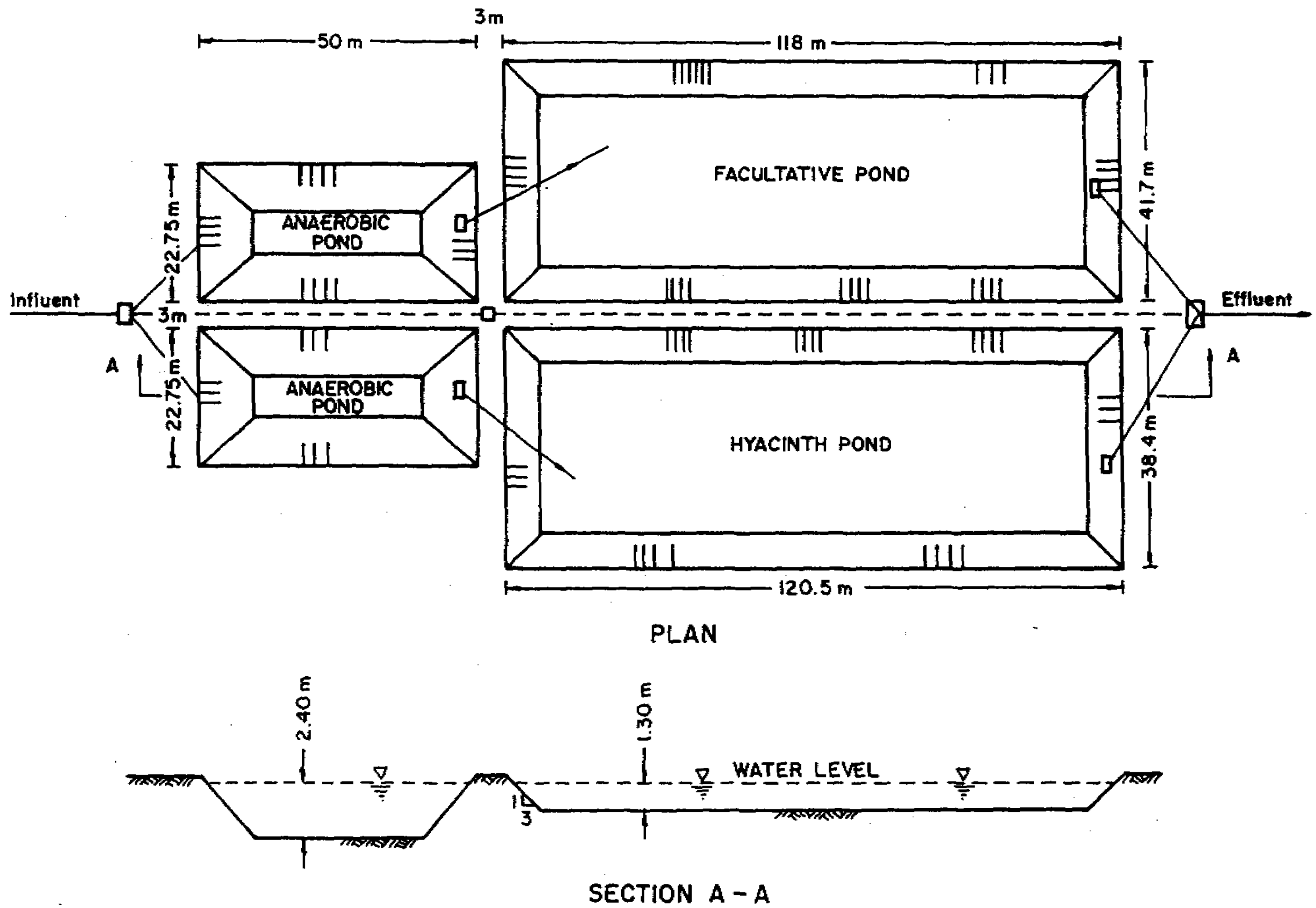


Fig. 3.1 Layout of AIT Waste Stabilization Pond

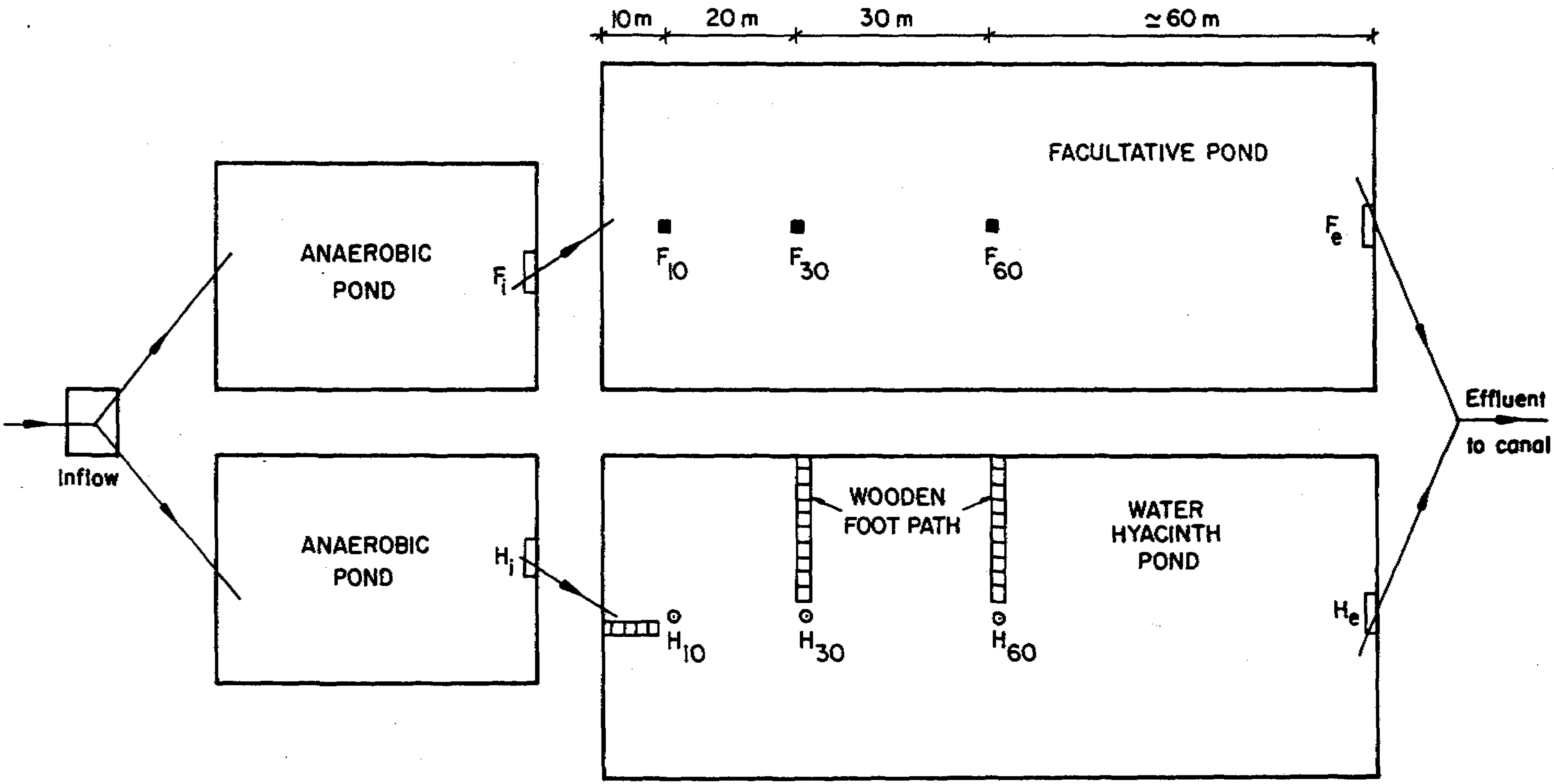


Fig. 3.2 : Sampling Points Location in Facultative Pond and Water Hyacinth Pond

[F_i , F_{10} , F_{30} , F_{60} , F_e : Sampling points in facultative pond
H_i , H_{10} , H_{30} , H_{60} , H_e : Sampling points in water hyacinth pond
Inflow : Anaerobic pond influent]

IV RESULTS AND DISCUSSION

4.1 Results

The detail data of the first and second stage experimental works are tabulated and shown in Appendix A and B sections. The average concentration value of each parameter at different points for first and second stage are given in Table 4.1 and 4.2, and their percent reduction are correspondingly presented in Table 4.3 and 4.4 respectively. The variation of effluent concentration with observation time and their reduction along the pond for both systems during both stages are presented graphically from Fig. 4.1 to 4.6 and 4.8 to 4.18 respectively.

The water hyacinth pond, after two years of operation without any maintenance like regular harvesting, did not show better treatment efficiency for total phosphorous and ammonia nitrogen , as compared to facultative pond in treating the domestic wastewater from AIT campus. However, organic, nitrite and nitrate nitrogen removal was comparatively better in water hyacinth ponds. On increasing the volumetric loading in water hyacinth pond the efficiency further decreased for all parameters, but their effluent concentration value were well within the limit. In the beginning of first stage, the water hyacinth pond effluent color was slightly yellowish but it turned to blackish at the end of second stage experiment. The dissolved oxygen concentration in facultative pond was much higher than water hyacinth pond. The mean effluent DO concentration in water hyacinth pond during first and second stage were 0.4 mg/L and 0.26 mg/L respectively compared to last year measured value of 0.9 mg/L (SAPKOTA, 1987). Odor was observed at the effluent weir of the water hyacinth pond which may be due to evolution of hydrogen sulfide gas from sediment. A large quantity of foam was produced in hyacinth pond effluent chamber during both stages, but it was never seen in facultative pond.

4.2 Discussion

On the basis of experimental data, a brief discussion about all the measured parameters for facultative and water hyacinth pond during both stages are presented in the following section.

4.2.1 Total Nitrogen

The average total kjeldahl nitrogen (TKN), ammonia nitrogen (NH_3-N), organic nitrogen (ORG-N), nitrite nitrogen (NO_2-N) and nitrate nitrogen (NO_3-N) concentration at different points in facultative and water hyacinth pond during first stage are given in Table 4.1. Total kjeldahl nitrogen was reduced in both systems with almost same rate. The mean TKN effluent concentration for facultative pond and water hyacinth pond were 9.03 mg/L and 9.20 mg/L respectively. At distance of 10 m, in facultative and hyacinth pond the concentration suddenly dropped from influent concentration of 14.40 mg/L to 9.56 mg/L and 14.38 mg/L to 11.65 mg/L respectively. The fluctuation of TKN concentration in facultative pond were comparatively higher than hyacinth pond. Table 4.2 shows the TKN concentration at differnt points in hyacinth pond during second stage.

Table 4.1 Average Wastewater Characteristics for Different Points in Facultative Pond and Water Hyacinth Pond During First and Second Stage Experiment

Parameters	Facultative Pond					Water Hyacinth Pond				
	Fi	F10	F30	F60	Fe	Hi	H10	H30	H60	He
NH_3-N mg/L	10.48	5.91	5.89	5.90	6.20	10.76	9.12	8.32	7.93	7.57
Org-N mg/L	3.83	3.40	3.05	3.11	2.84	3.64	2.46	1.83	1.55	1.27
NO_2-N mg/L	0.009	0.114	0.160	0.130	0.177	0.014	0.010	0.008	0.00	0.012
NO_3-N mg/L	0.077	0.095	0.102	0.096	0.119	0.115	0.079	0.079	0.06	0.069
TKN mg/L	14.40	9.56	9.19	9.23	9.03	14.38	11.65	10.41	9.74	9.20
TP mg/L	2.27	2.06	1.96	1.95	1.93	2.23	2.14	2.05	2.04	2.02
DO mg/L	2.12	10.75	12.09	12.07	8.52	1.18	0.59	0.49	0.50	0.40
pH	7.70	8.40	8.50	8.50	8.40	7.60	7.30	7.30	7.20	7.20
Temperature °C	30.70	30.70	30.80	30.80	30.50	30.80	28.50	28.00	27.80	27.30
Flow Rate, m^3/d	483.30				385.24	465.77				387.49
Detention Time (days)			13					13		

The average influent and effluent concentration were 15.67 mg/L and 11.15 mg/L respectively. However, the TKN concentration measured during second stage were higher than first stage value at any point in the system. Fig. 4.1 shows the variation of the effluent TKN concentration at different day of observations in facultative and hyacinth pond for both stages. The TKN value at the beginning of first stage was lower, but it increased with function of time during the entire experiment period.

Table 4.2 Average Wastewater Characteristics for Different Points in Water Hyacinth Pond During Second Stage.

Parameters	Hi	H10	H30	H60	He
NO -N mg/L	0.014	0.013	0.013	0.012	0.018
NO -N mg/L	0.059	0.05	0.053	0.050	0.05
TKN mg/L	15.07	13.24	12.26	11.74	11.15
TP mg/L	2.25	2.18	2.11	2.09	2.07
DO mg/L	0.22	0.45	0.39	0.36	0.26
pH	7.46	7.36	7.35	7.31	7.23
Temperature ^{0}C	29.27	26.89	26.28	25.94	25.59
Flow Rate m^3/d	839.32				579.09
Detention Time (day)			6		

Ammonia nitrogen reduction in facultative pond was comparatively higher than hyacinth pond. The mean effluent concentration for facultative pond and water hyacinth pond were 6.02 mg/L and 7.57 mg/L respectively. It was interesting to note that in case of facultative pond the concentration drop at 10 m was so low that the value was even lower than average effluent concentration. Minimum average concentration in facultative pond system was observed to be 5.89 mg/L at 30 m distance. Higher ammonia removal in facultative pond than hyacinth pond may be due to NH3 volatilization at high pH value and emperature. It has been observed during the experimental period that effluent ammonia concentration in hyacinth pond increases over as the time passes. The effluent concentrations at different days of observation are shown in Fig. 4.2. Organic nitrogen reduction in hyacinth pond were comparatively higher than facultative pond. Mean effluent concentration for facultative pond and water hyacinth pond were 2.84 mg/L and 1.27 mg/L respectively. The effluent organic nitrogen concentrations at different days of experiment are shown in Fig. 4.3.

Nitrite and nitrate nitrogen reduction in water hyacinth pond was much better than facultative pond. In facultative pond, the effluent concentrations of nitrite and nitrate nitrogen were significantly higher than influent value. The average effluent nitrite concentration for facultative and water hyacinth pond in first stage were 0.177 mg/L and 0.012 mg/L respectively. In second stage the effluent nitrite concentration of water hyacinth pond increased to an average value of 0.018 mg/L. The variation of effluent nitrite concentration at different

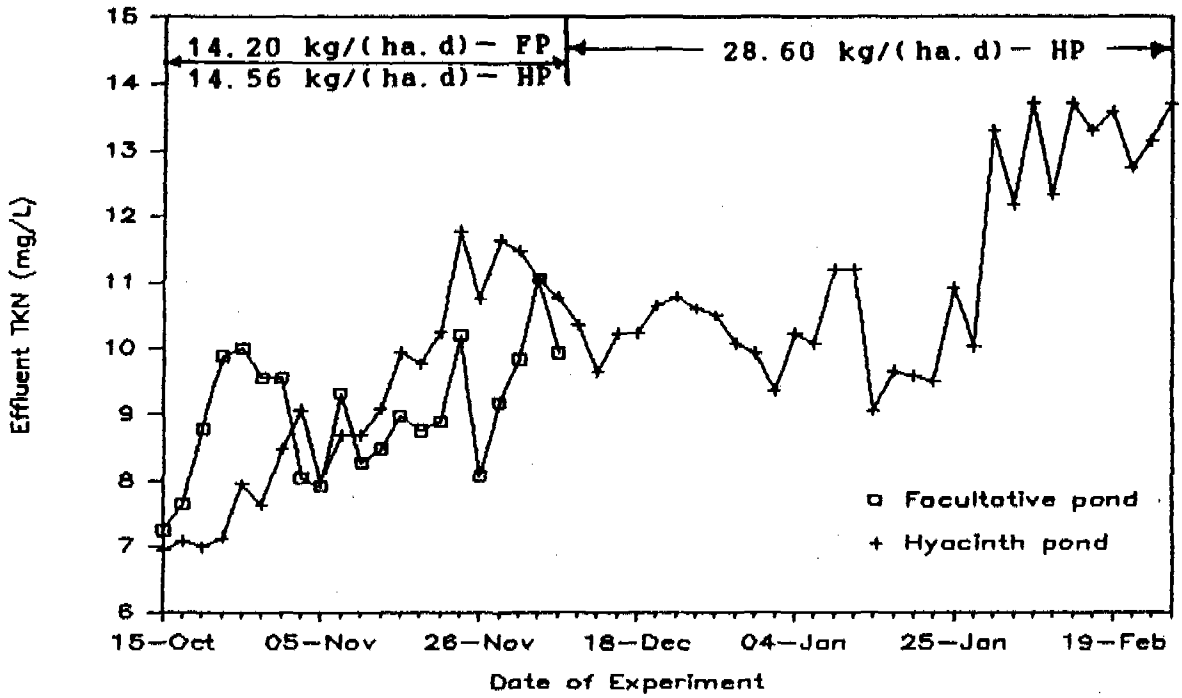


Fig. 4.1 Variation of Effluent TKN Concentration

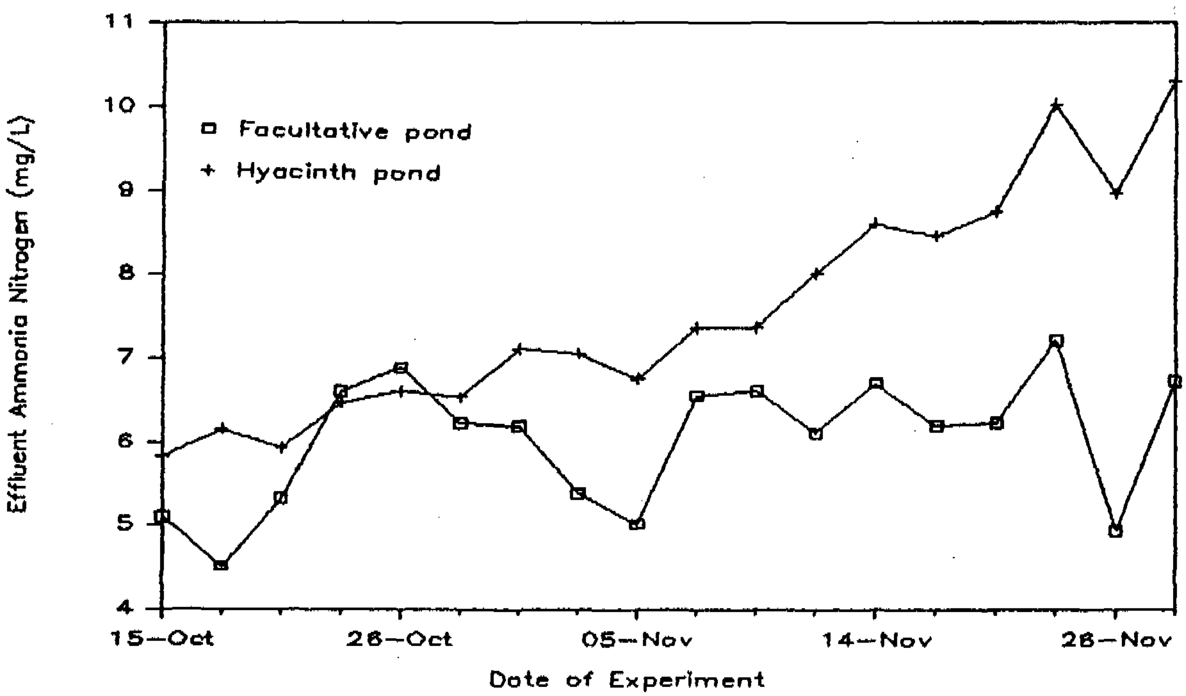


Fig. 4.2 Variation of Effluent NH_3-N Concentration

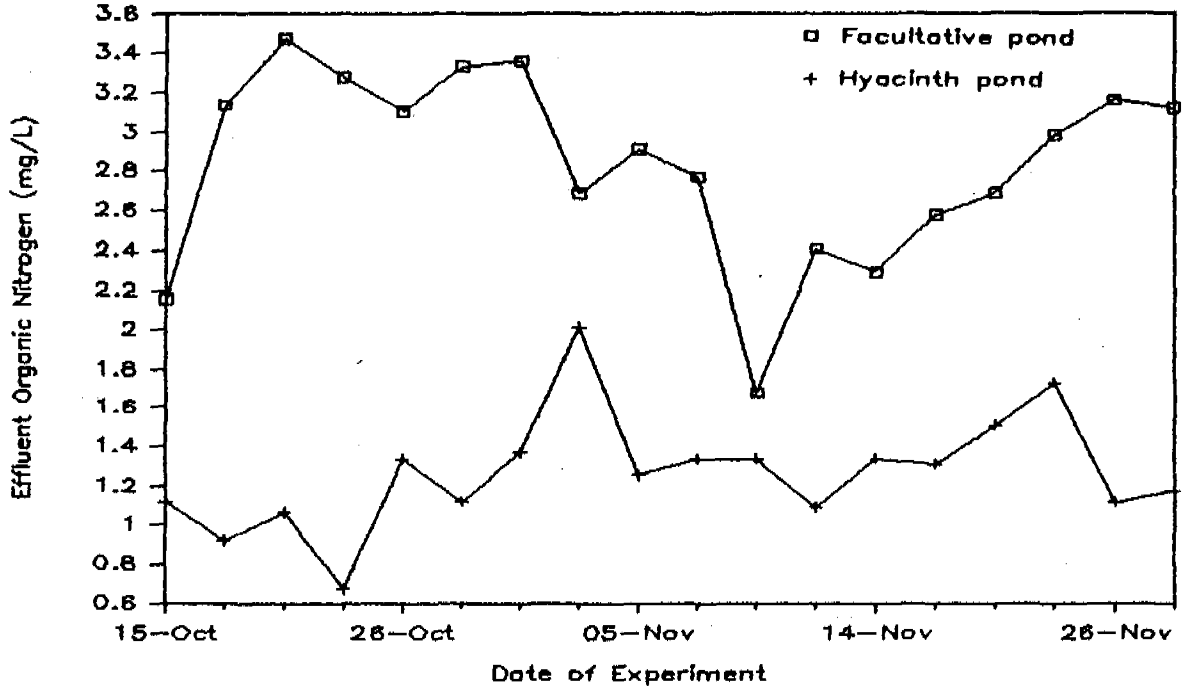


Fig. 4.3 Variation of Effluent Org-N Concentration

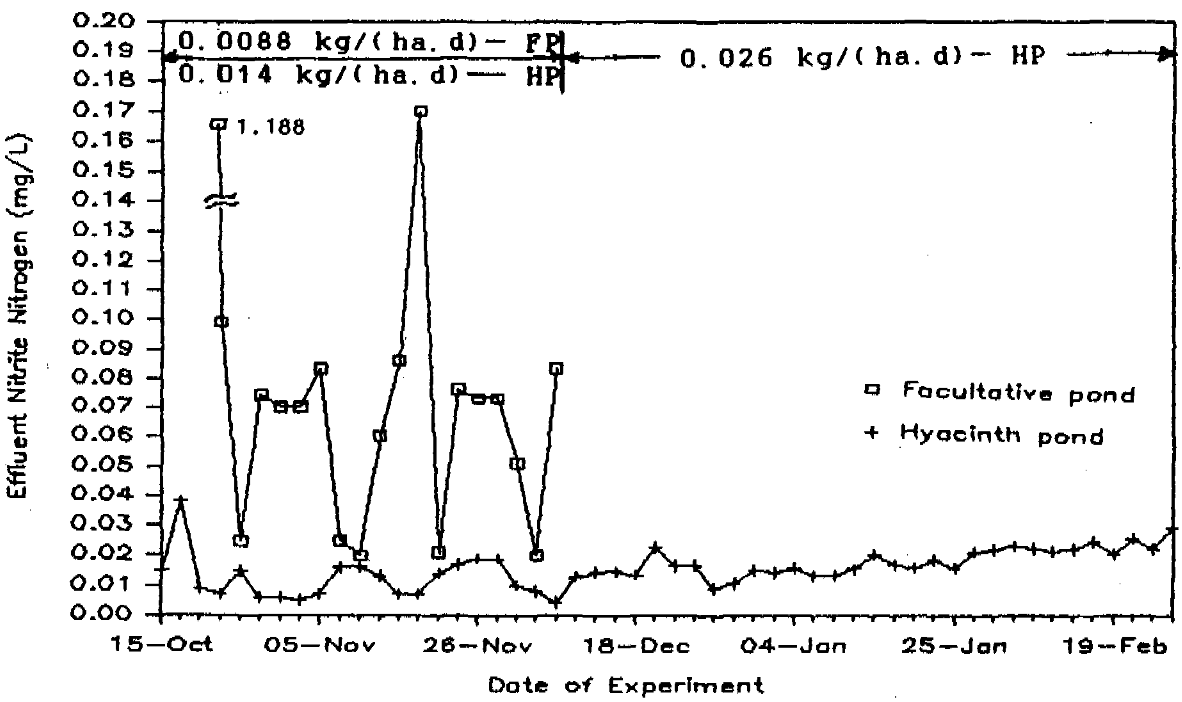


Fig. 4.4 Variation of Effluent NO_2 Concentration

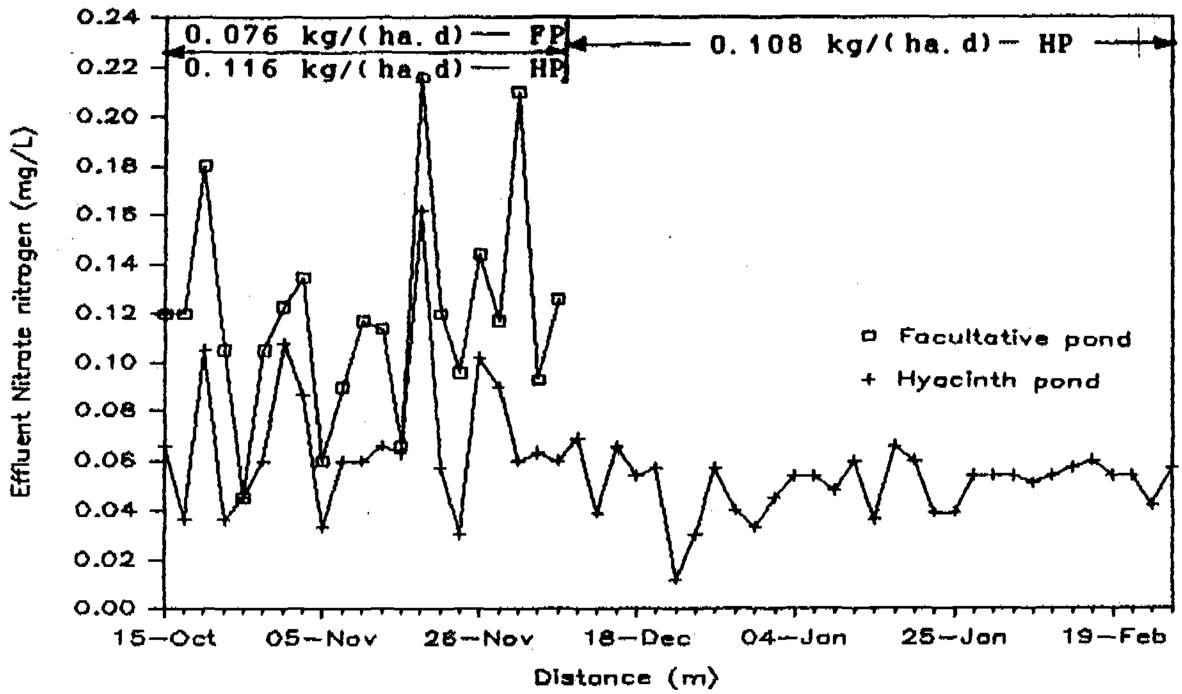


Fig. 4.5 Variation of Effluent NO_3 Concentration

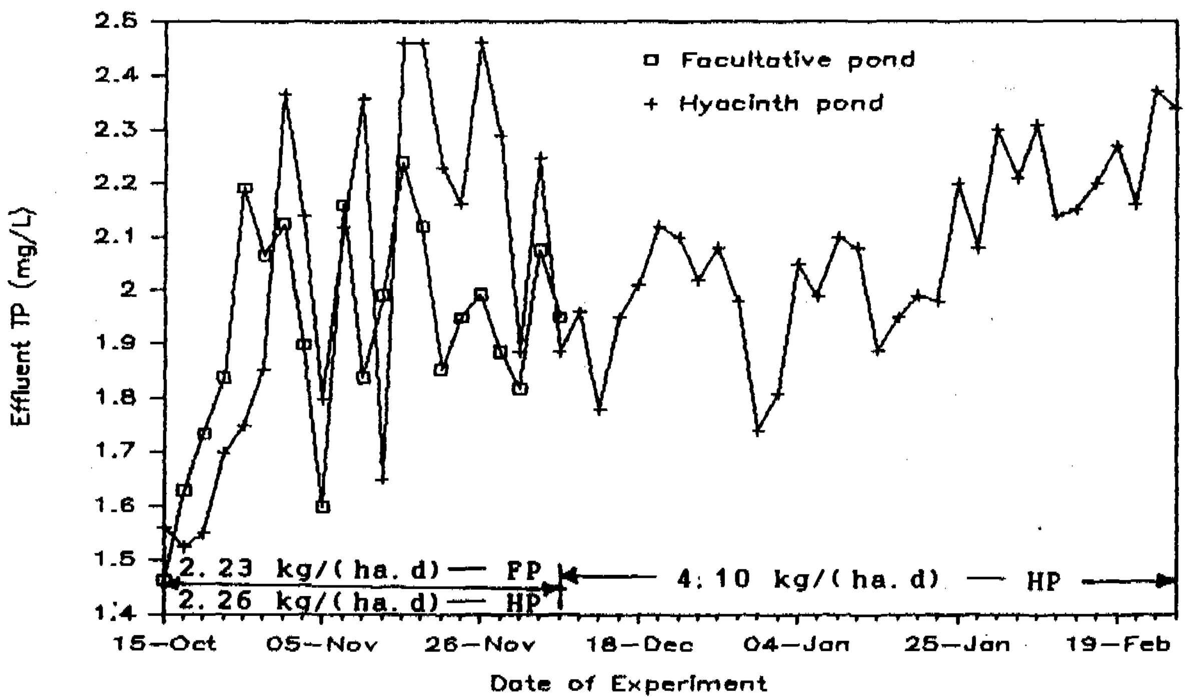


Fig. 4.6 Variation of Effluent TP Concentration

day of observations for both ponds and both stages are shown in Fig. 4.4. The average effluent nitrate nitrogen concentration of facultative and water hyacinth pond during first stage were 0.119 mg/L and 0.069 mg/L respectively. During second stage the effluent nitrate nitrogen concentration decreased to an average value of 0.05 mg/L. The concentration of effluent nitrate at different days of experiment are shown in Fig. 4.5. During first stage, the mean effluent total nitrogen (organic + inorganic) concentration was having the lower value of 9.281 mg/L in water hyacinth as compared to 9.326 mg/L value in facultative pond. On increasing the load in water hyacinth pond, the effluent value increased to 11.218 mg/L (Fig. 4.17).

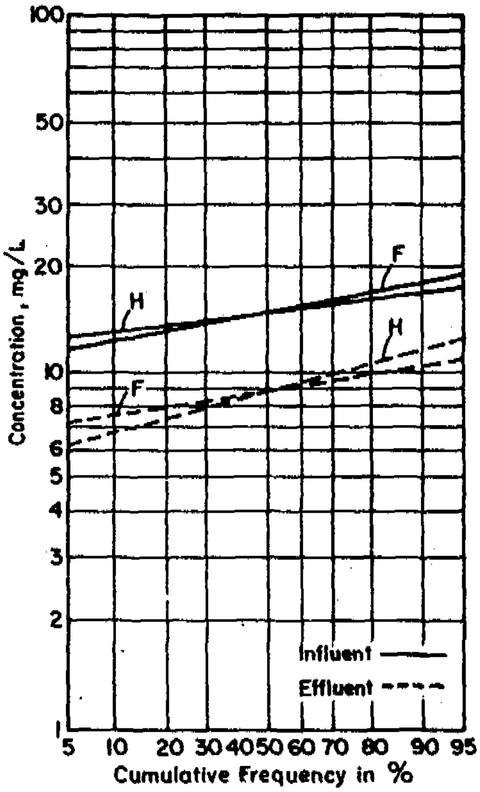
4.2.2 Total Phosphorous

During first stage, the reduction of total phosphorous (TP) in both ponds was insignificant. The TP effluent concentration of facultative pond and water hyacinth pond have little consistent. Mean TP concentration at different points in the both systems are given in Table 4.1. The average effluent concentration for facultative pond and water hyacinth pond were 1.93 mg/L and 2.02 mg/L respectively. TP removal was comparatively better in facultative pond than hyacinth pond system. The mean TP concentration at different points in water hyacinth pond during second stage are given in table 4.2. The average effluent TP concentration in water hyacinth pond for first stage was 2.02 mg/L compared to 2.07 mg/L value in second stage. However the increase in TP concentration during double loading was insignificant. The variation of effluent TP concentration at different days of observation, in facultative and hyacinth pond for both stages are shown in Fig. 4.6.

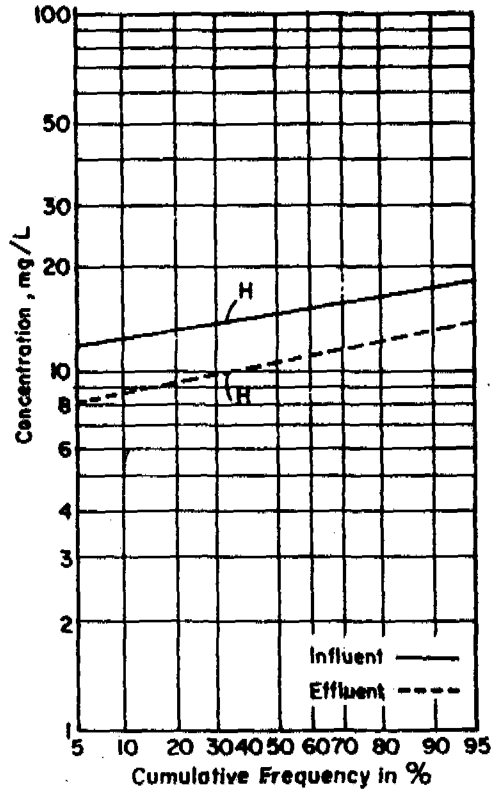
As shown in figure, the concentration of total phosphorous increased as time passed. Low TP concentration at the begining of the first stage was due to new water hyacinth planted in the water hyacinth pond whereas at the start of second stage it was due to introduction of new water hyacinth plant in the anaerobic pond. During second stage TP concentration increased further which might be due to release of phosphorous to wastewater at low DO concentration.

4.3 Statistical Analysis of the Data

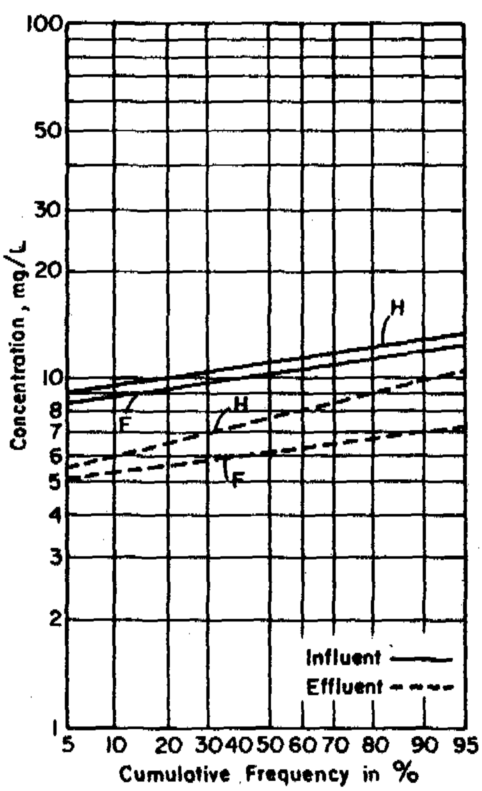
The measured parameters in facultative and water hyacinth pond showed a wide range of fluctuation. Therefore to describe the fluctuation of parameters, the influent and effluent concentration data were tested for normal distribution by statistical software (Statpro) and log normal distribution on log normal probability paper. Eventhough the data were normally distributed, the log-normal gave the better result and therefore to define the fluctuation of parameters, the influent and effluent concentration of all parameters for both systems and both stages were plotted on log-normal probability paper and presented in Fig. 4.7 (a) to 4.7 (j). The percent occurance of the data at any particular concentration, or vice versa, can be find out directely from these graphs.



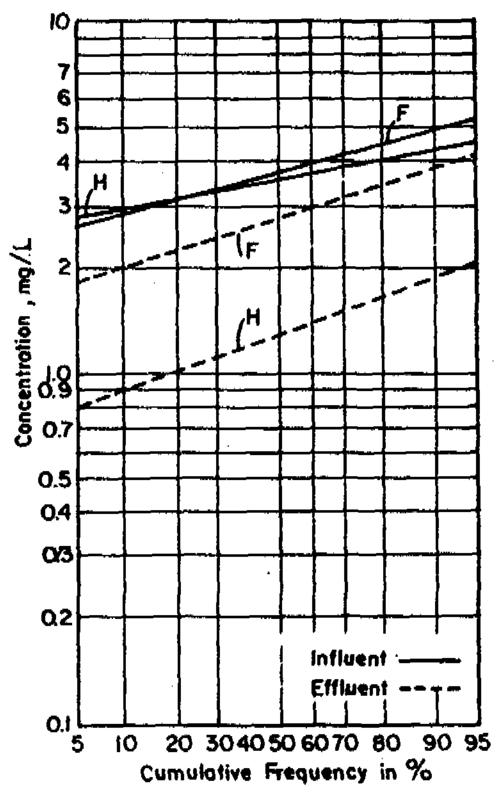
(a) TKN (1st stage)



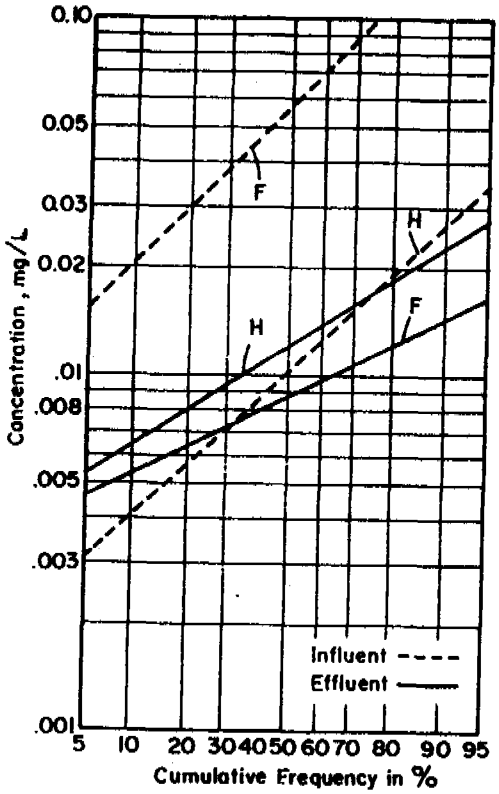
(b) TKN (2nd stage)



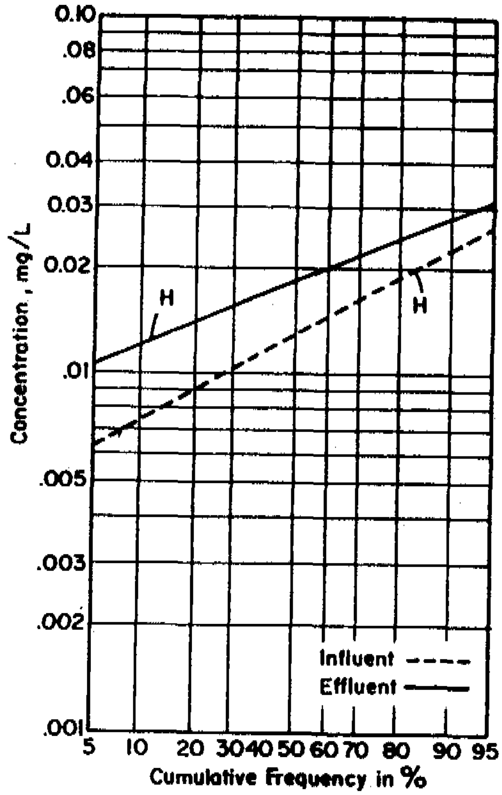
(c) NH_3- N (1st stage)



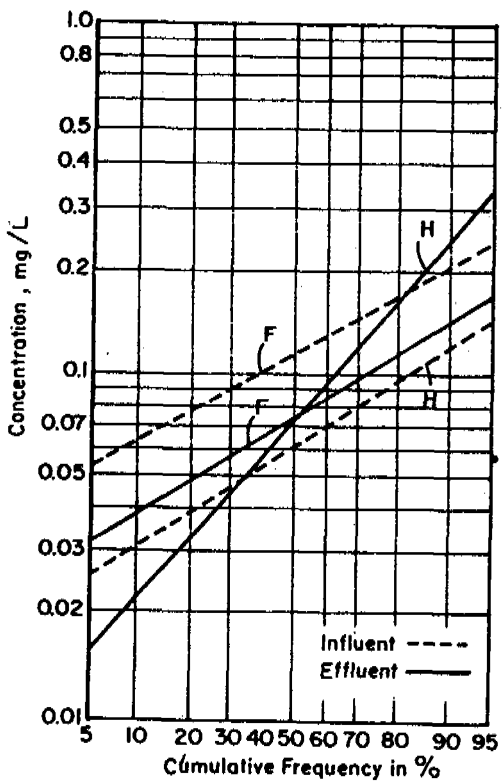
(d) Org - N (1st stage)



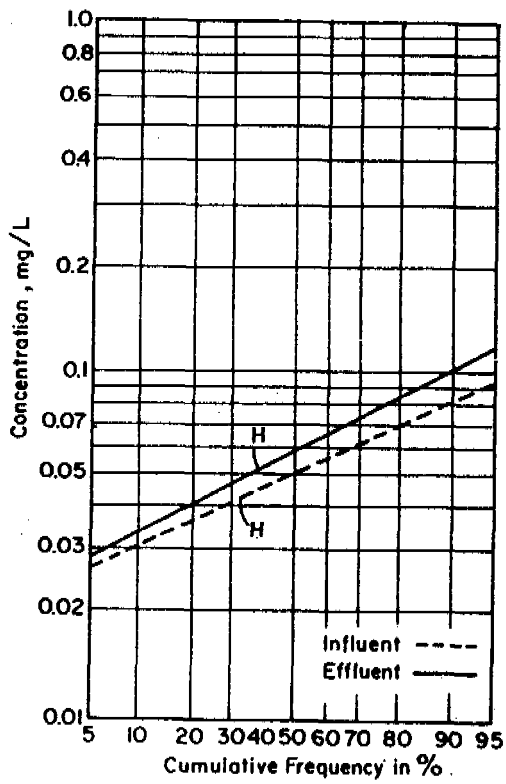
(e) NO_2-N (1st stage)



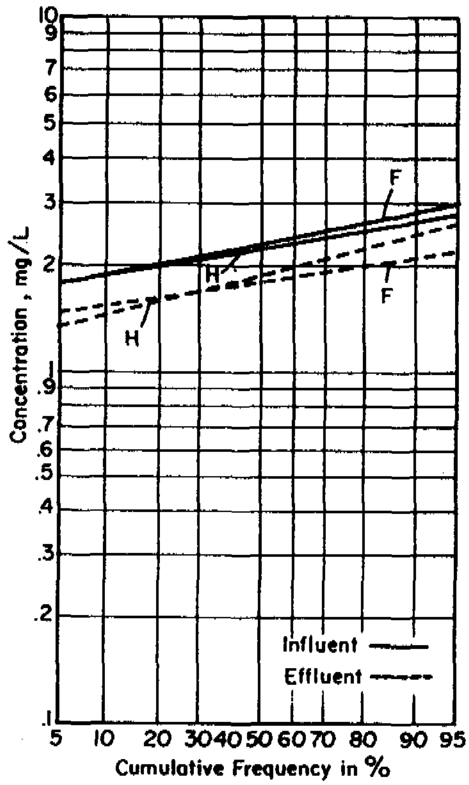
(f) NO_2-N (2nd stage)



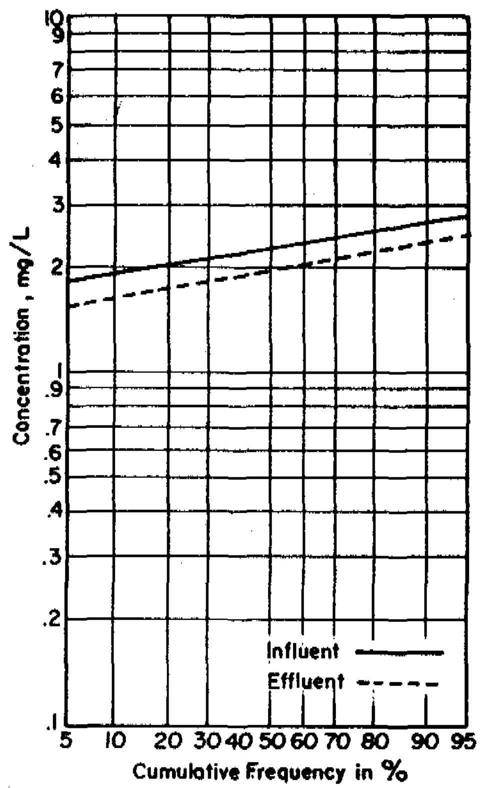
(g) NO_3-N (1st stage)



(h) NO_3-N (2nd stage)



(i) TP (1st stage)



(j) TP (2nd stage)

Fig.4.7 : Cumulative Frequency of Influent and Effluent Concentration (F= Facultative pond, H = Hyacinth pond)

4.4 Removal Efficiency

The removal efficiency for facultative pond and the water hyacinth pond, calculated on concentration basis for first and second stage are given in Table 4.3 and 4.4 respectively. Eventhough the water hyacinth was not harvested regularly the removal efficiency for the water hyacinth pond was much better than facultative pond in removing organic nitrogen, nitrite nitrogen and nitrate nitrogen. Other parameters like; TKN, ammonia nitrogen and total phosphorous removal was not better as compared to the facultative pond. During second stage, when the load was doubled, the removal efficiency for water hyacinth pond decreased considerably for all parameters, due to increase of hydraulic and organic loading and subsequently decrease of detention time. In both stages, the average percent removal for all measured parameters, except nitrite and nitrate nitrogen, was more than 50 % at 10 m distance in both facultative and water hyacinth pond. Table 4.3 and 4.4, and Fig. 4.8 to 4.13 shows the reduction of concentration for different parameters at different points along the facultative and water hyacinth pond for both stages.

The removal efficiency for facultative and water hyacinth pond on average mass flux basis has also been calculated for first and second stage and given in Table 4.5. The calculation is based on the average concentration and average flow rate, since the flow rate fluctuation in ponds was insignificant.

Average percent removal of total kjeldahl nitrogen, ammonia nitrogen, organic nitrogen, nitrite nitrogen and nitrate nitrogen at different points in facultative pond and hyacinth pond for first and second stage are given in Table 4.3 and 4.4 respectively and their concentration reduction are graphically presented in Fig. 4.8 to 4.12. During first stage, total kjeldahl nitrogen reduction for both systems was almost same, with slightly higher removal rate in facultative pond. The average TKN percent removal in facultative pond and water hyacinth pond were 37 % and 36 % respectively. TKN removal at 10 m distance in facultative and water hyacinth pond were about 90 % and 52 % respectively, of total TKN removal in corresponding pond system. The maximum rate of reduction at 10 m may be due to settling of settleable fraction of the TKN and presence of its high concentration near the inlet zone. The reason for maximum removal of TKN in facultative pond compared to hyacinth pond, may be due to high ammonia removal (which is main constituent of TKN) in facultative pond at suitable condition. The TKN reduction in water hyacinth decreased from 36 % in first stage to 26 % in second stage. The decrease in TKN reduction during second stage might be due to load increase and subsequently decrease in detention time (CORNWELL et al., 1977). The comparatively low DO concentration during second stage might be also one of the reason for decrease in nitrogen reduction. Fig 4.8 shows the average TKN reduction at different points in facultative and hyacinth pond for both stages.

Table 4.3 Removal Efficiency (%) at Different Points in Facultative and Water Hyacinth Pond During First Stage Experiment.

Sampling points	NH_3-N	Org-N	NO_2-N	NO_3-N	TKN	TP
Fi	0	0	0	0	0	0
F10	44	11	-1167	-23	34	9
F30	44	20	-1678	-31	36	14
F60	44	19	-1344	-25	36	14
Fe	43	26	-1867	-55	37	15
Hi	0	0	0	0	0	0
H10	15	32	29	31	19	4
H30	23	50	43	31	28	8
H60	26	57	50	45	32	9
He	30	65	14	40	36	9

Table 4.4 Removal Efficiency (%) at Different Points in Water Hyacinth Pond During Second Stage Experiment.

Sampling Points	NO_2-N	NO_3-N	TKN	TP
Hi	0	0	0	0
H10	7	15	12	3
H30	7	10	19	6
H60	14	15	22	7
He	-29	15	26	8

Table 4.5 Removal of NH_3-N, Org-N, NO_2-N, NO_3-N, TKN and TP in Facultative Pond and Water Hyacinth Pond for First and Second Stage.

Parameters	First Stage				Second Stage	
	Facultative Pond		Hyacinth Pond		Hyacinth Pond	
	kg/(ha.d)	%	kg/(ha.d)	%	kg/(ha.d)	%
NH -N	5.61	54	4.52	41	--	--
Org-N	1.55	41	2.62	71	--	--
NO -N	-0.08	-935	0.004	29	0.003	12
NO -N	-0.02	-24	0.058	50	0.045	42
TKN	7.10	50	6.81	47	14.564	51
TP	0.73	33	0.56	25	1.47	36

The average ammonia nitrogen removal in facultative pond was always higher than water hyacinth pond during the entire experiment period. Ammonia reduction in facultive pond was 43 % compared to 30 % in water hyacinth pond. However, it is believed that the main ammonia removal machanism like; ammonia volatilization, gaseous ammonis stripping to the atmosphere and nitrification are strongly dependent on pH value, temperature and dissolved oxygen of the wastewater (STOWELL et al., 1981, HAUSER, 1984 and SHAMMAS, 1986). According to WILD et al., (1971) and EDELINE and LAMBERT (1974), the dissolved oxygen concentration of the wastewater must be above 0.60-1.0 mg/L for bacterial nitrification. The optimum pH value and temperature for maximum rate of nitrification are 8.40 and 30°C respectively (WILD et al., 1971). This hypothesis is confirmed in case of facultative pond, when ammonia nitrogen removal was maximum at 10 m in the pond where pH value, temperature and DO concentration measured were favorable for nitrification. The sudden high reduction of ammonia near inlet zone is expected due to abrupt change of above mentioned affecting factors as well as the settling of settleable fraction of ammonia. Average ammonia nitrogen reduction at 10 m distance in facultative pond was 102 % of total reduction of pond system compared to 51 % in water hyacinth pond. Organic nitrogen removal in facultative pond and water hyacinth pond were 26 % and 65 % respectively. High organic nitrogen reduction in water hyacinth pond may be due to suitable condition for conversion of organic nitrogen to ammonia nitrogen by the action of saprophytic bacteria. Like other parameters, a marked reduction in organic nitrogen also occured at a distance of 10 m in both ponds. Fig. 4.9 and 4.10 show the average ammonia and organic nitrogen reduction at different points respectively.

The removal efficiency of water hyacinth pond in removing nitrite and nitrate nitrogen was always greater than facultative pond. During first stage the average percent removal of nitrite nitrogen in water

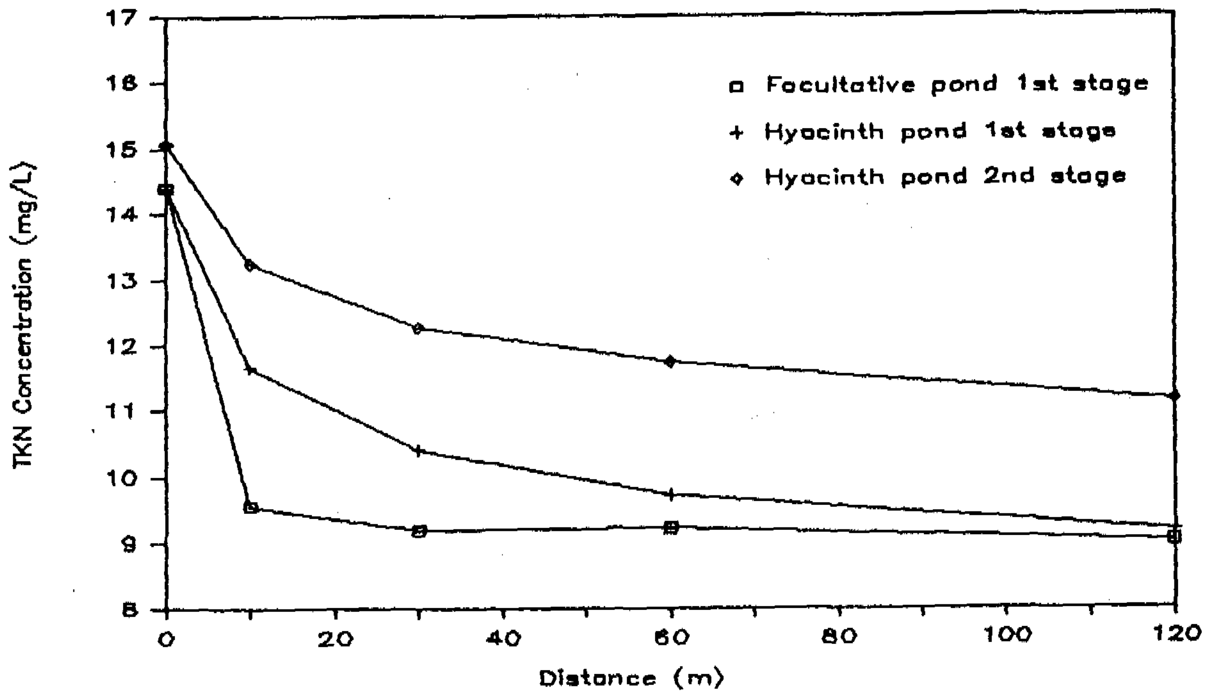


Fig. 4.8 TKN Reduction along the Ponds

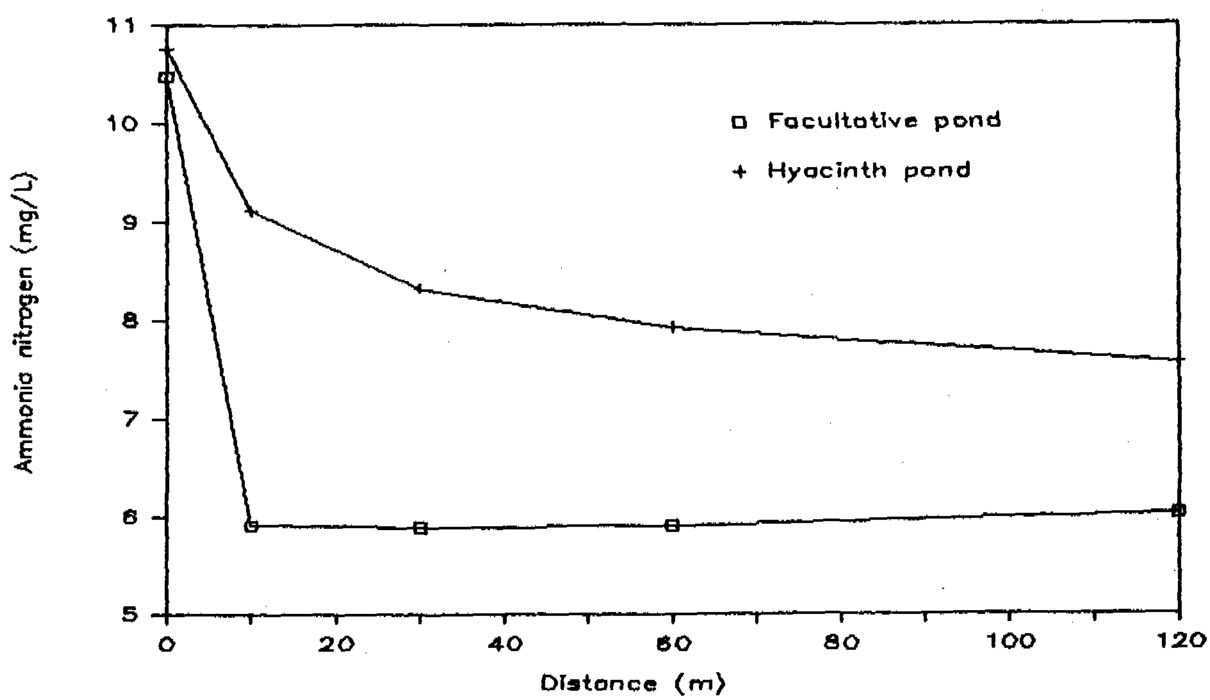


Fig. 4.9 Ammonia Reduction along the Ponds

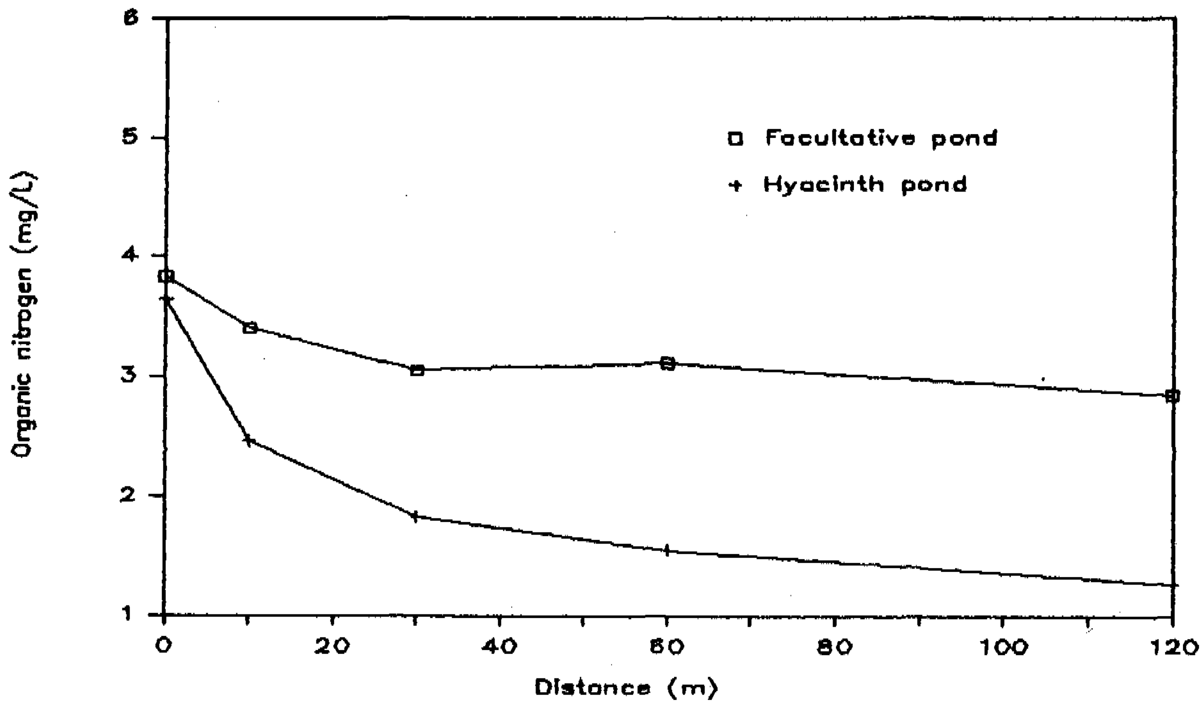


Fig. 4.10 ORG-N Reduction along the Ponds

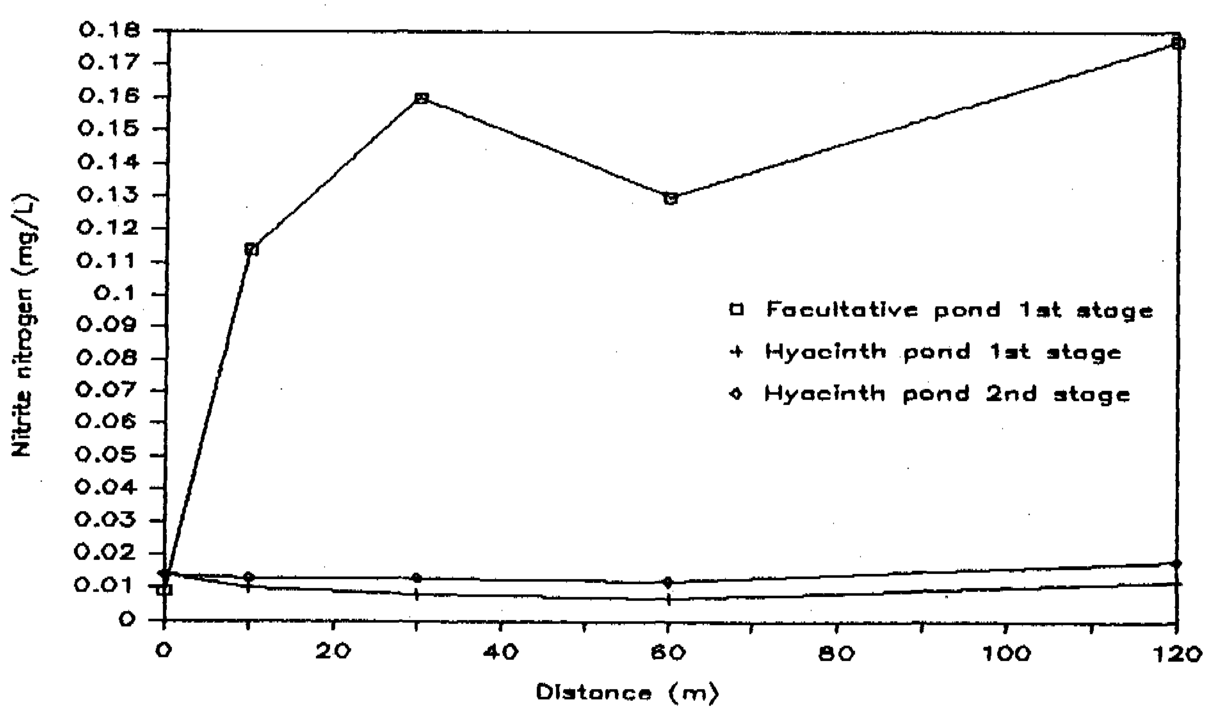


Fig. 4.11 Nitrite Reduction along the Ponds

hyacinth pond and facultative pond were 14 % and -1867 % respectively, but in second stage the removal efficiency decreased from 14 % to -29 % in water hyacinth pond. The average nitrite concentration at different points in both systems for both stages are shown in Fig. 4.11. Percent removal of nitrate nitrogen in water hyacinth pond was 40 % as compare to -54 % in facultative pond during first stage. However, in second stage the nitrate nitrogen removal efficiency of water hyacinth pond decreased to 15 %. The average nitrate concentration at different points in facultative pond and water hyacinth pond, along the systems, for both stages are shown in Fig. 4.12.

Nitrification and denitrification play a important role in increasing the nitrite and nitrate nitrogen concentration in facultative pond and their reduction in water hyacinth pond respectively. As already discussed in ammonia nitrogen removal mechanism, the facultative pond provides the suitable condition for nitrification process, and so the increase in nitrite and nitrate nitrogen concentration in facultative pond is justified. However, the reduction of nitrite and nitrate nitrogen in water hyacinth pond is the result of denitrification process.

In facultative pond, the nitrite and nitrate nitrogen concentration increased but amount present was insignificant compared to ammonia and organic nitrogen, hence increase in their concentration in facultative pond and decrease in hyacinth pond makes hardly any difference in total nitrogen concentration in the ponds. Fig. 4.13 and 4.14 shows the different forms of nitrogen present in facultative and water hyacinth pond respectively. Nitrite and nitrate nitrogen concentration in both ponds, as shown in graphs, are insignificant compare to ammonia and organic nitrogen. The trend of nitrite and nitrate nitrogen concentration change in facultative and water hyacinth pond during first and second stage are shown in Fig. 4.15 and 4.16 respectively. However the percent removal of total nitrogen in facultative and water hyacinth pond was equal with value of 36 %. During second stage, percent removal of total nitrogen in water hyacinth decreased to 26 %. Mean total nitrogen concentration at different points in facultative and water hyacinth pond during both stages are shown in Fig. 4.17.

The total phosphorous removal in facultative and hyacinth pond was not effective in either stage. TP reduction at different points in facultative and hyacinth pond during first stage are given in Table 4.3. The average TP removal in facultative pond and hyacinth pond were 15 % and 9 % respectively. The maximum TP reduction occured only upto 30 m distance in both systems, and the reason for this maximum removal is expected due to the occurance of physical, chemical and biological process at maximum rate near the entrance zone of facultative and hyacinth pond. In case of water hyacinth system, it is necessary to harvest the plant regularly to keep the phosphorous reduction rate maximum (WOLVERTON and McDONALD, 1975). After continuous operation of the same system for 25 to 30 days, the phosphorous removal efficiency declined upto 5 to 8 percent (CHEREMISINOFF, 1987). Data obtained from this experiment justify their statements.

The phosphorous removal decreased from 9 % in first stage to 8 % in second stage. The average percent reduction of TP at different points in

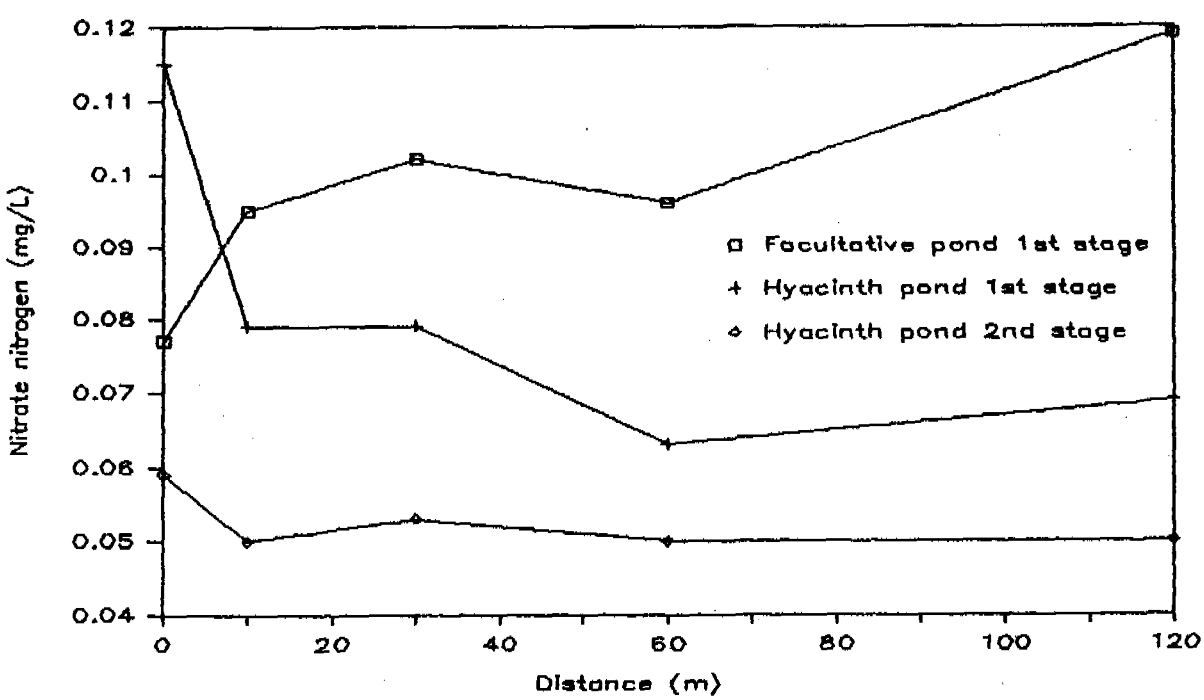


Fig. 4.12 Nitrate Reduction along the Ponds

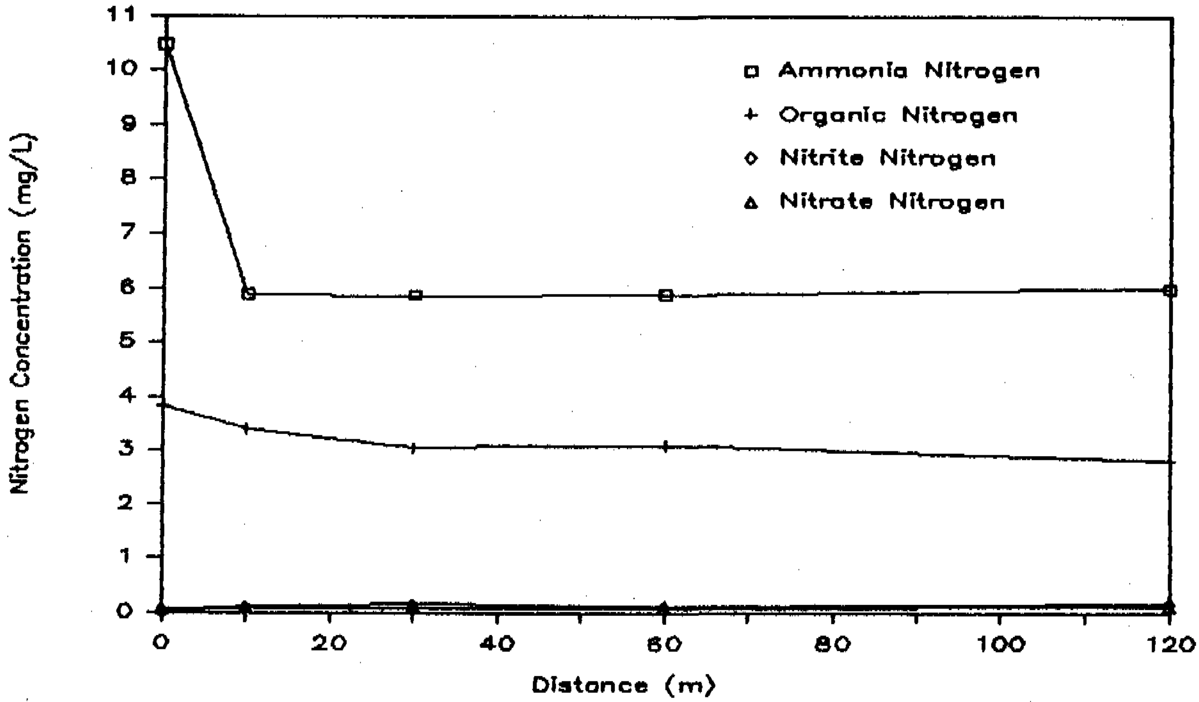


Fig. 4.13 Different forms of Nitrogen in Facultative Pond

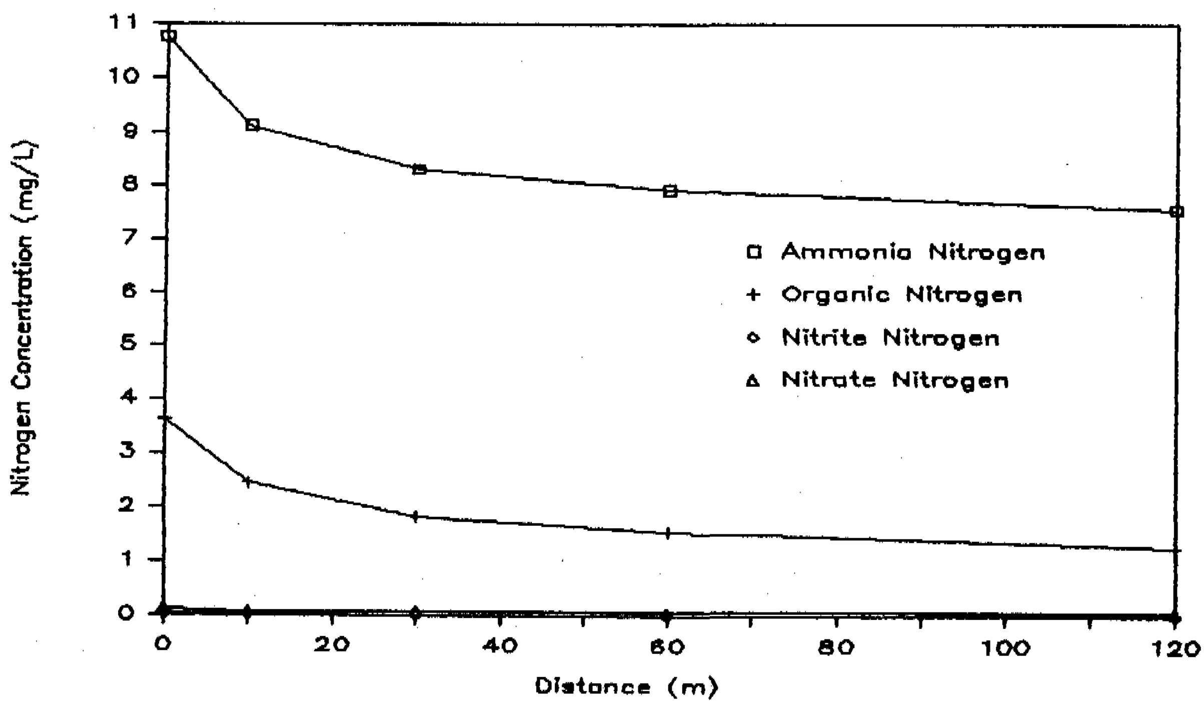


Fig. 4.14 Different forms of Nitrogen in Water Hyacinth Pond

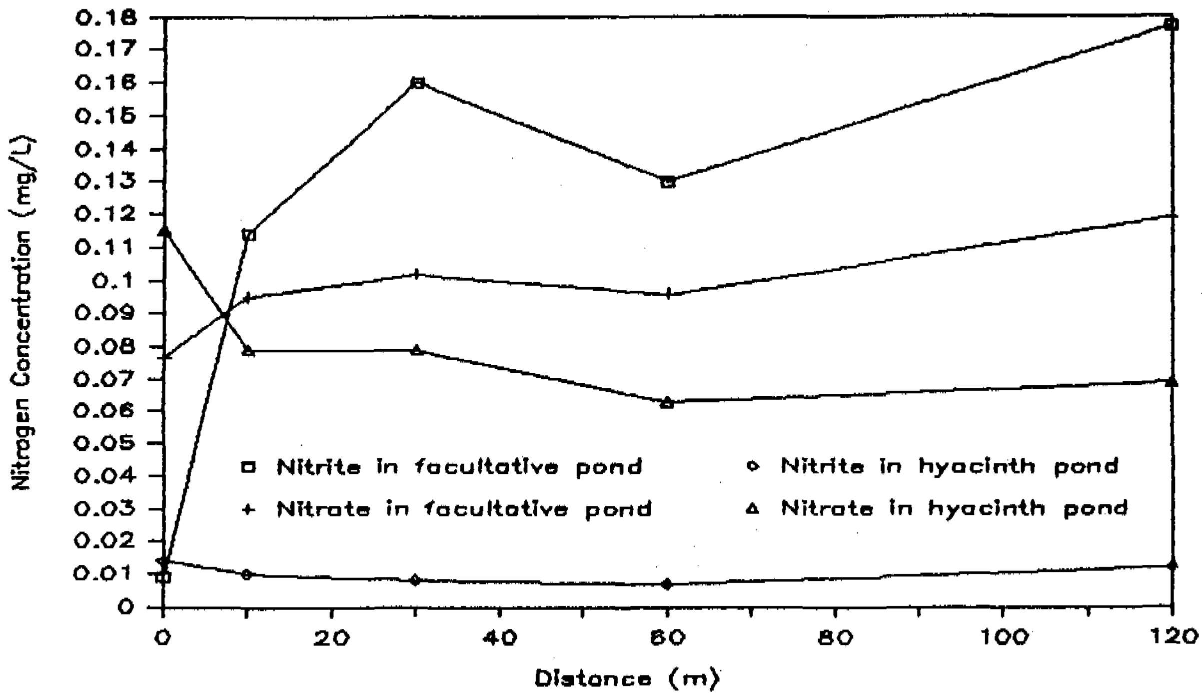


Fig. 4.15 NO_2-N and NO_3-N in Facultative and Water Hyacinth Pond

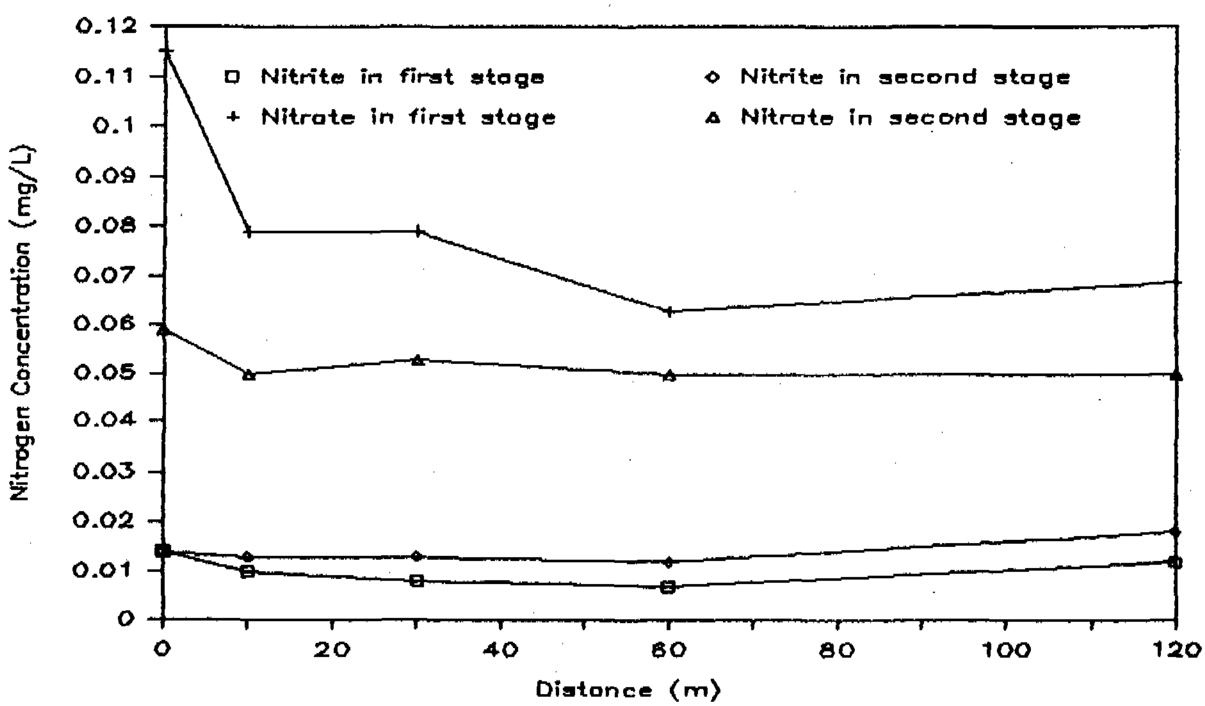


Fig. 4.16 NO_2-N and NO_3-N in Water Hyacinth Pond

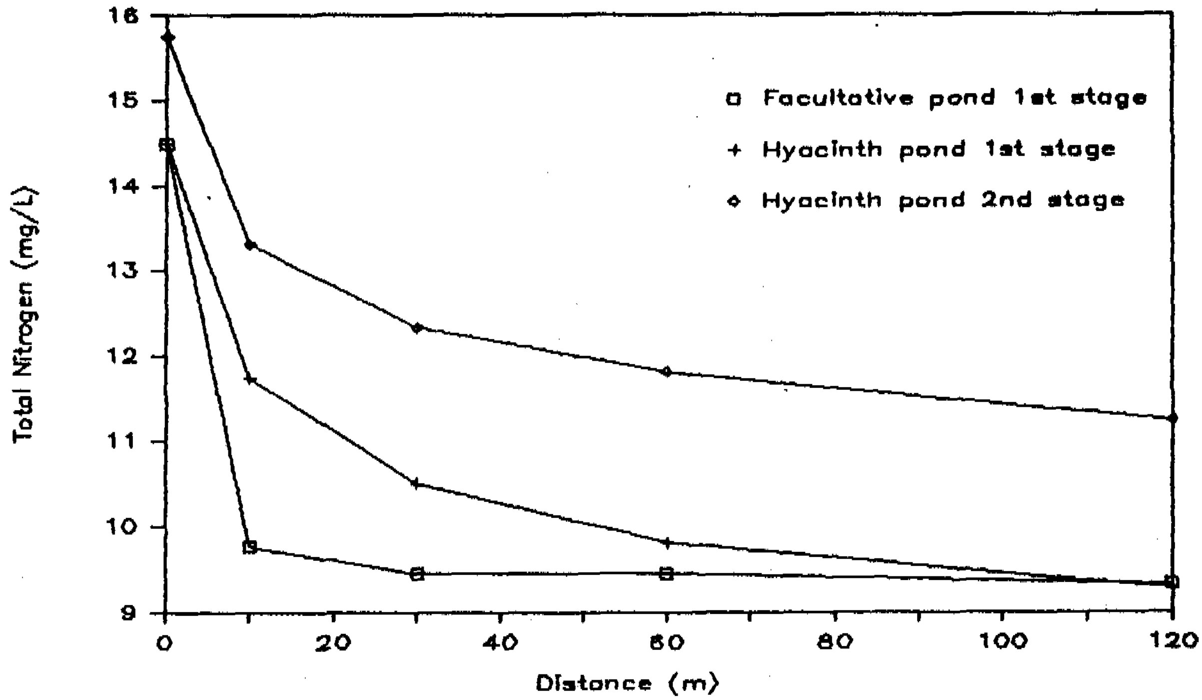


Fig. 4.17 Total Nitrogen Reduction along the Ponds

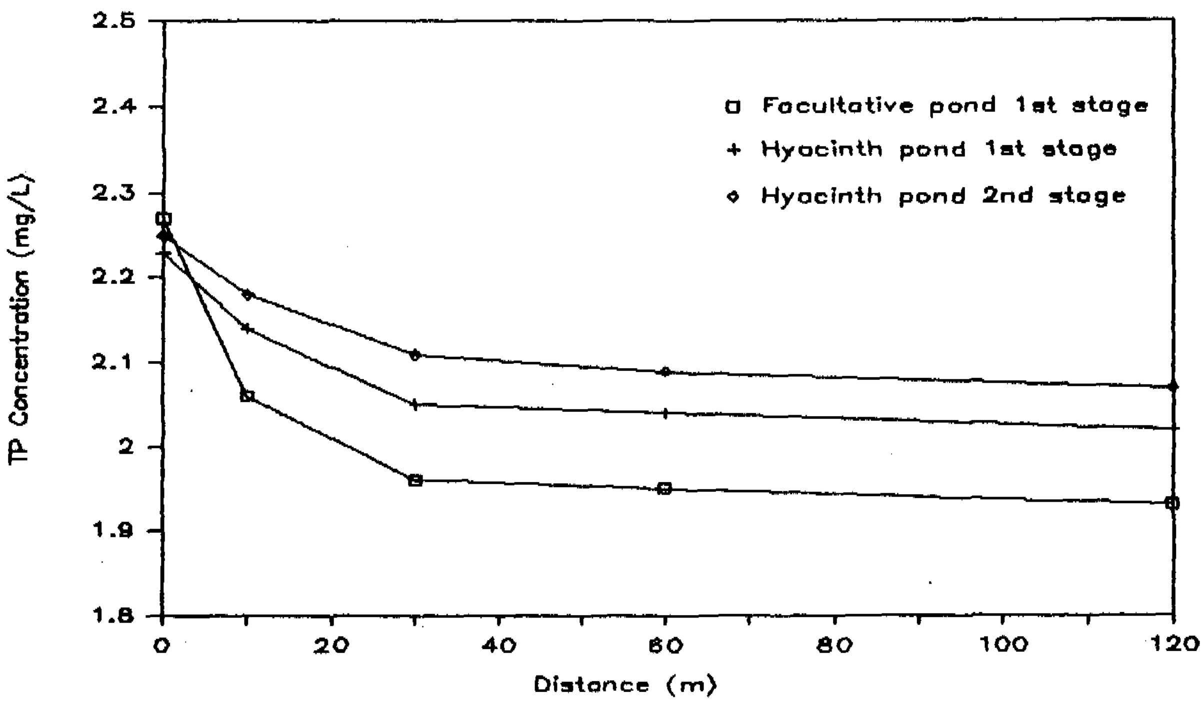


Fig. 4.18 TP Reduction along the Ponds

water hyacinth pond during second stage are given in Table 4.4 and their concentration along the pond are shown in Fig. 4.18. However, one of the reason for low TP reduction either in first or second stage may be due to low DO concentration, which make the system anaerobic in which case phosphorous is released instead of removed.

4.5 Dissolved Oxygen, pH and Temperature

The measured value of dissolved oxygen, pH and temperature at different points in facultative pond and water hyacinth pond during both stages are given in Table 4.1 and 4.2. DO concentration increased in facultative pond from influent average 2.12 mg/L to effluent average 8.52 mg/L. A maximum value of 28.60 mg/L was observed in facultative pond at 30 m distance at 1.45 PM. After calculating the average value for entire experiment period, corresponding to observation time and distance, the maximum value of 24.48 mg/L and 12.09 mg/L was observed at 3.00 PM and 30 m distance respectively. From the observed value it can be concluded that the photosynthesis rate, which is the main source of oxygen production in facultative pond is maximum at the middle of the pond and at around 3.00 PM. Fig. 4.19 shows the diurnal variation of dissolved oxygen at different points in facultative pond whereas its diurnal variation in complete pond system (calculated on average basis) is shown in Fig. 4.20. As shown in these figures the dissolved oxygen in the system were maximum all the time at 30 and 60 m and at 3.00 PM.

In water hyacinth pond, during first stage, dissolved oxygen decreased from an average value of 1.18 mg/L influent to 0.40 mg/L effluent. The average dissolved oxygen in hyacinth pond system was less than 0.6 mg/L, decreasing from influent to effluent side. The reason behind this low DO in hyacinth pond were 1) firstly, the oxygen produced by water hyacinth during photosynthesis did not contribute to the oxidation process within the pond thus increasing the anaerobic portion of pond (Thomas & Phelp, 1987), 2) secondly, because of slow growth of the plant (after becoming the plants old), black color of the roots (due to absorption of pollutants from wastewater) and persistence of hydrogen sulfide produced check the oxygen transfer capacity of the hyacinth plant (Orth et al., 1987).

During second stage, the average influent and effluent DO concentration of water hyacinth pond were 0.22 mg/L and 0.26 mg/L respectively. The maximum DO concentration of 0.45 mg/L was measured at 10 m distance. DO concentration at different points in facultative pond and water hyacinth pond for both stages are shown in Fig. 4.21.

The pH value fluctuation in both system was moderate. The influent and effluent pH value in facultative pond averaged 7.7 and 8.4 respectively, with maximum average pH value of 8.5 at middle of pond, whereas in hyacinth pond the influent and effluent pH value averaged 7.6 and 7.2 respectively. The increase in pH of 0.70 units in facultative pond was due to the depletion of carbon di-oxide during algal photosynthesis, as confirmed by sporadic measurements, whereas the decrease of 0.40 pH units in hyacinth pond was due to saturation of wastewater with carbon di-oxide produced in anaerobic condition which was obstructed to release

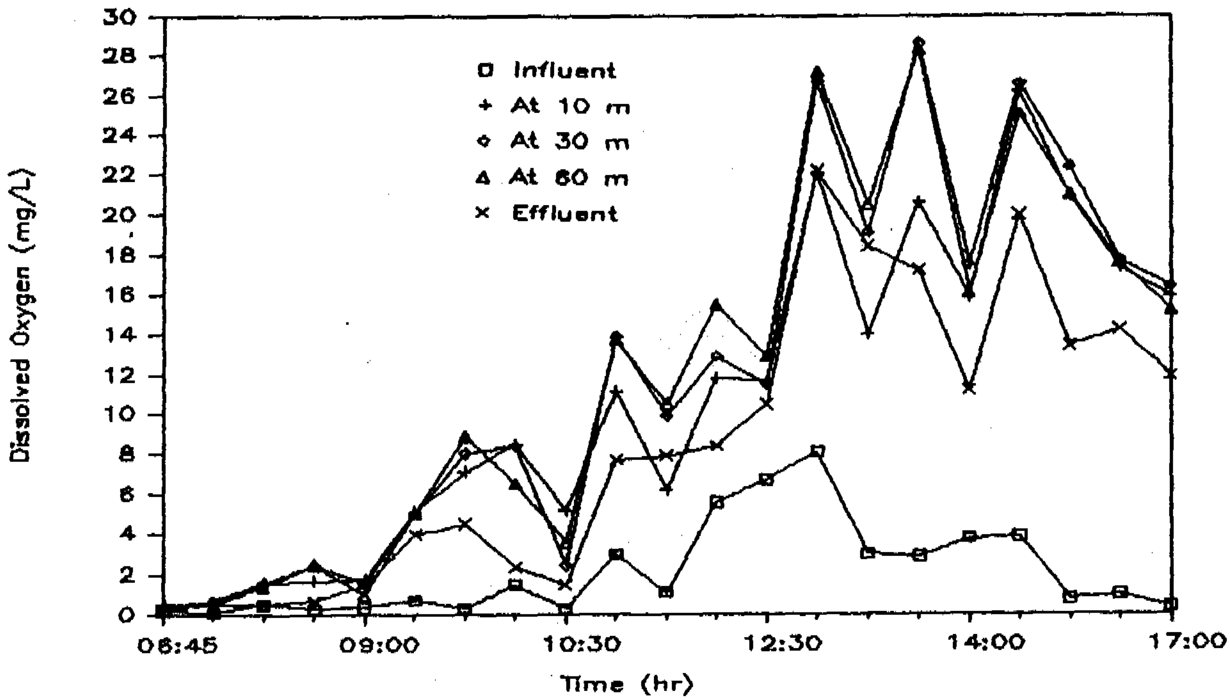


Fig. 4.19 Diurnal Variation of DO at Differnt Points in Facultative Pond

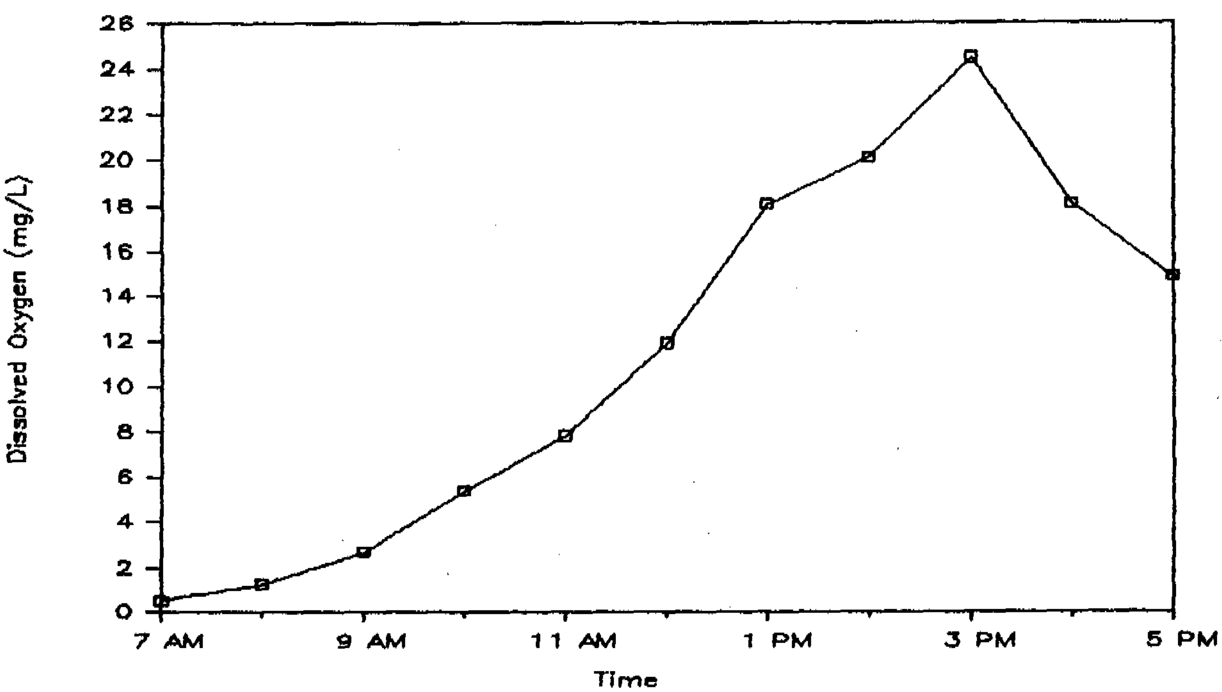


Fig. 4.20 Diurnal Variation of DO in Facultative Pond

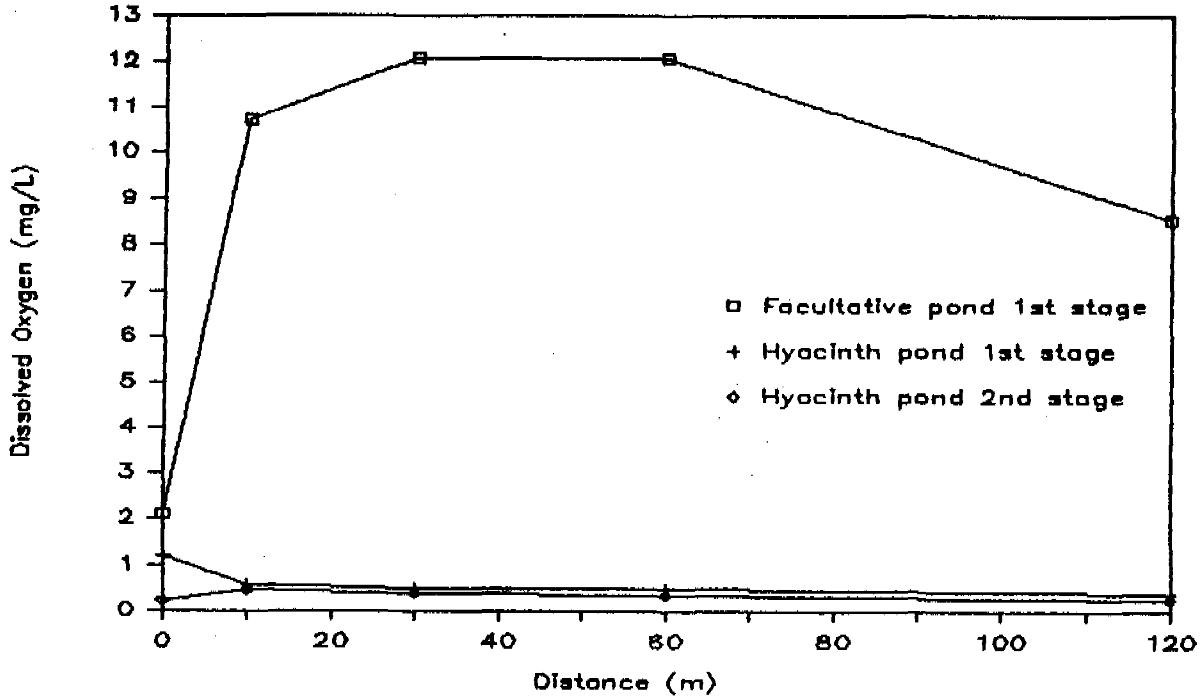


Fig. 4.21 DO Distribution in Ponds

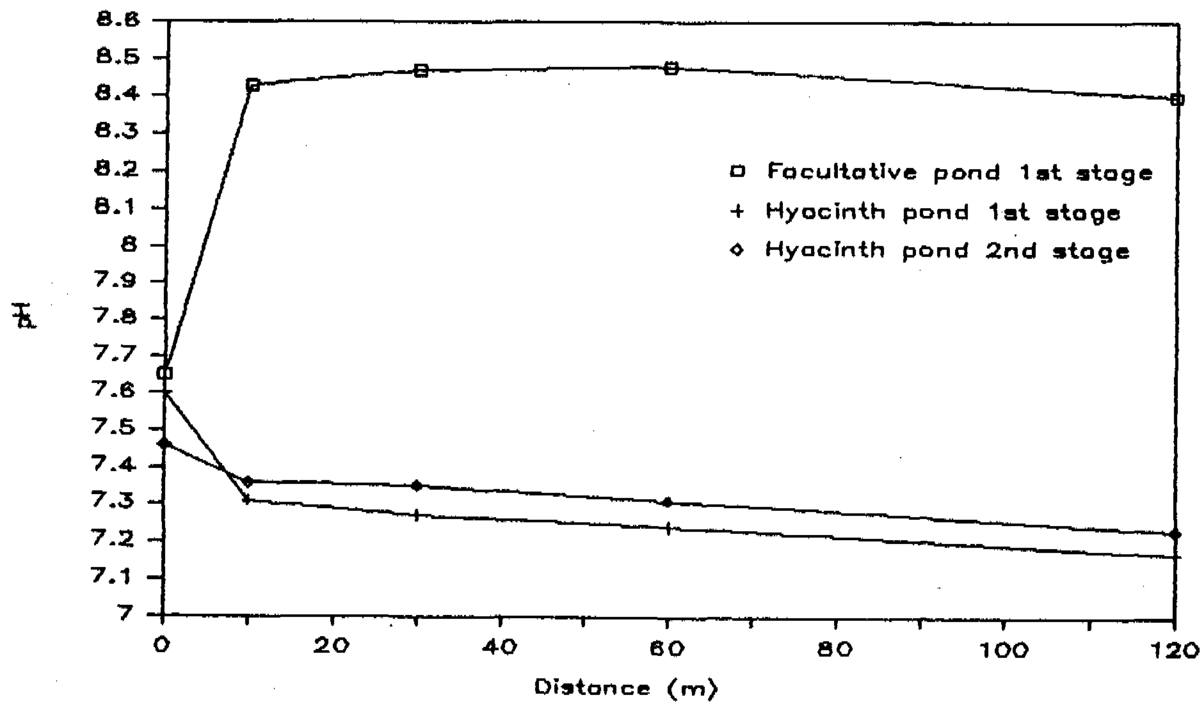


Fig. 4.22 pH Value in Ponds

by a dense mat of water hyacinth to some extent. The pH in water hyacinth system was maintained around 7.3 units with the buffering capacity of hyacinth. This buffering effect by water hyacinth was also observed in previous studies (WOLVERTON & McDONALD, 1979, and McDoNALD & WOLVERTON, 1980). During second stage, the average influent pH value decreased from 7.60 units of first stage to 7.50. The decrease of pH in second stage may be due to introduction of water hyacinth in anaerobic pond. However the pH at other points in the system were higher than first stage, and the reason for this increment is not known. The average pH value at different points in facultative and water hyacinth pond for both stages are given in Table 4.2 and 4.2, and also shown in Fig. 4.22.

The average influent temperature of facultative and hyacinth ponds were 30.70°C and 30.80°C respectively. In facultative pond temperature raised at 30 m and 60 m to the average value of 30.83°C and 30.80°C respectively and decreased slightly at effluent to an average value of 30.50°C. The average effluent temperature in water hyacinth pond was 27.30°C showing a temperature loss of 3.50°C in the pond. This effect was perhaps due to shading and evaporating cooling. All measured value were above 22°C throughout the study period showing very favourable for water hyacinth growth. A considerable decrease in temperature was observed during load increase. The average temperature at different points in facultative pond and hyacinth pond during both stages are given in Table 4.1 and 4.2, and presented graphically in Fig. 4.23.

4.6 Water Losses

By measuring the influent and effluent discharge of facultative pond and water hyacinth pond, the water loss through each system has been calculated. The water loss of 20 % and 17 % was observed in facultative pond and water hyacinth pond respectively during first stage, and 31 % in water hyacinth pond during second stage. During second stage, the facultative pond and anaerobic pond, parallel to water hyacinth section presently on operation, were dry and seepage towards these empty ponds was noticed which caused the increase in water loss. Secondly the weather, which was dry and hot during second stage compared to seldom rain in first stage, might have effected the loss due to evaporation and evapotranspiration.

Loss of water in any treatment system has considerable effect on its effluent concentration. Having the same pollutants content in effluent, the decrease in effluent flow will increase the concentration. Here in second stage, the water loss in water hyacinth pond is comparatively 14 % higher than the first stage, so the effluent concentration in second stage is expected 14 % less than first stage.

4.7 Sludge Accumulation and its Characteristics

In facultative pond, a certain amount of sludge accumulation has taken place. Anaerobic decomposition gives a non-degradable residue while the original load of silt and inorganic solids entering the pond along with raw sewage also settles at the pond bottom.

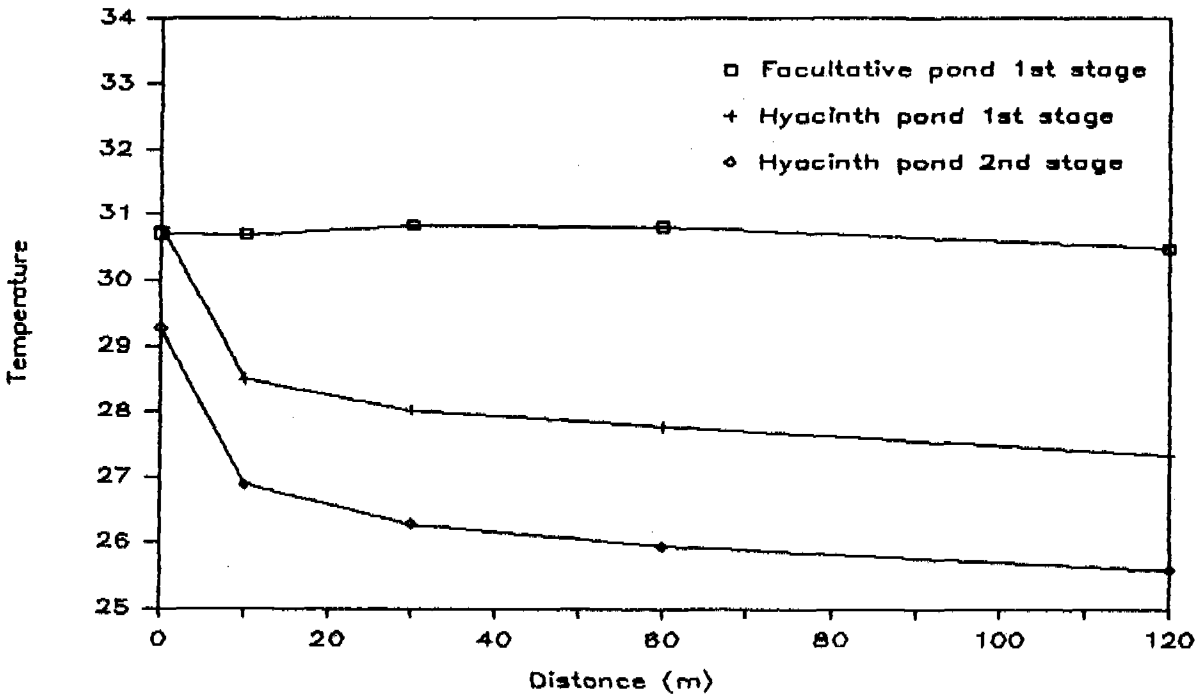


Fig. 4.23 Temperature distribution in ponds

Depth of the sludge accumulated in facultative pond was measured at different points, along and across the pond (Fig 4.24), after two weeks of pumping out the wastewater. The average depth of sludge in the system was found 22.15 cm, and during measuring time about 5.0 cm depth of sludge was reduced, which was observed by fixing the three pegs at differnt points along the pond. Hence the actual total average depth of sludge accumulated in facultative pond was 27.15 cm.

Sludge depth of 45 cm was measured near the inlet at the middle of the pond width and tapered down to about 15 cm near the outlet end. As shown in Fig. 4.24, the sludge depth was also tapered down to about 10 cm near the ends of the pond width. The total volume of the sludge accumulated during 15 years of pond operation and serving a population of about 1200 people was found to be about 4563.0 m^3 at rate of 0.069 m^3 per person per year. This value is in the middle range of 0.05 and 0.08 m^3 per person per year as reported by GLOYNA (1971) and ARCEIVALA et al. (1970) respectively.

The fixed or inorganic solids contained in the sludge was found to be about 15 percent whereas the volatile or organic fraction was about 85 percent. The moisture content and dry density of the sludge was measured about 85 % and 693 kg/m^3 respectively. After two week of drying, the average total kjeldahl nitrogen (TKN) and total phosphorous (TP) contents in the accumulated sludge was found to be about 0.45 and 0.28 % respectively. Maximum nitrogen and phosphorous content in the sludge was found to be near the inlet and its values decreased toward the outlet of the pond.

4.8 Odor Release

A certain amount of hydrogen sulfide, which is most odorous gases often occurs in the domestic stabilization ponds, but when this is excessive it may cause the malodor problem around the pond. Generally sulfide formation by bacterial reduction of sulfate contained in wastewater is limited to the anaerobic bottom layer of the pond, and is chemically or biochemically oxidized as it diffuses upward into the aerobic layers. But, if sulfide production is excessive and sufficient oxygen is not present on upper layer to oxidize the sulfide, odor problem results.

During the entire period of experiment some odor was observed in facultative and hyacinth pond. In facultative pond, odor was felt only in the early morning, when DO concentration was very low in the upper layer of the pond. In water hyacinth pond odor was recognised at the effluent weir as DO concentration was always less than 0.5 mg/L making upper layer anaerobic.

The reason behind the absence of malodor in facultative pond during day time was the absence of hydrogen sulfide in the presence of sufficient DO in the upper layers and a pH value always higher than 8 in the pond system. The sufide formed in the anaerobic layers of the pond was oxidized chemically or biochemically in the upper layers in presence of oxygen

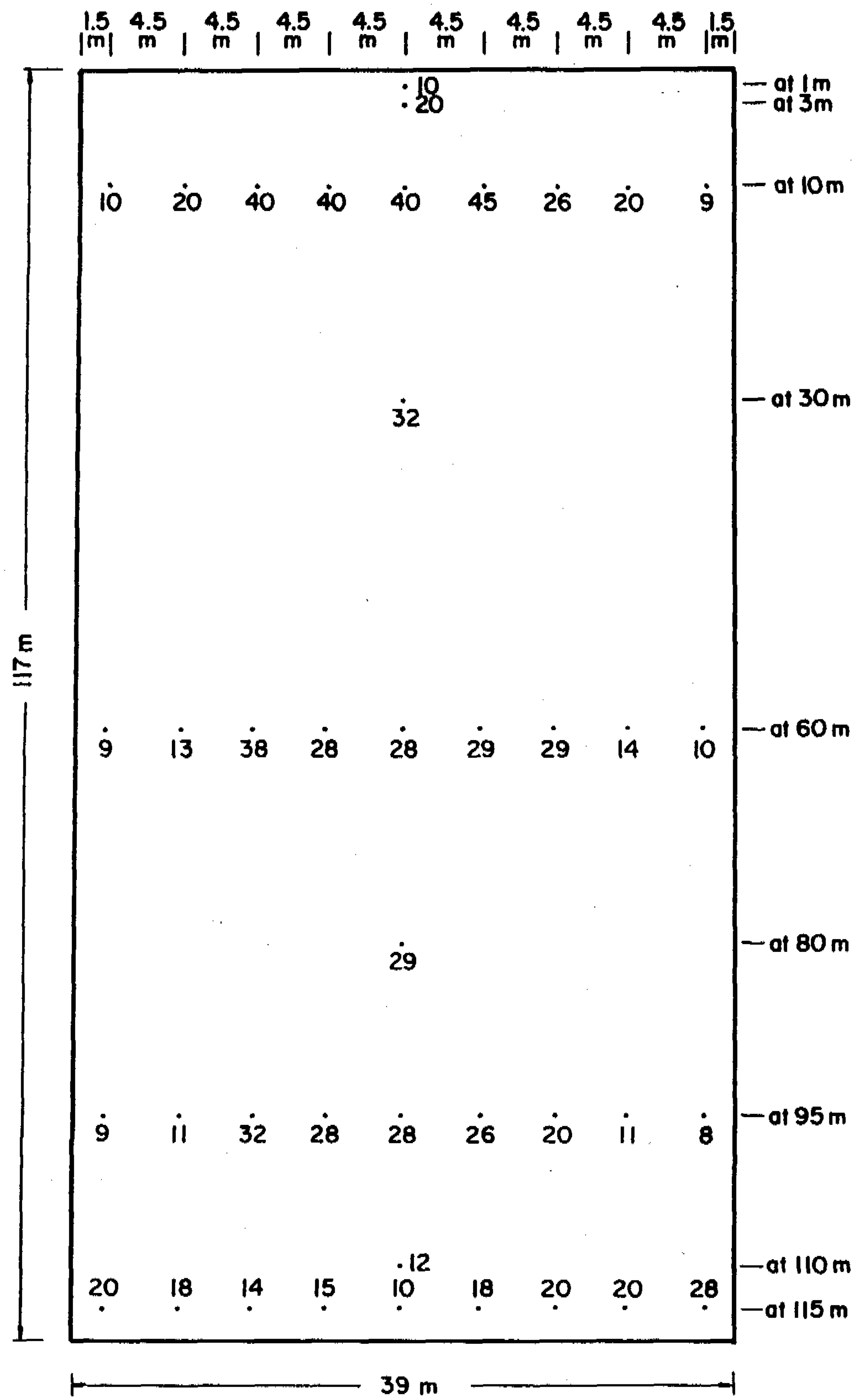


Fig.4.24 : Sludge Depth in Facultative Pond
(Average sludge depth = 22.15 cm)

which produced odorless product. Secondly at pH 8 or more, the most of sulfide existed as odorless hydrosulfide ion (HS^-) under conditions of which the release of malodorous hydrogen sulfide gas was virtually non-existent (MARA, 1976). On the other hand, both the DO and pH value were comparatively lower in the water hyacinth pond which enhance the production of hydrogen sulfide (H_2S) gas causing the malodor all the time.

The sulfide production in the pond is directly related with surface BOD loading, detention time and influent sulfate concentration (GLOYNA and ESPINO, 1968). When the load was doubled in hyacinth pond, BOD load and sulfate concentration was increased and detention time was decreased which caused the more sulfide and then hydrogen sulfide production in suitable condition resulting the strong malodor at that time.

4.9 Foaming in Water Hyacinth Pond

During the entire experiment period, a large quantity of foam was produced at effluent chamber of water hyacinth pond. Foam production was not so extensive in first stage, but during second stage it was extensive with maximum height of about 2.0 meter at early morning and minimum height of about 0.50 meter at rest of day. It has been concluded that foaming in effluent wastewater was due to presence of surplus amount of detergent in wastewater, but at the same time it was interesting to note that foam was never seen in the effluent of facultative pond where same type of wastewater was treated.

SAWYER (1958) reported that foaming in any treatment plant is directly related to the aeration of that wastewater. He also reported that although the amount of detergent removal by sedimentation is very small, when it accumulates in the small volume of settled sludge, the concentration is increased by factor of 100-400 fold. WELLS and SCHERER (1952) reported that frothing in sewage is function of suspended solid present, froth formation is high at low suspended solid concentration and vice versa. According to the statements mentioned above, the expected reasons for foaming in water hyacinth effluent may be as follows:

i) Suspended solid concentration in water hyacinth pond effluent was much lower than facultative pond.

ii) On mixing of the pond water, the accumulated detergent in sludge was released to wastewater and discharged with effluent

Detergent concentration in the influent and effluent of water hyacinth pond was measured and found that detergent content in effluent was higher than influent which may be due to release of detergent accumulated in the sediment. The average influent and effluent detergent concentration were 0.39 mg/L and 0.47 mg/L respectively.

V CONCLUSIONS

1 After two years operation of water hyacinth pond without any regular maintenance, the efficiency of the system decreased significantly in removing the nitrogen and phosphorous, but BOD5 removal was not reduced proportionally. Nutrient removal, therefore is directly related to plants growth and their harvesting rate, but BOD_5 removal is not. Organic, nitrite and nitrate nitrogen removal rate in water hyacinth system were comparatively higher, but ammonia nitrogen and phosphorous removal were lower than facultative pond. On increasing the volumetric load in water hyacinth pond, the removal efficiency decreased further for all parameters.

2 Dissolved oxygen concentration in facultative pond was much higher than water hyacinth pond. The effluent DO concentration in water hyacinth pond was always lower than 0.5 mg/L. and this value decreased further when load was increased.

3 In water hyacinth pond, foaming at effluent point and nuisance smell from system, due to evolution of hydrogen sulfide gas, was observed throughout the experiment period.

4 During first stage, the percent removal for mean TKN, NH_3-N, Org-N, NO_2-N, NO_3 TP and BOD_5 for facultative pond system were 37, 43, 26, -1867, -55, 15 and 67 % and for water hyacinth system the corresponding reduction were 36, 30, 65, 14, 40, 9, and 71 % respectively. When load increased in water hyacinth pond, the percentage removal for NO_2-N, NO_3-N, TKN, TP and BOD_5 were -29, 15, 26, 8, and 66 % respectively.

5 Comparing the present study data with last year study, which was conducted in the same pond by SAPKOTA (1987), it is concluded that the nutrient removal in water hyacinth pond decreases with time. To keep the nutrient reduction rate maximum, it is necessary to harvest the plant regularly and increase the DO concentration by aeration.

6 Water hyacinth is not effective for primary treatment of wastewater. Although new water hyacinth plant was introduced in anaerobic pond during second stage, the removal efficiency system was poor compared to water hyacinth pond.

VI RECOMMENDATIONS FOR FUTURE STUDY

1 The experiment period should be increased at least for on year to observe the effect of weather change on the treatment efficiency of the system.

2 The effect of desludging on facultaive pond should be investigated to evaluate the operation of the pond systems and their maintenance.

3 Nutrients removal by water hyacinth plants, during their growth phase, is significantly high compared to other systems (ORTH and SAPKOTA, 1987). To keep the plants in growth phase, regular harvesting is essential which is most undesirable with economical point of veiw. Hence the study should be conducted by restricting the plants only near the effluent side with regular harvesting, and the response of the system should be evaluated.

4 Harvesting frequency of the water hyacinth plant should be investigated for proper maintenance and operation of the system and also the proper utilization of the plant in removing nitrogen and phosphorous from the wastewater.

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APPENDIX - A

EXPERIMENTAL DATA DURING FIRST STAGE

LABORATORY ANALYSIS REPORT OF DIFFERENT PARAMETERS MEASURED FOR FACULTATIVE AND WATER HYACINTH POND DURING FIRST STAGE

Table A.1 BOD During First Stage

Sampling		BOD (mg/L)									
Date	Time, hr	Fi	F10	F30	F60	Fe	Hi	H10	H3	H60	He
15-Oct	11:00	46.00	24.00	15.40	16.55	10.80	47.50	25.20	23.50	20.00	13.75
17-Oct	13:00	40.00	22.40	18.50	21.00	20.50	36.75	29.00	16.50	19.50	13.50
19-Oct	15:00	42.00	24.00	16.50	17.50	15.75	40.00	27.60	16.00	17.40	12.50
22-Oct	06:45	62.50	19.80	23.40	20.00	11.10	48.50	28.00	19.80	18.50	12.90
26-Oct	08:00	45.00	16.80	22.20	13.00	10.20	42.50	19.20	13.80	12.00	10.00
30-Oct	08:30	37.50	19.80	15.60	17.50	10.00	49.40	31.20	22.80	16.50	11.40
01-Nov	10:00	30.00	21.60	18.60	14.40	11.20	43.75	39.00	17.50	19.00	14.40
03-Nov	12:00	33.50	20.70	17.60	15.20	13.80	38.60	20.40	16.80	12.50	10.60
05-Nov	14:00	31.00	21.50	16.20	14.50	14.00	38.75	36.00	21.60	18.00	11.60
08-Nov	09:00	45.00	19.70	17.50	13.00	6.80	42.80	27.60	22.80	19.50	14.50
09-Nov	10:30	30.00	17.80	14.40	13.10	10.20	37.50	27.60	23.40	19.40	13.20
11-Nov	15:45	36.00	20.00	19.50	19.50	20.00	40.75	25.20	14.40	13.20	12.60
14-Nov	17:00	32.10	19.80	11.40	15.00	12.40	35.00	27.60	21.60	17.14	13.50
18-Nov	09:45	52.00	29.50	18.50	17.14	10.60	58.00	26.40	20.40	20.57	14.10
20-Nov	10:45	37.00	22.20	13.80	15.86	12.60	42.20	24.00	23.40	20.14	12.30
23-Nov	13:45	36.00	23.40	27.00	23.14	20.50	41.40	27.60	26.00	24.42	13.50
26-Nov	15:30	40.00	24.00	25.00	22.70	20.50	37.50	27.60	24.00	19.29	11.10
30-Nov	13:30	48.80	28.80	22.50	22.20	22.10	50.40	22.20	19.00	15.00	14.40
03-Dec	07:30	49.60	18.00	14.50	14.14	10.12	33.00	23.40	21.00	14.57	11.63
06-Dec	09:30	47.50	21.50	14.00	14.57	11.10	48.70	15.60	13.00	12.00	8.10
09-Dec	12:30	42.40	20.30	16.40	14.70	12.80	45.60	18.95	15.80	14.60	11.50
Average Value		41.14	21.70	18.02	16.89	13.67	42.79	26.16	19.67	17.30	12.43
Stand. Deviation		8.10	3.12	3.93	3.22	4.33	5.89	5.28	3.71	3.21	1.60
Maximum Value		62.50	29.50	27.00	23.14	22.10	58.00	39.00	26.00	24.42	14.50
Minimum Value		30.00	16.80	11.40	13.00	6.80	33.00	15.60	13.00	12.00	8.10
Percent Removal		---	47.26	56.19	58.94	66.77	---	38.87	54.03	59.58	70.95

Table A.1 BOD During First Stage

Sampling		BOD (mg/L)									
Date	Time, hr	Fi	F10	F30	F60	Fe	Hi	H10	H3	H60	He
15-Oct	11:00	46.00	24.00	15.40	16.55	10.80	47.50	25.20	23.50	20.00	13.75
17-Oct	13:00	40.00	22.40	18.50	21.00	20.50	36.75	29.00	16.50	19.50	13.50
19-Oct	15:00	42.00	24.00	16.50	17.50	15.75	40.00	27.60	16.00	17.40	12.50
22-Oct	06:45	62.50	19.80	23.40	20.00	11.10	48.50	28.00	19.80	18.50	12.90
26-Oct	08:00	45.00	16.80	22.20	13.00	10.20	42.50	19.20	13.80	12.00	10.00
30-Oct	08:30	37.50	19.80	15.60	17.50	10.00	49.40	31.20	22.80	16.50	11.40
01-Nov	10:00	30.00	21.60	18.60	14.40	11.20	43.75	39.00	17.50	19.00	14.40
03-Nov	12:00	33.50	20.70	17.60	15.20	13.80	38.60	20.40	16.80	12.50	10.60
05-Nov	14:00	31.00	21.50	16.20	14.50	14.00	38.75	36.00	21.60	18.00	11.60
08-Nov	09:00	45.00	19.70	17.50	13.00	6.80	42.80	27.60	22.80	19.50	14.50
09-Nov	10:30	30.00	17.80	14.40	13.10	10.20	37.50	27.60	23.40	19.40	13.20
11-Nov	15:45	36.00	20.00	19.50	19.50	20.00	40.75	25.20	14.40	13.20	12.60
14-Nov	17:00	32.10	19.80	11.40	15.00	12.40	35.00	27.60	21.60	17.14	13.50
18-Nov	09:45	52.00	29.50	18.50	17.14	10.60	58.00	26.40	20.40	20.57	14.10
20-Nov	10:45	37.00	22.20	13.80	15.86	12.60	42.20	24.00	23.40	20.14	12.30
23-Nov	13:45	36.00	23.40	27.00	23.14	20.50	41.40	27.60	26.00	24.42	13.50
26-Nov	15:30	40.00	24.00	25.00	22.70	20.50	37.50	27.60	24.00	19.29	11.10
30-Nov	13:30	48.80	28.80	22.50	22.20	22.10	50.40	22.20	19.00	15.00	14.40
03-Dec	07:30	49.60	18.00	14.50	14.14	10.12	33.00	23.40	21.00	14.57	11.63
06-Dec	09:30	47.50	21.50	14.00	14.57	11.10	48.70	15.60	13.00	12.00	8.10
09-Dec	12:30	42.40	20.30	16.40	14.70	12.80	45.60	18.95	15.80	14.60	11.50
Average Value		41.14	21.70	18.02	16.89	13.67	42.79	26.16	19.67	17.30	12.43
Stand. Deviation		8.10	3.12	3.93	3.22	4.33	5.89	5.28	3.71	3.21	1.60
Maximum Value		62.50	29.50	27.00	23.14	22.10	58.00	39.00	26.00	24.42	14.50
Minimum Value		30.00	16.80	11.40	13.00	6.80	33.00	15.60	13.00	12.00	8.10
Percent Removal		---	47.26	56.19	58.94	66.77	---	38.87	54.03	59.58	70.95

Table A.2 Ammonia Nitrogen During First Stage

Sampling		NH3-N (mg/L)									
Date	Time, hr	Fi	F10	F30	F60	Fe	Hi	H10	H30	H60	He
15-Oct	11:00	11.76	5.54	5.24	5.29	5.10	9.58	8.68	7.31	6.27	5.82
17-Oct	13:00	8.57	4.00	4.23	4.40	4.51	9.63	8.06	6.78	6.61	6.16
19-Oct	15:00	10.11	4.34	4.65	4.31	5.32	9.77	7.81	6.44	6.38	5.94
22-Oct	06:45	13.97	6.75	6.80	6.55	6.61	12.35	9.35	7.00	6.10	6.47
26-Oct	08:00	10.92	7.45	6.78	7.00	6.89	11.17	8.34	6.80	6.66	6.61
30-Oct	08:30	11.73	6.64	6.52	6.58	6.22	12.94	9.41	8.60	8.06	6.52
01-Nov	10:00	9.88	5.88	6.36	6.22	6.19	10.50	8.51	8.32	7.53	7.11
03-Nov	12:00	6.74	5.32	5.32	5.38	5.38	8.29	7.39	7.42	6.97	7.06
05-Nov	14:00	9.18	4.82	4.73	4.79	5.01	10.36	8.40	7.64	7.00	6.75
08-Nov	09:00	10.22	6.72	6.52	6.61	6.55	10.67	8.65	8.32	7.90	7.36
09-Nov	10:30	11.14	6.75	7.03	6.61	6.61	11.17	9.21	7.64	7.59	7.36
11-Nov	15:45	10.08	6.16	6.02	5.52	6.10	11.12	10.53	8.85	8.32	8.01
14-Nov	17:00	9.63	5.77	6.30	5.94	6.69	10.50	9.35	9.10	8.90	8.60
18-Nov	09:45	11.48	6.33	6.05	6.16	6.19	11.06	9.66	9.41	9.16	8.46
20-Nov	10:45	10.70	5.94	5.99	6.13	6.22	11.59	10.28	9.94	9.46	8.74
23-Nov	13:45	11.49	6.06	6.20	6.28	7.21	12.02	10.73	10.63	10.52	10.03
26-Nov	15:30	9.69	5.10	4.20	5.38	4.93	9.35	9.18	9.13	9.10	8.95
30-Nov	07:30	11.31	6.78	7.11	7.06	6.72	11.54	10.64	10.30	10.14	10.30
Average Value		10.48	5.91	5.89	5.90	6.02	10.76	9.12	8.32	7.93	7.57
Stand. Deviation		1.49	0.90	0.91	0.81	0.76	1.12	0.96	1.23	1.33	1.31
Maximum Value		13.97	7.45	7.11	7.06	7.21	12.94	10.73	10.63	10.52	10.30
Minimum Value		6.74	4.00	4.20	4.31	4.51	8.29	7.39	6.44	6.10	5.82
Percent Removal		---	3.61	43.80	43.70	42.56	---	15.24	22.68	26.30	29.65

Table A.3 Organic Nitrogen During First Stage

Sampling Date	Time, hr	Org-N (mg/L) Fi	F10	F30	F60	Fe	Hi	H10	H30	H60	He
15-Oct	11:00	3.72	2.18	2.63	2.63	2.16	3.58	2.74	3.00	1.82	1.12
17-Oct	13:00	5.38	3.39	3.33	3.42	3.14	4.59	2.74	1.18	1.06	0.92
19-Oct	15:00	4.06	4.79	3.44	3.50	3.47	3.95	2.86	1.62	1.40	1.06
22-Oct	06:45	3.47	4.98	4.28	3.67	3.28	3.92	3.53	1.12	0.70	0.67
26-Oct	08:00	5.94	3.19	3.22	3.02	3.11	3.00	2.07	1.40	1.12	1.34
30-Oct	08:30	4.12	3.44	3.72	3.44	3.33	3.72	2.60	2.18	1.62	1.12
01-Nov	10:00	3.81	3.28	3.28	3.75	3.36	3.95	2.55	2.18	2.04	1.37
03-Nov	12:00	3.53	3.56	3.44	3.61	2.69	3.53	2.55	2.35	1.99	2.02
05-Nov	14:00	4.20	3.08	2.77	3.50	2.91	4.20	2.49	2.55	1.88	1.26
08-Nov	09:00	3.95	2.58	2.74	2.66	2.77	2.94	2.30	1.32	1.57	1.34
09-Nov	10:30	3.28	2.32	2.32	2.16	1.68	3.16	1.93	1.62	1.62	1.34
11-Nov	15:45	3.14	2.46	1.48	2.46	2.41	3.58	2.41	1.71	1.32	1.09
14-Nov	17:00	2.60	3.81	2.38	2.35	2.30	3.28	2.66	1.68	1.88	1.34
18-Nov	09:45	3.81	2.46	2.86	2.83	2.58	4.42	2.16	1.68	1.51	1.32
20-Nov	10:45	3.33	3.39	3.11	3.22	2.69	3.58	2.24	1.93	1.57	1.51
23-Nov	13:45	3.58	3.46	3.21	3.30	2.98	3.72	2.34	2.07	1.74	1.74
26-Nov	15:30	3.47	4.03	3.53	3.28	3.16	3.19	1.96	1.79	1.57	1.12
30-Nov	07:30	3.53	4.76	3.14	3.25	3.12	3.19	2.13	1.57	1.40	1.18
Average Value		3.83	3.40	3.05	3.11	2.84	3.64	2.46	1.83	1.55	1.27
Stand. Deviation		0.75	0.82	0.60	0.47	0.46	0.46	0.37	0.47	0.33	0.29
Maximum Value		5.94	4.98	4.28	3.75	3.47	4.59	3.53	3.00	2.04	2.02
Minimum Value		2.60	2.18	1.48	2.16	1.68	2.94	1.93	1.12	0.70	0.67
Percent Removal		---	11.23	20.37	18.80	25.85	---	32.42	49.73	57.54	65.11

Table A.4 Nitrite Nitrogen During First Stage

Sampling		NO2-N (mg/L)									
Date	Time, hr	Fi	F10	F30	F60	Fe	Hi	H10	H30	H60	He
15-Oct	11:00	0.016	0.678	0.985	0.966	1.188	0.006	0.006	0.019	0.005	0.015
17-Oct	13:00	0.013	0.494	0.675	0.323	0.681	0.019	0.009	0.011	0.007	0.038
19-Oct	15:00	0.012	0.689	1.037	0.474	0.662	0.031	0.023	0.022	0.003	0.009
22-Oct	06:45	0.010	0.051	0.051	0.118	0.099	0.014	0.009	0.007	0.006	0.007
26-Oct	08:00	0.007	0.008	0.019	0.089	0.025	0.012	0.010	0.009	0.006	0.015
30-Oct	08:30	0.007	0.046	0.053	0.089	0.074	0.017	0.010	0.005	0.003	0.006
01-Nov	10:00	0.010	0.028	0.010	0.059	0.070	0.007	0.008	0.006	0.012	0.006
03-Nov	12:00	0.011	0.024	0.025	0.052	0.070	0.008	0.006	0.006	0.006	0.005
05-Nov	14:00	0.006	0.038	0.019	0.095	0.083	0.010	0.007	0.005	0.005	0.007
08-Nov	09:00	0.009	0.010	0.009	0.022	0.025	0.019	0.009	0.009	0.007	0.016
09-Nov	10:30	0.010	0.090	0.013	0.051	0.020	0.016	0.012	0.009	0.006	0.016
11-Nov	15:45	0.007	0.027	0.045	0.070	0.060	0.013	0.012	0.003	0.005	0.013
14-Nov	17:00	0.013	0.040	0.054	0.061	0.086	0.013	0.011	0.004	0.003	0.007
18-Nov	09:45	0.006	0.055	0.139	0.046	0.170	0.010	0.009	0.004	0.003	0.007
20-Nov	10:45	0.010	0.013	0.014	0.039	0.021	0.013	0.010	0.009	0.007	0.014
23-Nov	13:45	0.006	0.016	0.077	0.033	0.076	0.010	0.009	0.013	0.011	0.017
26-Nov	15:30	0.007	0.028	0.035	0.044	0.073	0.016	0.014	0.012	0.014	0.019
30-Nov	13:30	0.006	0.007	0.014	0.025	0.073	0.019	0.012	0.009	0.015	0.019
03-Dec	07:30	0.012	0.008	0.009	0.010	0.051	0.015	0.008	0.003	0.010	0.010
06-Dec	09:30	0.012	0.014	0.017	0.015	0.020	0.013	0.007	0.004	0.008	0.008
09-Dec	12:30	0.006	0.028	0.050	0.040	0.083	0.007	0.006	0.004	0.008	0.004
Average Value		0.009	0.114	0.160	0.130	0.177	0.014	0.010	0.008	0.007	0.012
Stand. Deviation		0.003	0.210	0.309	0.216	0.289	0.005	0.004	0.005	0.003	0.007
Maximum Value		0.016	0.689	1.037	0.966	1.188	0.031	0.023	0.022	0.015	0.038
Minimum Value		0.006	0.007	0.009	0.010	0.020	0.006	0.006	0.003	0.003	0.004
Percent Removal		---	-1166.7	-1677.8	-1344.4	-1866.7	---	28.57	42.86	50.00	14.30

(Source: BHIMADIPATI, 1988)

Table A.5 Nitrate Nitrogen During First Stage

Sampling		NO3-N (mg/L)									
Date	Time, hr	Fi	F10	F30	F60	Fe	Hi	H10	H30	H60	He
15-Oct	11:00	0.120	0.120	0.150	0.144	0.120	0.150	0.060	0.084	0.057	0.066
17-Oct	13:00	0.123	0.120	0.135	0.120	0.120	0.870	0.090	0.045	0.060	0.036
19-Oct	15:00	0.090	0.150	0.180	0.135	0.180	0.234	0.324	0.189	0.081	0.105
22-Oct	06:45	0.030	0.108	0.084	0.060	0.105	0.045	0.075	0.057	0.033	0.036
26-Oct	08:00	0.030	0.033	0.054	0.030	0.045	0.027	0.030	0.045	0.045	0.045
30-Oct	08:30	0.084	0.120	0.114	0.120	0.105	0.015	0.060	0.066	0.060	0.060
01-Nov	10:00	0.120	0.120	0.132	0.120	0.123	0.105	0.105	0.135	0.126	0.108
03-Nov	12:00	0.087	0.120	0.135	0.114	0.135	0.090	0.102	0.114	0.117	0.087
05-Nov	14:00	0.030	0.090	0.066	0.033	0.060	0.060	0.033	0.024	0.027	0.033
08-Nov	09:00	0.090	0.096	0.093	0.090	0.090	0.060	0.060	0.060	0.060	0.060
09-Nov	10:30	0.060	0.033	0.093	0.048	0.117	0.054	0.060	0.075	0.054	0.060
11-Nov	15:45	0.114	0.093	0.090	0.114	0.114	0.063	0.066	0.096	0.060	0.066
14-Nov	17:00	0.066	0.090	0.063	0.075	0.066	0.060	0.075	0.063	0.093	0.063
18-Nov	09:45	0.072	0.093	0.084	0.183	0.216	0.156	0.093	0.096	0.072	0.162
20-Nov	10:45	0.054	0.036	0.090	0.048	0.120	0.048	0.063	0.072	0.051	0.057
23-Nov	13:45	0.060	0.090	0.066	0.072	0.096	0.063	0.054	0.036	0.033	0.030
26-Nov	15:30	0.096	0.117	0.096	0.117	0.144	0.087	0.072	0.087	0.075	0.102
30-Nov	13:30	0.099	0.087	0.195	0.156	0.117	0.084	0.060	0.057	0.054	0.090
03-Dec	07:30	0.060	0.072	0.039	0.066	0.210	0.036	0.039	0.147	0.063	0.060
06-Dec	09:30	0.060	0.090	0.093	0.090	0.093	0.054	0.069	0.060	0.057	0.063
09-Dec	12:30	0.063	0.114	0.087	0.090	0.126	0.054	0.075	0.057	0.051	0.060
Average Value		0.077	0.095	0.102	0.096	0.119	0.115	0.079	0.079	0.063	0.069
Stand. Deviation		0.029	0.030	0.039	0.040	0.042	0.176	0.058	0.039	0.024	0.030
Maximum Value		0.123	0.150	0.195	0.183	0.216	0.870	0.324	0.189	0.126	0.162
Minimum Value		0.030	0.033	0.039	0.030	0.045	0.015	0.030	0.024	0.027	0.030
Percent Removal			-23.38	-32.47	-24.68	-54.55	---	31.30	31.30	45.22	40.000

(Source: BHIMADIPATI, 1988)

Table A.6 TKN During First Stage

Sampling		TKN (mg/L)									
Date	Time, hr	Fi	F10	F30	F60	Fe	Hi	H10	H30	H60	He
15-Oct	11:00	15.48	7.73	7.87	7.92	7.25	13.16	11.42	10.30	8.09	6.94
17-Oct	13:00	13.94	7.92	7.56	7.81	7.64	14.22	10.81	7.95	7.67	7.08
19-Oct	15:00	14.17	9.13	8.09	7.81	8.79	13.72	10.67	8.06	7.78	7.00
22-Oct	06:45	17.44	11.73	11.09	10.22	9.88	16.27	12.88	8.12	6.80	7.14
26-Oct	08:00	16.86	10.64	10.00	10.02	10.00	14.17	10.42	8.20	7.78	7.95
30-Oct	08:30	15.85	10.08	10.25	10.02	9.55	16.66	12.01	10.78	9.69	7.64
01-Nov	10:00	13.69	9.16	9.63	9.97	9.55	14.45	11.06	10.50	9.58	8.48
03-Nov	12:00	10.47	8.88	8.76	8.99	8.06	11.82	9.94	9.77	8.96	9.07
05-Nov	14:00	13.38	7.89	7.50	8.29	7.92	14.56	10.89	10.19	8.88	8.01
08-Nov	09:00	14.17	9.30	9.27	9.27	9.32	13.61	10.95	10.25	9.46	8.70
09-Nov	10:30	14.42	9.07	9.35	8.76	8.29	14.34	11.14	9.27	9.21	8.70
11-Nov	15:45	13.22	8.62	7.50	7.98	8.51	14.70	12.94	10.56	9.63	9.10
14-Nov	17:00	12.24	9.58	8.68	8.29	8.99	13.78	12.01	10.78	10.78	9.94
18-Nov	09:45	15.29	8.79	8.90	8.99	8.76	15.48	11.82	11.09	10.67	9.77
20-Nov	10:45	14.03	9.32	9.10	9.35	8.90	15.18	12.52	11.87	11.03	10.25
23-Nov	13:45	15.06	9.52	9.41	9.58	10.19	15.74	13.07	12.69	12.26	11.76
26-Nov	15:30	13.16	9.13	7.73	8.66	8.09	12.54	12.32	10.98	10.92	10.75
30-Nov	13:30	15.74	10.64	10.53	10.53	9.18	15.18	10.30	12.21	11.59	11.65
03-Dec	07:30	14.84	11.54	10.25	10.30	9.84	14.73	12.77	11.87	11.54	11.48
06-Dec	09:30	14.28	11.06	10.78	10.64	11.06	13.86	12.18	11.76	11.20	11.06
09-Dec	12:30	14.70	11.06	10.78	10.50	9.94	13.86	12.46	11.34	10.92	10.78
Average Value		14.40	9.56	9.19	9.23	9.03	14.38	11.65	10.41	9.74	9.20
Stand. Deviation		1.49	1.14	1.15	0.95	0.94	1.13	0.94	1.38	1.49	1.59
Maximum Value		17.44	11.73	11.09	10.64	11.06	16.66	13.07	12.69	12.26	11.76
Minimum Value		10.47	7.73	7.50	7.81	7.25	11.82	9.94	7.95	6.80	6.94
Percent Removal		---	33.61	36.18	35.88	37.29	---	18.98	27.61	32.27	36.02

Table A.7 Total Phosphorous During First Stage

Sampling		TP (mg/L)									
Date	Time, hr	Fi	F10	F30	F60	Fe	Hi	H10	H30	H60	He
15-Oct	11:00	2.28	1.64	1.48	1.56	1.46	1.92	1.86	1.92	1.52	1.56
17-Oct	13:00	2.16	1.60	1.63	1.59	1.63	2.13	2.09	1.69	1.55	1.53
19-Oct	15:00	2.15	1.94	1.76	1.80	1.74	2.28	2.20	1.55	1.50	1.55
22-Oct	06:45	2.35	2.27	1.96	1.90	1.84	2.35	2.51	1.86	1.62	1.70
26-Oct	08:00	2.46	2.07	2.02	1.89	2.19	2.14	1.76	1.81	1.80	1.75
30-Oct	08:30	2.36	2.11	2.28	2.13	2.07	2.42	2.02	2.19	2.04	1.86
01-Nov	10:00	2.41	2.33	2.29	2.39	2.13	2.59	2.37	2.47	2.40	2.37
03-Nov	12:00	1.96	2.04	2.12	2.10	1.90	2.08	1.98	2.12	2.10	2.14
05-Nov	14:00	1.80	1.76	1.60	1.62	1.60	1.90	1.64	1.64	1.66	1.80
08-Nov	09:30	2.12	2.18	1.98	1.91	2.16	2.08	1.95	2.07	2.05	2.12
09-Nov	10:30	2.27	2.31	1.88	1.99	1.84	2.31	2.13	2.10	2.16	2.36
11-Nov	15:45	2.42	2.05	1.99	2.00	1.99	2.45	2.26	2.03	2.26	1.65
14-Nov	17:00	2.67	2.37	2.07	2.16	2.24	2.54	2.41	2.33	2.41	2.46
18-Nov	09:45	2.57	2.42	2.29	2.14	2.12	2.61	2.50	2.44	2.54	2.46
20-Nov	10:45	2.67	2.08	2.08	1.93	1.86	2.37	2.52	2.08	2.23	2.23
23-Nov	13:45	2.08	1.89	1.84	1.86	1.95	2.10	2.07	2.12	2.14	2.16
26-Nov	15:30	2.46	2.08	2.04	2.01	1.99	2.44	2.29	2.33	2.42	2.46
30-Nov	13:30	2.40	2.12	2.12	2.08	1.89	2.25	2.21	2.16	2.21	2.29
03-Dec	07:30	1.83	1.82	1.81	1.81	1.82	1.83	1.91	1.95	1.93	1.89
06-Dec	09:30	2.16	2.13	2.04	2.10	2.08	1.93	2.16	2.21	2.23	2.25
09-Dec	12:30	2.18	2.10	1.99	2.08	1.95	2.06	2.01	2.01	2.12	1.89
Average Value		2.27	2.06	1.96	1.95	1.93	2.23	2.14	2.05	2.04	2.02
Stand. Deviation		0.24	0.22	0.21	0.20	0.20	0.23	0.24	0.24	0.31	0.32
Maximum Value		2.67	2.42	2.29	2.39	2.24	2.61	2.52	2.47	2.54	2.46
Minimum Value		1.80	1.60	1.48	1.56	1.46	1.83	1.64	1.55	1.50	1.53
Percent Removal		--	9.25	13.66	14.10	14.98	--	4.04	8.07	8.52	9.42

Table A.8 Dissolved Oxygen During First Stage

Sampling		DO (mg/L)									
Date	Time, hr	Fi	F10	F30	F60	Fe	Hi	H10	H30	H60	He
15-Oct	11:00	1.10	6.20	9.90	10.50	7.90	0.60	0.30	0.20	0.30	0.40
17-Oct	13:00	8.10	22.10	26.70	27.20	22.20	9.80	0.40	0.30	0.30	0.50
19-Oct	15:00	3.90	26.20	26.60	25.10	20.00	8.60	1.00	0.30	0.20	0.20
22-Oct	06:45	0.20	0.40	0.40	0.50	0.30	0.20	0.70	0.80	0.70	0.30
26-Oct	08:00	0.50	1.60	1.60	1.40	0.50	0.70	0.80	0.90	0.90	0.90
30-Oct	08:30	0.30	1.70	2.50	2.50	0.70	0.20	0.50	0.50	0.50	0.30
01-Nov	10:00	1.50	8.50	8.40	6.50	2.40	0.50	1.00	0.40	0.60	0.50
03-Nov	12:00	5.60	11.80	12.90	15.50	8.40	0.40	0.60	0.60	0.80	0.50
05-Nov	14:00	3.80	15.90	17.50	16.10	11.20	0.30	0.60	0.70	0.70	0.50
08-Nov	09:00	0.40	1.80	1.60	1.00	1.50	0.30	0.60	0.60	0.50	0.40
09-Nov	10:30	0.30	5.20	2.50	3.60	1.50	0.30	0.50	0.40	0.40	0.40
11-Nov	15:45	1.00	17.30	17.70	17.60	14.20	0.30	0.40	0.50	0.40	0.40
14-Nov	17:00	0.40	15.90	16.40	15.20	11.90	0.40	0.50	0.50	0.50	0.40
18-Nov	09:45	0.30	7.10	8.00	8.90	4.50	0.40	0.70	0.80	0.60	0.60
20-Nov	10:45	3.00	11.10	13.90	13.70	7.70	0.30	0.60	0.10	0.60	0.40
23-Nov	13:45	2.90	20.60	28.60	28.30	17.20	0.30	0.90	0.40	0.40	0.40
26-Nov	15:30	0.80	20.90	22.40	21.00	13.40	0.20	0.60	0.40	0.40	0.20
30-Nov	13:30	3.00	14.00	19.10	20.50	18.40	0.20	0.30	0.50	0.30	0.30
03-Dec	07:30	0.10	0.60	0.70	0.50	0.50	0.20	0.40	0.50	0.50	0.30
06-Dec	09:30	0.70	5.10	5.00	5.00	4.00	0.20	0.40	0.40	0.50	0.30
09-Dec	12:30	6.70	11.70	11.50	12.90	10.50	0.40	0.50	0.50	0.50	0.20
Average Value		2.12	10.75	12.09	12.07	8.52	1.18	0.59	0.49	0.50	0.40
Stand. Deviation		2.29	7.67	8.97	8.85	6.91	2.61	0.20	0.19	0.17	0.15
Maximum Value		8.10	26.20	28.60	28.30	22.20	9.80	1.00	0.90	0.90	0.90
Minimum Value		0.10	0.40	0.40	0.50	0.30	0.20	0.30	0.10	0.20	0.20

Table A.9 pH Value During First Stage

Sampling Date	Time, hr	pH Fi	F10	F30	F60	Fe	Hi	H10	H30	H60	He
15-Oct	11:00	7.55	8.40	8.60	8.65	8.50	7.70	7.45	7.45	7.35	7.25
17-Oct	13:00	8.20	9.10	9.20	9.20	9.10	8.15	7.60	7.50	7.50	7.50
19-Oct	15:00	7.90	9.05	9.00	9.00	8.70	7.85	7.30	7.20	7.10	7.10
22-Oct	06:45	7.50	8.05	8.15	8.25	8.20	7.75	7.30	7.25	7.20	7.20
26-Oct	08:00	7.55	8.15	8.10	8.10	8.10	7.55	7.20	7.10	7.10	7.10
30-Oct	08:30	7.60	8.20	8.25	8.30	8.30	7.50	7.20	7.20	7.10	7.05
01-Nov	10:00	7.60	8.35	8.40	8.40	8.20	7.55	7.30	7.25	7.25	7.20
03-Nov	12:00	8.05	8.40	8.50	8.55	8.40	7.55	7.20	7.15	7.15	7.05
05-Nov	14:00	7.50	8.60	8.70	8.60	8.50	7.50	7.20	7.15	7.10	7.00
08-Nov	09:00	7.45	7.80	7.85	7.80	7.90	7.30	7.20	7.15	7.15	7.05
09-Nov	10:30	7.50	8.00	7.90	7.95	7.90	7.40	7.20	7.15	7.10	7.05
11-Nov	15:45	7.60	8.65	8.65	8.65	8.55	7.50	7.25	7.20	7.15	7.00
14-Nov	17:00	7.50	8.70	8.55	8.50	8.30	7.30	7.10	7.05	7.05	6.95
18-Nov	09:45	7.45	8.20	8.25	8.30	8.10	7.35	7.15	7.10	7.10	7.00
20-Nov	10:45	7.65	8.60	8.65	8.60	8.55	7.70	7.45	7.45	7.40	7.30
23-Nov	13:45	7.85	8.90	8.95	8.90	8.65	7.75	7.45	7.45	7.40	7.30
26-Nov	15:30	7.55	8.75	8.80	8.70	8.70	7.45	7.30	7.30	7.35	7.25
30-Nov	13:30	7.70	8.60	8.80	8.85	8.85	7.80	7.45	7.40	7.40	7.35
03-Dec	07:30	7.40	7.90	7.95	8.00	8.00	7.50	7.30	7.30	7.20	7.20
06-Dec	09:30	7.55	8.20	8.25	8.25	8.30	7.50	7.40	7.40	7.35	7.25
09-Dec	12:30	7.90	8.40	8.45	8.50	8.60	7.90	7.55	7.50	7.45	7.40
Average Value		7.65	8.43	8.47	8.48	8.40	7.60	7.31	7.27	7.24	7.17
Stand. Deviation		0.21	0.35	0.36	0.35	0.31	0.21	0.13	0.14	0.14	0.15
Maximum Value		8.20	9.10	9.20	9.20	9.10	8.15	7.60	7.50	7.50	7.50
Minimum Value		7.40	7.80	7.85	7.80	7.90	7.30	7.10	7.05	7.05	6.95

Table A.10 Temperature During First Stage

Sampling		Temperature									
Date	Time, hr	Fi	F10	F30	F60	Fe	Hi	H10	H30	H60	He
15-Oct	11:00	31.70	31.90	32.10	32.10	32.60	31.60	29.70	29.40	29.10	28.70
17-Oct	13:00	36.40	36.30	36.80	36.50	35.40	36.20	31.00	31.00	30.90	29.20
19-Oct	15:00	33.90	36.20	35.80	35.40	34.00	34.30	30.90	29.50	29.10	28.70
22-Oct	06:45	30.40	30.80	30.80	30.80	30.90	30.60	28.80	28.30	28.00	28.00
26-Oct	08:00	29.70	30.00	29.90	30.00	29.70	30.00	28.20	27.60	27.40	27.30
30-Oct	08:30	29.70	29.80	29.80	29.80	29.70	30.10	28.70	28.10	27.60	27.10
01-Nov	10:00	30.10	30.70	30.50	30.20	29.40	30.00	28.40	28.30	28.00	27.40
03-Nov	12:00	33.50	32.20	32.70	33.10	33.30	31.60	29.70	29.90	29.50	28.20
05-Nov	14:00	31.40	31.50	31.50	31.40	31.40	31.40	29.00	28.70	28.60	27.90
08-Nov	09:00	29.10	29.30	29.30	29.20	29.20	29.60	28.30	27.90	27.80	27.50
09-Nov	10:30	29.50	29.50	29.40	29.20	29.00	29.60	28.10	27.70	27.60	27.20
11-Nov	15:45	31.50	31.90	31.90	32.00	31.80	31.60	29.10	28.70	28.50	28.00
14-Nov	17:00	30.00	31.40	31.00	30.90	30.70	30.70	28.90	28.40	28.00	27.70
18-Nov	09:45	31.10	31.30	31.40	31.70	30.40	31.70	28.90	28.50	28.30	28.00
20-Nov	10:45	31.50	31.50	31.80	31.90	31.10	31.30	29.30	28.60	28.30	27.90
23-Nov	13:45	32.50	32.90	34.40	33.70	32.40	32.30	29.50	28.90	28.70	28.40
26-Nov	15:30	32.00	32.10	32.30	32.30	32.20	32.10	29.60	29.10	29.00	28.50
30-Nov	13:30	31.90	30.80	31.50	31.70	32.20	32.10	28.90	28.00	27.70	27.70
03-Dec	07:30	25.40	24.70	24.80	25.00	24.60	25.90	25.00	24.80	24.60	24.40
06-Dec	09:30	26.70	25.30	25.30	25.30	25.10	27.00	25.00	24.40	24.20	24.00
09-Dec	12:30	26.80	24.40	24.40	24.50	24.80	27.40	24.00	23.10	22.50	22.40
Average Value		30.70	30.69	30.83	30.80	30.47	30.81	28.52	28.04	27.78	27.34
Stand. Deviation		2.45	2.97	3.07	2.98	2.79	2.24	1.75	1.80	1.84	1.65
Maximum Value		36.40	36.30	36.80	36.50	35.40	36.20	31.00	31.00	30.90	29.20
Minimum Value		25.40	24.40	24.40	24.50	24.60	25.90	24.00	23.10	22.50	22.40

APPENDIX - B

EXPERIMENTAL DATA DURING SECOND STAGE

LABORATORY ANALYSIS REPORT OF DIFFERENT PARAMETERS MEASURED FOR WATER HYACINTH POND DURING SECOND STAGE

Table B.1 BOD Value During Second Stage

Sampling		BOD_5(mg/L)					
Date	Time, hr	Inflow	Hi	H10	H30	H60	He
12-Dec	10:30	72.00	50.20	23.80	16.50	10.71	9.80
14-Dec	17:00	60.00	54.70	19.80	13.00	11.29	10.40
16-Dec	15:30	71.25	55.00	24.00	17.00	13.71	10.20
18-Dec	11:30	54.38	53.90	19.80	14.50	12.86	12.00
20-Dec	08:30	24.80	45.40	29.40	16.00	15.00	11.90
23-Dec	10:30	95.63	47.80	22.20	20.00	16.71	13.20
25-Dec	12:30	82.50	48.50	27.60	24.00	18.86	18.00
27-Dec	07:30	25.00	44.10	27.00	28.00	22.70	17.70
29-Dec	10:00	67.50	42.30	25.60	17.50	18.43	13.50
31-Dec	11:00	67.50	45.20	21.00	17.50	17.57	15.60
02-Jan	11:45	121.87	47.90	27.00	21.00	17.57	17.40
04-Jan	13:00	108.75	43.00	20.40	16.00	15.86	14.80
06-Jan	14:00	88.13	55.00	29.00	22.00	20.00	17.70
08-Jan	15:00	84.38	55.00	33.00	24.50	19.29	16.20
10-Jan	16:00	91.00	51.00	34.80	27.00	21.86	17.10
13-Jan	17:00	69.38	49.50	30.00	24.00	21.86	18.00
16-Jan	10:00	76.88	48.00	22.80	20.00	18.00	17.10
19-Jan	10:30	108.75	47.90	25.20	21.00	20.57	17.70
22-Jan	09:00	101.25	48.40	24.00	24.00	23.57	15.00
25-Jan	12:30	99.38	50.80	20.40	19.40	18.30	17.57
28-Jan	13:30	78.75	52.40	27.60	22.50	19.30	17.70
31-Jan	15:00	93.75	50.20	29.40	23.40	20.15	19.50
04-Feb	08:00	35.62	55.10	36.60	30.00	27.00	22.20
07-Feb	17:00	54.38	52.80	26.40	19.00	15.00	22.80
10-Feb	10:00	120.00	48.40	28.20	25.50	21.00	20.70
13-Feb	14:00	117.50	45.75	25.20	20.50	17.00	18.75
16-Feb	12:00	92.15	55.00	32.40	29.50	25.25	24.00
19-Feb	16:00	80.63	59.40	37.13	32.40	24.50	23.73
22-Feb	09:00	120.00	45.00	30.75	25.00	22.75	16.50
25-Feb	11:00	115.00	52.50	35.00	30.75	28.80	22.50
28-Feb	13:00	102.86	60.00	38.00	30.40	27.12	23.30
Average Value		83.26	50.33	27.53	22.32	19.44	17.18
Stand. Deviation		26.26	4.49	5.21	5.11	4.45	3.94
Maximum Value		121.87	60.00	38.00	32.40	28.80	24.00
Minimum Value		24.80	42.30	19.80	13.00	10.71	9.80
Percent Removal		---	39.55	45.30	55.65	61.38	65.87

Inflow = Anaerobic pond influent

Table B.2 Nitrite Nitrogen During Second Stage

Sampling		NO_2-N (mg/L)					
Date	Time, hr	Inflow	Hi	H10	H30	H60	He
12-Dec	10:30	0.009	0.011	0.008	0.011	0.009	0.013
14-Dec	17:00	0.010	0.011	0.010	0.010	0.007	0.014
16-Dec	15:30	0.011	0.013	0.009	0.013	0.007	0.015
18-Dec	11:30	0.010	0.012	0.010	0.009	0.007	0.014
20-Dec	08:30	0.015	0.007	0.007	0.004	0.003	0.023
23-Dec	10:30	0.006	0.009	0.007	0.009	0.015	0.017
25-Dec	12:30	0.013	0.018	0.011	0.009	0.004	0.017
27-Dec	07:30	0.001	0.004	0.006	0.006	0.006	0.009
29-Dec	10:00	0.010	0.010	0.009	0.008	0.012	0.011
31-Dec	11:00	0.006	0.010	0.010	0.003	0.004	0.015
02-Jan	11:45	0.006	0.009	0.010	0.014	0.011	0.014
04-Jan	13:00	0.007	0.010	0.010	0.013	0.008	0.016
06-Jan	14:00	0.006	0.011	0.010	0.006	0.006	0.013
08-Jan	15:00	0.009	0.012	0.013	0.009	0.008	0.013
10-Jan	16:00	0.007	0.012	0.012	0.008	0.006	0.016
13-Jan	17:00	0.009	0.013	0.013	0.017	0.017	0.020
16-Jan	10:00	0.010	0.012	0.012	0.014	0.022	0.017
19-Jan	10:30	0.007	0.011	0.013	0.014	0.015	0.016
22-Jan	09:00	0.006	0.012	0.010	0.015	0.013	0.018
25-Jan	12:30	0.009	0.010	0.006	0.009	0.011	0.016
28-Jan	13:30	0.014	0.019	0.013	0.016	0.012	0.021
31-Jan	15:00	0.013	0.015	0.017	0.013	0.011	0.022
04-Feb	08:00	0.003	0.016	0.019	0.028	0.025	0.023
07-Feb	17:00	0.011	0.010	0.018	0.009	0.006	0.023
10-Feb	10:00	0.010	0.016	0.011	0.016	0.021	0.022
13-Feb	14:00	0.012	0.017	0.019	0.016	0.012	0.023
16-Feb	12:00	0.010	0.022	0.021	0.022	0.011	0.025
19-Feb	16:00	0.006	0.016	0.017	0.004	0.008	0.021
22-Feb	09:00	0.007	0.025	0.025	0.029	0.021	0.026
25-Feb	11:00	0.011	0.025	0.026	0.026	0.020	0.022
28-Feb	13:00	0.011	0.024	0.030	0.022	0.028	0.030
Average Value		0.009	0.014	0.013	0.013	0.012	0.018
Stand. Deviation		0.003	0.005	0.006	0.007	0.006	0.005
Maximum Value		0.015	0.025	0.030	0.029	0.028	0.030
Minimum Value		0.001	0.004	0.006	0.003	0.003	0.009
Percent Removal		---	-55.56	7.15	7.15	14.28	-28.60

Inflow = Anaerobic pond influent

(Source: BHIMADIPATI, 1988)

Table B.3 Nitrate Nitrogen During Second Stage

Sampling Date	Time, hr	NO_3-N (mg/L) Inflow	Hi	H10	H30	H60	He
12-Dec	10:30	0.096	0.066	0.066	0.087	0.069	0.069
14-Dec	17:00	0.039	0.090	0.057	0.051	0.042	0.039
16-Dec	15:30	0.090	0.117	0.060	0.066	0.063	0.066
18-Dec	11:30	0.072	0.093	0.051	0.045	0.045	0.054
20-Dec	08:30	0.024	0.060	0.057	0.063	0.054	0.057
23-Dec	10:30	0.090	0.057	0.027	0.036	0.021	0.012
25-Dec	12:30	0.090	0.072	0.054	0.048	0.051	0.030
27-Dec	07:30	0.027	0.042	0.051	0.054	0.042	0.057
29-Dec	10:00	0.090	0.078	0.060	0.042	0.045	0.040
31-Dec	11:00	0.060	0.030	0.030	0.033	0.033	0.033
02-Jan	11:45	0.105	0.027	0.033	0.039	0.039	0.045
04-Jan	13:00	0.105	0.051	0.054	0.063	0.057	0.054
06-Jan	14:00	0.075	0.087	0.051	0.060	0.045	0.054
08-Jan	15:00	0.120	0.054	0.054	0.051	0.045	0.048
10-Jan	16:00	0.075	0.039	0.036	0.036	0.045	0.060
13-Jan	17:00	0.066	0.033	0.036	0.048	0.036	0.036
16-Jan	10:00	0.141	0.045	0.042	0.051	0.057	0.066
19-Jan	10:30	0.096	0.060	0.057	0.060	0.066	0.060
22-Jan	09:00	0.096	0.045	0.039	0.042	0.036	0.039
25-Jan	12:30	0.093	0.051	0.042	0.036	0.057	0.039
28-Jan	13:30	0.075	0.060	0.057	0.063	0.060	0.054
31-Jan	15:00	0.105	0.051	0.048	0.057	0.054	0.054
04-Feb	08:00	0.054	0.048	0.051	0.045	0.045	0.054
07-Feb	17:00	0.057	0.048	0.045	0.057	0.057	0.051
10-Feb	10:00	0.135	0.039	0.045	0.051	0.054	0.054
13-Feb	14:00	0.105	0.066	0.060	0.054	0.057	0.057
16-Feb	12:00	0.099	0.066	0.063	0.066	0.066	0.060
19-Feb	16:00	0.091	0.066	0.057	0.054	0.051	0.054
22-Feb	09:00	0.093	0.060	0.063	0.057	0.060	0.054
25-Feb	11:00	0.096	0.063	0.045	0.057	0.048	0.042
28-Feb	13:00	0.087	0.051	0.057	0.060	0.057	0.057
Average Value		0.085	0.059	0.050	0.053	0.050	0.050
Stand. Deviation		0.027	0.019	0.010	0.011	0.011	0.012
Maximum Value		0.141	0.117	0.066	0.087	0.069	0.069
Minimum Value		0.024	0.027	0.027	0.033	0.021	0.012
Percent Removal		---	30.58	15.25	10.17	15.25	15.25

Inflow = Anaerobic pond influent

(Source: BHIMADIPATI, 1988)

Table B.4 Total Kjeldahl Nitrogen During Second Stage

Sampling		TKN (mg/L)					
Date	Time, hr	Inflow	Hi	H10	H30	H60	He
12-Dec	10:30	18.76	14.98	11.20	11.06	10.50	10.36
14-Dec	17:00	18.06	15.20	12.60	10.64	10.20	9.66
16-Dec	15:30	18.20	15.68	14.84	10.50	10.64	10.22
18-Dec	11:30	19.99	15.26	12.04	11.76	10.78	10.22
20-Dec	08:30	5.60	13.30	12.32	11.20	11.34	10.64
23-Dec	10:30	19.88	14.28	11.48	11.90	11.48	10.78
25-Dec	12:30	18.63	14.98	12.46	11.76	11.76	10.60
27-Dec	07:30	7.25	13.50	11.48	11.48	10.90	10.50
29-Dec	10:00	19.74	12.46	11.34	10.92	10.50	10.08
31-Dec	11:00	16.66	13.34	10.78	10.50	10.34	9.94
02-Jan	11:45	24.64	14.50	13.02	12.18	10.50	9.38
04-Jan	13:00	17.22	12.18	10.78	10.50	10.36	10.22
06-Jan	14:00	17.36	15.40	12.46	11.48	10.78	10.08
08-Jan	15:00	18.20	15.96	12.32	11.76	11.48	11.20
10-Jan	16:00	20.02	15.40	12.74	11.76	10.64	11.20
13-Jan	17:00	19.46	14.56	12.60	11.20	10.50	9.07
16-Jan	10:00	20.16	14.00	12.46	10.50	10.20	9.66
19-Jan	10:30	19.60	14.00	12.04	11.48	10.64	9.60
22-Jan	09:00	24.50	13.02	11.76	10.92	10.50	9.52
25-Jan	12:30	20.16	14.41	12.46	12.04	11.62	10.92
28-Jan	13:30	18.20	15.10	12.60	11.70	11.20	10.04
31-Jan	15:00	16.24	16.66	15.26	14.84	13.30	13.30
04-Feb	08:00	9.80	15.40	18.76	14.00	13.72	12.18
07-Feb	17:00	16.52	16.52	15.96	14.14	12.88	13.72
10-Feb	10:00	27.86	15.82	14.56	13.72	13.72	12.32
13-Feb	14:00	16.80	16.66	15.26	14.84	14.00	13.72
16-Feb	12:00	20.02	16.24	14.14	14.00	13.30	13.30
19-Feb	16:00	17.22	16.95	15.40	13.72	13.72	13.58
22-Feb	09:00	27.58	17.36	14.84	14.00	13.58	12.74
25-Feb	11:00	21.28	16.94	15.68	15.12	14.70	13.16
28-Feb	13:00	16.38	17.08	14.70	14.42	14.14	13.72
Average Value		18.45	15.07	13.24	12.26	11.74	11.15
Stand. Deviation		4.62	1.38	1.82	1.49	1.44	1.51
Maximum Value		27.86	17.36	18.76	15.12	14.70	13.72
Minimum Value		5.60	12.18	10.78	10.50	10.20	9.07
Percent Removal		---	18.32	12.14	18.65	22.10	26.01

Inflow = Anaerobic pond influent

Table B.5 Total Phosphorous During Second Stage

Sampling		TP (mg/L)					
Date	Time, hr	Inflow	Hi	H10	H30	H60	He
12-Dec	10:30	2.88	2.18	1.95	2.03	1.86	1.96
14-Dec	17:00	2.70	2.21	2.04	1.84	1.79	1.78
16-Dec	15:30	2.85	2.29	2.59	1.86	1.89	1.95
18-Dec	11:30	3.08	2.25	2.13	2.12	2.06	2.01
20-Dec	08:30	0.85	1.99	2.18	2.04	2.10	2.12
23-Dec	10:30	3.10	2.12	1.92	2.14	2.08	2.10
25-Dec	12:30	2.90	2.16	2.21	2.11	2.18	2.02
27-Dec	07:30	0.98	2.10	1.99	2.14	2.08	2.08
29-Dec	10:00	3.24	1.95	1.99	2.08	1.94	1.98
31-Dec	11:00	2.60	1.95	1.53	1.83	1.81	1.74
02-Jan	11:45	3.90	2.10	2.23	2.20	2.13	1.81
04-Jan	13:00	2.78	1.88	1.75	1.80	1.78	2.05
06-Jan	14:00	2.82	2.25	2.15	2.03	1.97	1.99
08-Jan	15:00	2.98	2.35	2.18	2.02	2.14	2.10
10-Jan	16:00	3.34	2.12	2.12	2.12	1.92	2.08
13-Jan	17:00	3.22	2.10	2.15	1.95	1.98	1.89
16-Jan	10:00	3.52	2.14	2.07	1.91	2.08	1.95
19-Jan	10:30	3.33	2.16	1.99	2.06	2.08	1.99
22-Jan	09:00	3.88	2.18	1.89	2.01	1.96	1.98
25-Jan	12:30	3.48	2.20	2.20	2.22	2.20	2.20
28-Jan	13:30	3.54	2.46	2.17	2.11	2.19	2.08
31-Jan	15:00	2.51	2.48	2.48	2.40	2.29	2.30
04-Feb	08:00	1.41	2.38	2.75	2.31	2.31	2.21
07-Feb	17:00	2.61	2.42	2.51	2.35	2.25	2.31
10-Feb	10:00	4.13	2.41	2.17	2.27	2.28	2.14
13-Feb	14:00	3.01	2.69	2.45	2.41	2.37	2.15
16-Feb	12:00	2.74	2.42	2.18	2.17	2.16	2.20
19-Feb	16:00	3.14	2.50	2.42	2.29	2.25	2.27
22-Feb	09:00	3.76	2.18	2.19	2.20	2.15	2.16
25-Feb	11:00	3.56	2.52	2.29	2.23	2.31	2.37
28-Feb	13:00	2.74	2.47	2.59	2.30	2.30	2.34
Average Value		2.95	2.25	2.18	2.11	2.09	2.07
Stand. Deviation		0.74	0.19	0.25	0.16	0.16	0.16
Maximum Value		4.13	2.69	2.75	2.41	2.37	2.37
Minimum Value		0.85	1.88	1.53	1.80	1.78	1.74
Percent Removal		---	23.73	3.11	6.22	7.11	8.00

Inflow = Anaerobic pond influent

Table B.6 Dissolved Oxygen During Second Stage

Sampling		DO (mg/L)					
Date	Time, hr	Inflow	Hi	H10	H30	H60	He
12-Dec	10:30	0.20	0.20	0.50	0.40	0.30	0.20
14-Dec	17:00	0.20	0.20	0.40	0.30	0.40	0.30
16-Dec	15:30	0.30	0.20	0.50	0.50	0.40	0.30
18-Dec	11:30	0.20	0.20	0.40	0.30	0.30	0.20
20-Dec	08:30	0.20	0.20	0.40	0.40	0.40	0.30
23-Dec	10:30	0.10	0.20	0.50	0.40	0.40	0.30
25-Dec	12:30	0.20	0.20	0.45	0.40	0.40	0.30
27-Dec	07:30	0.10	0.10	0.40	0.50	0.50	0.30
29-Dec	10:00	0.20	0.20	0.40	0.30	0.30	0.20
31-Dec	11:00	0.30	0.20	0.40	0.30	0.30	0.20
02-Jan	11:45	0.30	0.20	0.50	0.30	0.20	0.20
04-Jan	13:00	0.40	0.30	0.40	0.30	0.30	0.20
06-Jan	14:00	0.20	0.20	0.40	0.40	0.30	0.20
08-Jan	15:00	0.30	0.20	0.40	0.30	0.30	0.20
10-Jan	16:00	0.20	0.20	0.40	0.40	0.40	0.30
13-Jan	17:00	0.40	0.30	0.40	0.30	0.30	0.20
16-Jan	10:00	0.10	0.20	0.40	0.30	0.30	0.20
19-Jan	10:30	0.20	0.20	0.40	0.30	0.30	0.30
22-Jan	09:00	0.30	0.30	0.40	0.40	0.40	0.30
25-Jan	12:30	0.30	0.40	0.50	0.40	0.40	0.30
28-Jan	13:30	0.30	0.20	0.40	0.50	0.50	0.30
31-Jan	15:00	0.20	0.20	0.30	0.20	0.20	0.20
04-Feb	08:00	0.30	0.20	0.30	0.30	0.30	0.20
07-Feb	17:00	0.20	0.30	0.50	0.50	0.50	0.30
10-Feb	10:00	0.20	0.30	0.60	0.50	0.40	0.30
13-Feb	14:00	0.30	0.20	0.50	0.40	0.50	0.30
16-Feb	12:00	0.30	0.20	0.50	0.50	0.40	0.20
19-Feb	16:00	0.20	0.20	0.50	0.40	0.40	0.30
22-Feb	09:00	0.20	0.20	0.60	0.50	0.40	0.30
25-Feb	11:00	0.20	0.20	0.60	0.50	0.40	0.30
28-Feb	13:00	0.20	0.20	0.60	0.50	0.40	0.30
Average Value		0.24	0.22	0.45	0.39	0.36	0.26
Stand. Deviation		0.07	0.05	0.08	0.09	0.08	0.05
Maximum Value		0.40	0.40	0.60	0.50	0.50	0.30
Minimum Value		0.10	0.10	0.30	0.20	0.20	0.20

Inflow = Anaerobic pond influent

Table B.7 pH Value During Second Stage

Sampling Date	Time, hr	Inflow	Hi	H10	H30	H60	He
12-Dec	10:30	7.60	7.40	7.25	7.25	7.25	7.20
14-Dec	17:00	7.55	7.60	7.40	7.40	7.35	7.25
16-Dec	15:30	7.45	7.55	7.40	7.35	7.30	7.20
18-Dec	11:30	7.60	7.50	7.40	7.40	7.35	7.20
20-Dec	08:30	7.55	7.50	7.40	7.40	7.35	7.25
23-Dec	10:30	7.70	7.50	7.35	7.35	7.30	7.20
25-Dec	12:30	7.60	7.50	7.40	7.40	7.35	7.30
27-Dec	07:30	7.50	7.40	7.35	7.30	7.30	7.20
29-Dec	10:00	7.60	7.50	7.40	7.40	7.35	7.30
31-Dec	11:00	7.60	7.45	7.40	7.40	7.40	7.30
02-Jan	11:45	7.50	7.40	7.30	7.30	7.30	7.25
04-Jan	13:00	7.60	7.50	7.45	7.40	7.30	7.20
06-Jan	14:00	7.60	7.45	7.35	7.35	7.30	7.25
08-Jan	15:00	7.50	7.50	7.35	7.35	7.30	7.20
10-Jan	16:00	7.60	7.50	7.40	7.40	7.40	7.30
13-Jan	17:00	7.60	7.50	7.40	7.40	7.35	7.30
16-Jan	10:00	7.70	7.55	7.45	7.40	7.40	7.30
19-Jan	10:30	7.60	7.50	7.35	7.35	7.30	7.20
22-Jan	09:00	7.70	7.55	7.40	7.40	7.35	7.25
25-Jan	12:30	7.55	7.45	7.35	7.30	7.30	7.20
28-Jan	13:30	7.40	7.50	7.45	7.40	7.40	7.30
31-Jan	15:00	7.60	7.50	7.40	7.40	7.30	7.20
04-Feb	08:00	7.45	7.50	7.40	7.40	7.30	7.25
07-Feb	17:00	7.60	7.40	7.30	7.30	7.30	7.20
10-Feb	10:00	7.60	7.40	7.35	7.35	7.30	7.25
13-Feb	14:00	7.55	7.40	7.30	7.30	7.25	7.20
16-Feb	12:00	7.60	7.35	7.30	7.30	7.30	7.20
19-Feb	16:00	7.50	7.40	7.30	7.30	7.20	7.10
22-Feb	09:00	7.50	7.40	7.30	7.20	7.20	7.15
25-Feb	11:00	7.50	7.40	7.35	7.35	7.30	7.20
28-Feb	13:00	7.50	7.30	7.25	7.25	7.20	7.10
Average Value		7.56	7.46	7.36	7.35	7.31	7.23
Stand. Deviation		0.07	0.07	0.05	0.06	0.05	0.05
Maximum Value		7.70	7.60	7.45	7.40	7.40	7.30
Minimum Value		7.40	7.30	7.25	7.20	7.20	7.10

Inflow = Anaerobic pond influent

Table B.8 Temperature During Second Stage

Sampling		Temperature °C					
Date	Time, hr	Inflow	Hi	H10	H30	H60	He
12-Dec	10:30	29.20	28.30	25.30	24.60	24.20	23.70
14-Dec	17:00	29.10	30.10	26.80	25.90	25.50	24.80
16-Dec	15:30	29.40	30.10	26.50	25.70	25.20	24.80
18-Dec	11:30	28.50	28.00	25.30	24.60	24.10	23.80
20-Dec	08:30	27.50	25.40	23.80	23.20	23.00	22.80
23-Dec	10:30	28.00	26.80	24.10	23.10	22.80	22.60
25-Dec	12:30	28.20	27.90	24.60	23.80	23.10	22.80
27-Dec	07:30	28.50	26.40	24.50	24.00	23.80	23.30
29-Dec	10:00	29.30	28.30	25.70	25.30	25.10	24.60
31-Dec	11:00	29.30	28.90	26.30	25.70	25.40	25.00
02-Jan	11:45	29.10	29.70	26.40	25.30	24.80	24.60
04-Jan	13:00	29.20	29.70	26.10	25.20	24.70	24.40
06-Jan	14:00	29.80	30.20	26.70	25.80	25.40	24.90
08-Jan	15:00	29.50	30.30	27.20	26.20	25.80	25.20
10-Jan	16:00	29.40	30.20	27.10	26.20	25.80	25.30
13-Jan	17:00	29.60	30.00	27.30	26.70	26.10	25.60
16-Jan	10:00	29.50	29.00	26.80	26.20	25.80	25.70
19-Jan	10:30	29.50	29.00	26.80	26.40	25.90	25.70
22-Jan	09:00	29.10	28.30	26.10	25.70	25.40	25.20
25-Jan	12:30	30.00	30.10	27.60	27.00	26.80	26.40
28-Jan	13:30	30.40	31.00	28.60	28.20	28.00	27.60
31-Jan	15:00	30.60	30.90	28.80	28.60	28.20	27.80
04-Feb	08:00	29.40	29.10	27.90	27.60	27.50	27.20
07-Feb	17:00	30.50	30.40	28.70	28.40	28.10	27.60
10-Feb	10:00	30.30	29.50	28.30	28.00	27.70	27.50
13-Feb	14:00	30.70	30.40	29.00	28.30	28.10	27.80
16-Feb	12:00	30.40	30.20	28.60	28.20	27.90	27.80
19-Feb	16:00	30.20	29.90	28.20	27.70	27.50	27.20
22-Feb	09:00	29.90	28.80	27.20	26.70	26.50	26.20
25-Feb	11:00	30.70	30.00	28.20	27.90	27.60	27.40
28-Feb	13:00	31.00	30.40	29.00	28.50	28.30	27.90
Average Value		29.54	29.27	26.89	26.28	25.94	25.59
Stand. Deviation		0.83	1.31	1.46	1.58	1.63	1.64
Maximum Value		31.00	31.00	29.00	28.60	28.30	27.90
Minimum Value		27.50	25.40	23.80	23.10	22.80	22.60

Inflow = Anaerobic pond influent

APPENDIX C

FLOW RATE OF THE PONDS DURING FIRST AND SECOND STAGE

Table C.1 Flow rate (m^3/d) for facultative and water hyacinth pond during first stage

Date	Fi	Hi	Fe	He
1.11.87	464.94	--	--	--
2.11.87	505.72	522.38	411.98	--
3.11.87	543.12	482.31	420.31	460.47
4.11.87	504.82	435.11	395.23	387.49
5.11.87	488.16	439.81	376.02	363.87
6.11.87	445.54	498.47	352.82	411.04
7.11.87	451.22	496.62	407.85	435.03
8.11.87	527.79	450.75	400.84	382.11
9.11.87	513.34	440.75	392.39	362.44
10.11.87	527.06	425.73	417.41	346.19
11.11.87	503.28	447.30	407.25	385.93
12.11.87	495.59	453.35	396.22	374.32
13.11.87	494.90	460.31	380.25	385.26
14.11.87	476.36	450.23	370.63	380.37
15.11.87	484.00	446.11	369.61	361.79
16.11.87	496.95	462.58	410.76	375.32
17.11.87	475.55	481.23	395.35	390.49
18.11.87	456.84	459.68	376.27	383.41
19.11.87	473.27	451.63	358.91	373.96
20.11.87	485.05	444.86	368.16	364.93
21.11.87	474.44	466.32	359.74	379.58
22.11.87	423.80	524.15	350.30	424.20
23.11.87	443.57	491.15	364.07	406.14
24.11.87	443.78	477.45	350.04	390.50
25.11.87	--	446.03	416.60	--
26.11.87	--	480.52	385.24	--
27.11.87	--	475.14	381.92	--
Average Value	483.30	465.77	385.24	387.49

Table C.2 Flow rate (m^3/d) in Water Hyacinth Pond during second stage

Date	Hi	He	Date	Hi	He
11.12.87	868.41	676.87	19.1.88	886.36	635.44
12.12.87	861.93	646.93	20.1.88	872.44	618.95
13.12.87	765.96	611.21	21.1.88	--	598.68
14.12.87	888.66	636.81	22.1.88	840.86	601.43
15.12.87	873.38	623.79	23.1.88	532.36	429.55
16.12.87	883.39	685.01	24.1.88	885.74	581.12
17.12.87	896.98	641.39	25.1.88	--	597.75
18.12.87	874.29	580.67	26.1.88	--	591.86
19.12.87	858.44	562.27	27.1.88	--	581.17
20.12.87	802.34	509.65	28.1.88	--	576.44
21.12.87	843.64	523.07	29.1.88	--	589.87
22.12.87	885.78	554.45	30.1.88	--	614.65
23.12.87	868.96	590.70	31.1.88	--	578.84
24.12.87	867.56	554.45	1.2.88	--	596.46
25.12.87	856.09	544.30	2.2.88	844.86	618.26
26.12.87	831.97	533.46	3.2.88	836.56	604.24
27.12.87	781.64	509.41	4.2.88	924.12	624.67
28.12.87	818.97	501.88	5.2.88	838.23	611.55
29.12.87	822.11	505.56	6.2.88	829.64	586.86
30.12.87	790.63	530.73	7.2.88	799.44	576.40
31.12.87	775.26	518.03	8.2.88	801.88	581.22
1.1.88	721.27	499.11	9.2.88	865.95	597.54
2.1.88	786.56	499.90	10.2.88	912.82	612.25
3.1.88	828.52	511.29	11.2.88	825.22	609.77
4.1.88	861.51	540.53	12.2.88	798.15	587.41
5.1.88	801.92	543.35	13.2.88	822.35	574.22
6.1.88	896.82	622.31	14.2.88	--	579.55
7.1.88	872.33	629.25	15.2.88	--	546.34
8.1.88	861.72	603.88	16.2.88	--	538.87
9.1.88	850.50	564.38	17.2.88	915.12	598.80
10.1.88	875.39	552.42	18.2.88	862.21	608.45
11.1.88	919.76	667.03	19.2.88	845.74	601.65
12.1.88	907.01	687.07	20.2.88	854.10	581.56
13.1.88	938.50	669.99	21.2.88	868.77	564.72
14.1.88	927.60	627.83	22.2.88	806.93	547.66
15.1.88	214.66	344.22	23.2.88	856.19	573.16
16.1.88	950.45	425.60	24.2.88	827.17	--
17.1.88	890.30	639.48	25.2.88	848.18	--
18.1.88	915.25	621.69	26.2.88	858.15	--
	839.40	571.54		839.24	586.59

Average Influent Flow = 839.32 (m^3/d)
Average Effluent Flow = 579.07 (m^3/d)