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Assessment of Nitrification & Denitrification Efficiency and Phosphorus Removal Efficiency in Activated Sludge Process

S. Seah*
* Diploma in Environmental & Water Technology,
Ngee Ann Polytechnic,
Singapore
shawnseah93@gmail.com

Y.S. Cao#, Y.L.Wah# and B.H. Kwok#
Water Reclamation Plant Department,
PUB,
Singapore.

***Abstract*—Studies were undertaken to examine the efficiency of nitrification, denitrification and phosphorus removal in the biological treatment at Changi Water Reclamation Plant (CWRP). Samples were collected and tested over a period of three months. NH_3-N is greatly reduced in the aerobic zone (54-89%), considerable denitrification (~64-92%) is observed across the anoxic zones. The overall P removal is ~58% with P release in the anoxic zone (10-22%), P uptake in the aerobic zone (33-47%).**

Keywords—*Nitrification;denitrification; phosphorus removal; activated sludge; used water, NEWater , Re-used water*

I. INTRODUCTION

CWRP is the largest water reclamation plant in Singapore. It is designed for 800,000m^3 /day and it uses Step Feed Anoxic/Aerobic Activated Sludge process for N & BOD removal. Also, 75% of the treated effluent flow is for NEWater production. Nitrification is a 2-step biological process during which ammonia (NH_3-N) is oxidized to nitrite (NO_2-N), which then is oxidized to nitrate (NO_3-N). Water quality concerns dictate the need for nitrification in wastewater treatment: 1) effect of ammonia on dissolved oxygen (DO) and toxicity to fish 2) need to control eutrophication 3) nitrogen control for water-reuse applications [1]. In CWRP, water reclamation to produce NEWater from used water is the main objective. Discharge to sea is also practised. Denitrification is biological reduction of nitrate to nitrogen gas as shown: $NO_3^- \rightarrow NO_2^- \rightarrow NO \rightarrow N_2O \rightarrow N_2$. It is an integral part of biological nitrogen removal. Biological nitrogen removal involves both nitrification and denitrification. Biological phosphorus (P) removal is essential in prevention of eutrophication. In this process, P from the influent wastewater is incorporated into cell biomass by a combination of anaerobic and aerobic conditions. Thus P can be removed by the process of sludge wasting [1]. The objectives of this project at CWRP were: 1) To assess the efficiency of nitrification and denitrification processes, 2) To determine the efficiency of biological phosphorus removal.

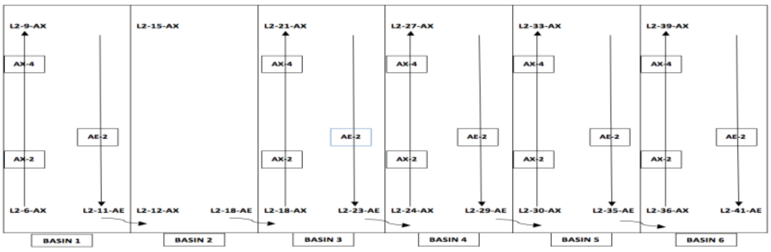
II. MATERIAL AND METHODS

pH, Dissolved Oxygen (DO), Phosphate (PO_4^{3-}), Nitrate(NO_3^--N), Nitrite (NO_2^--N), Ammonia Nitrogen (NH_3-N), Alkalinity were tested. Water quality parameters were tested in accordance with APHA and USEPA-approved methods.

The Bioreactor: Figure 1 is a schematic representation of the 6 basins that make up the Anoxic/Aerobic step feed Bioreactor at CWRP. Each basin has an anoxic zone followed by an aerobic zone. Primary Effluent is fed to the anoxic zone of all the basins in the operation and Return Activated Sludge (RAS) is fed into Basin 1. The aerated effluent from basin 1 gravitates into basin 3 while Basin 2 is kept on standby. Data presented here represent samples taken from basins 3 to 6. There is no appropriate sampling point for feed to anoxic zone and the flow weighted calculated values of upstream samples were used for the study.

Sampling: Sampling was done on a daily basis over a period of 3 months. Samples were filtered on-site before transfer to the CWRP laboratory for immediate analysis. Two samples were taken from the anoxic and aerobic zones of each basin. The sampling points are indicated in Figure 1.

***Figure 1*: Schematic view of the Activated Sludge Process at CWRP**



III. RESULTS AND DISCUSSIONS

Figure 2 shows the trend in variation of NO_2^--N, NO_3^--N and NH_3-N. In general, there was little change in the NH_3-N concentration in the Anoxic zone. The slight reduction can be accounted for by DO carried over from the preceding aerobic zone. Considerable denitrification (~70-80%) is observed across the anoxic zones of basins 3 & 4. NO_2^--N and NO_3^--N concentration remains steady – further reduction is recorded in Basin 6.

NH_3-N is reduced greatly in the Aerobic zone and percentage reduction in Basins 3-6 were seen to be 89%, 88%, 73% and 54% respectively. It looks that the higher biomass in the preceding basin causes an increase in the nitrification rate. A corresponding increase in the NO_2^--N and NO_3^--N is observed. It was noted that the NO_2^--N levels are higher than NO_3^--N levels indicating limiting conditions for conversion of NO_2^- to NO_3^-. Figure 3 shows the changes of pH and Alkalinity. pH is observed to rise marginally due to release of OH^- ions in the Anoxic Zone (ranging between 6.4-6.5) and drop due to release of H^+ ions in the Aerobic Zone. The overall pH of the entire bioreactor ranges from 6.2-6.5. Alkalinity is observed to be stable in the anoxic zone and decrease in the aerobic zone. Figure 4 shows the variation in soluble P concentration - P is released in the anoxic zone (10-22%) and P uptake in the aerobic zone (33-47%) showing there is some biological P removal in the Bioreactors: The overall P removal is ~58%.

Figure 5 shows the variation in DO across the 5 basins in operation. In the Anoxic zone, a stable DO level of 0.1 mg/l is recorded throughout the entire bioreactor. In the Aerobic zone, the trend is stable across the basins ranging from 1.4-2.2 mg/l. DO level is a very important factor as it determines the rate of denitrification and nitrification as well as biological phosphorus removal.

Figure 2: Changes in N species

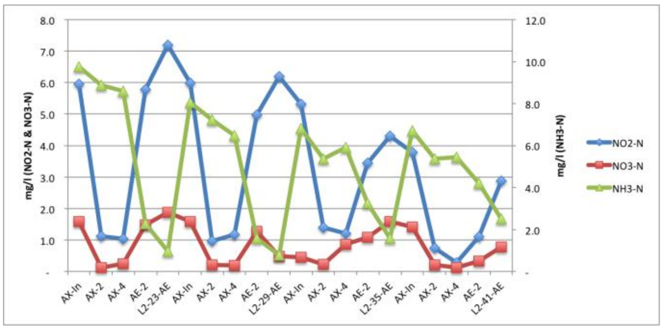


Figure 3: Variation in pH and Alkalinity

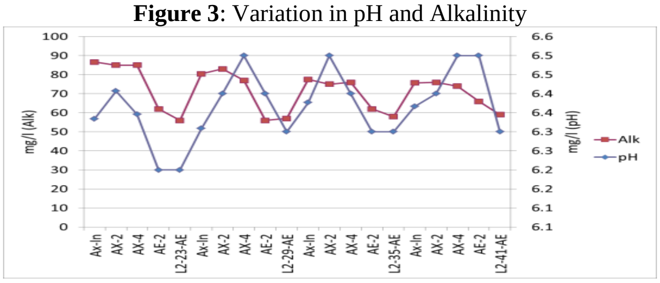


Figure 4: Changes in soluble P concentration

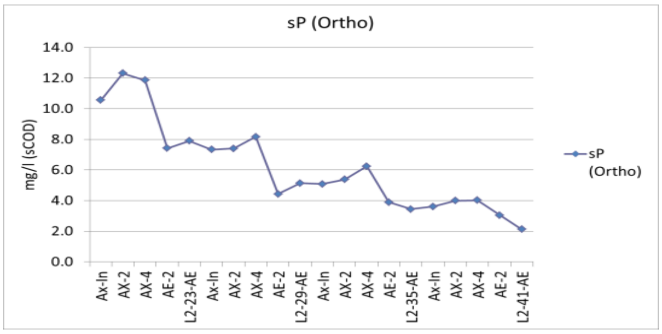
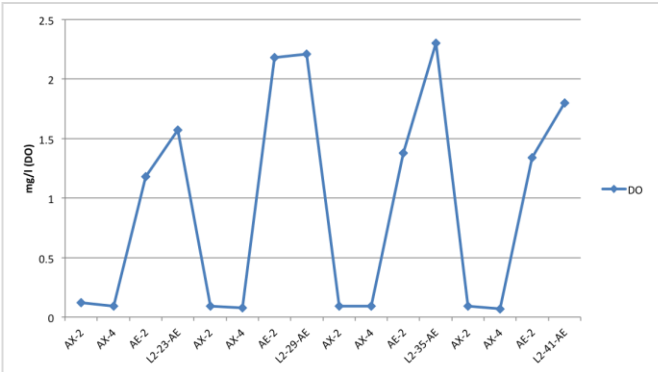


Figure 5 : Variation in DO



IV.CONCLUSION AND RECOMMENDATIONS

From the data collected, it can be concluded that: Nitrification & Denitrification are equally efficient at CWRP- effective denitrification occurs in the anoxic zone – in particular the front basins account for 80% of the denitrification. Nitrification process is efficient with 54-89% NH_3-N reduction in the aerobic zones. There is some biological P removal occurring with an overall removal of 58%. These findings have set the baseline information for future works to determine the ammonia oxidizing bacteria (AOB) and nitrite oxidizing bacteria (NOB).

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