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ALGAE AND PHOSPHOROUS REMOVAL FROM EUTROPHIC WATER BY USING DOLOMITE POWDER

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KeyWords

Eutrophication, Dolomite, Total Phosphorous, Total Nitrogen, Coagulation, Flocculation, Wastewater Treatment .

ABSTRACT

The algae growth and nutrition values like total phosphorous and total nitrogen have been increasing by disposing sewage waste in the ponds of Kathmandu valley. Due to which water become eutrophic and microbiologically unsafe for agricultural and aquacultural reuse; It's necessary to find out the low cost and environmentally friendly substances for the removal of algae and phosphorous from eutrophic pond to recover oxygen depletion and ecological damage. The principle of flocculation has been considered as the removal of algae and phosphorous with effect on nitrogen, turbidity and pH.

This study investigates the calcium-magnesium containing burned dolomite powder as a inorganic coagulant has been used to remove the algae and phosphorous simultaneously. For the removal of algae and phosphorous, the dolomite powder was calcined at 1000°C for 2Hr and from 2.5g/l to 15g/l was used in this experiment as Jar test. The water samples with algae was collected from Nagdaha and Godawari Kund. A series of experimental investigations such as pH and turbidity after Jar test was done using pH meter and turbidity meter showed that algae was removed sufficiently. In addition, TP and TN analyses at different amount of doses were done by UV/Vis Spectrophotometer (UVmini-1240).

In the present analysis shows an effective removal of turbidity caused by algae at optimum dose of 2.5g/l at turbidity range of 5-12NTU and 7.5g/l at range of 20-30NTU. At optimum dose pH was raised upto 11 due to release of OH^- ions in the solution. Experiment also showed that the phosphorous was almost removed at 7.5g/l dose, but in case of nitrogen no obvious effect was observed.

From the present work it can be concluded that burned dolomite as a low cost coagulant is found efficient in flocculation of algae and phosphorous from wastewater.

1. Introduction

Nutrients, which are flowing to water bodies from different sources can cause eutrophication. Eutrophication is a photosynthetic enrichment of water bodies by algae and cyanobacteria that progresses from oligotrophic, mesotrophic, to eutrophic states.

Main outcome of eutrophication includes algae growth and high nutrient condition. These consequences of eutrophication have negative effects on fish life and economic use of fresh water resources for aquacultural activities, industrial activities, recreation, agriculture and drinking purposes. Algae growth in surface water bodies causes oxygen depletion, which leads to fish deaths and affects other water biota. The major problem of algae growth in freshwater resources is cyanobacteria, which may cause bad odors and unpalatability in drinking water. It also causes formation of trihalomethane during chlorination process on treatment plants (Carpenter et al., 1998). Trophic characteristics of fresh water resources are provided in Table 1.1.

Table 1.1 Average characteristics of streams, lake, and coastal marine waters of various trophic states (V.H. Smith et al., 1999)

	Trophic state	TN (mg m-3)	TP (mg m-3)	chl a (mg m-3)	SD (m)
Lakes	Oligotrophic	<350	<10	<3.5	>4
	Mesotrophic	350-650	10-30	3.5-9	2-4
	Eutrophic	650-1200	30-100	9-25	1-2
	Hypertrophic	>1200	>100	>25	<1
Streams				Suspended chl a (mg m-3)	Benthic chl a (mg m-3)
	Oligotrophic	<700	<25	<10	<20
	Mesotrophic	700-1500	25-75	10-30	20-70
	Eutrophic	>1500	>25	>30	>70
Marine				chl a (mg m-3)	SD (m)
	Oligotrophic	<260	<10	<1	>6
	Mesotrophic	260-350	10-30	1-3	3-6
	Eutrophic	350-400	30-40	3-5	1.5-3
	Hypertrophic	>400	>40	>5	<1.5

Nutrients (phosphorus and nitrogen) are transported to lakes and rivers as either a diffuse source inflow (Figure 1.1) or a point source inflow. Point source pollution includes sewage discharges from municipalities and industrial wastewater loads, while diffuse pollution generally comes from roads, agricultural fields and other land uses (Carpenter et al., 1998)

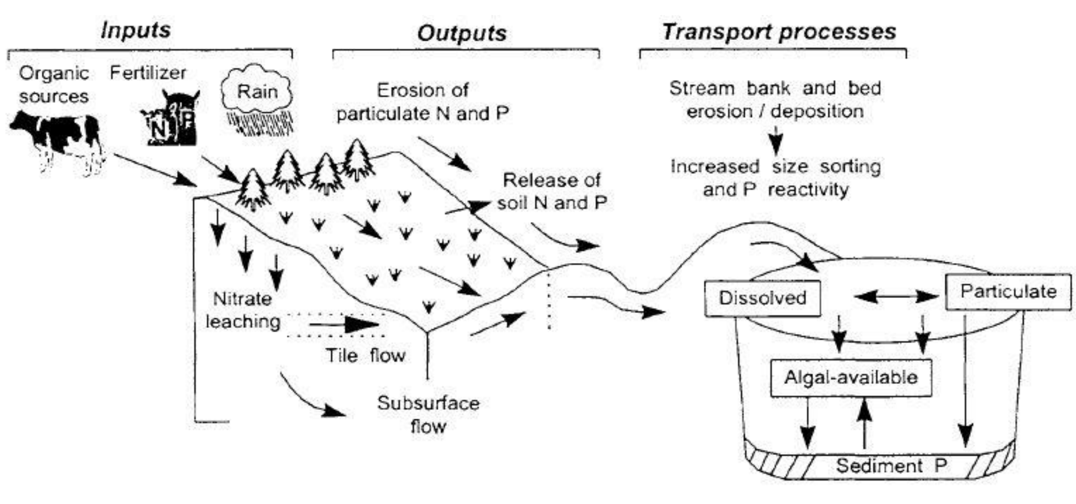

Figure 1.1 Input, output and process of transport of N and P from agricultural land

Types of algae and concentration in the eutrophic water depend on the residence time, climate and weather, amount of pollutants entering the pond and dimension of the pond. The main problem of the algae in treatment system happens when high concentration of the algae enter the plant, the particulate load on flocculation and clarification system will block the filter and allows the pass of harmful toxin produced by cyanobacteria into the system. Merits and flaws of the different algae removal process are shown in (Table 1.2).

Table 1.2 Algae removal method:- merits and flaws (B. Ghernaout et al., 2010)

Process	Advantages	Limitations
Copper sulphate	Simple and inexpensive	Creates toxicity: only some algal forms attacked
Chlorine	Simple and inexpensive	High doses needed: not all algae attacked
Coagulation and settling	All types of algae are removed	High chemical doses required: sludges produced are difficult to handle
Sand filters	Removal of all algae	Rapid filter clogging problem may occur
Microstraining	Simple and inexpensive	All algal types not removed
Air flotation	All types of algae are removed in this process	All algal forms not removed; sludges produced are difficult to handle

Low cost and environmentally friendly inorganic coagulant like dolomite is taken into consideration for the removal of algae which is different than others conventional treatment system as mentioned in (Table 1.2). Algae removal by conventional treatment is more difficult than inorganic particle, due to their low specific density, motility, morphological characteristics and negative surface charge (B. Ghernaout et al., 2010).
One of the main reason for the eutrophication of water bodies is presence of Phosphorous . Even in small concentration it affects trophic state of water source. Total P in water sources consists of particulate and dissolved part. Both phosphorous can be either organic or inorganic. The dissolved inorganic bounded P consists of orthophosphates and polyphosphates. In the pond the inorganic dissolved phosphorous P is converted to organic P when utilized by plants. After the death of animals and plants and by the bacterial decomposition of organic P from their tissues converts to inorganic P. Which is the cycle of Phosphorous in water.
In this study of algae and phosphorous removal from eutrophic water. The algae is removed by physical method of coagulation and flocculation by adding burned dolomite as a chemical coagulants. In which the Ca++ and Mg++ ions of dolomite flocculate algae by forming ionic bond with CO2 or CO_3^{2-}on the surface of the algae. And another nutrient phosphorous elements causing eutrophication is removed by chemical coagulation and precipitation.
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2. Methodology.

In this study the analysis of method of removal of algae and phosphorous from eutrophic water was done by adding dolomite as a inorganic chemical coagulant. Removal experiment were conducted in 600ml beaker containing 500 ml of algal solution. The amount of dolomite doses from 2.5 g/l to 15 g/l were added in the algae containing solution. The total six samples of different doses from 2.5 g/l to 15 g/l were placed in jar test apparatus. The samples were mixed for 2 min on 100 rpm for the proper mixing of coagulants then after 30 minute on 30 rpm for formation of flocculation. Finally 30 minutes was left for the sedimentation. The samples obtained from the reaction were collected and analyzed to determine the pH and turbidity. To figure out the total phosphorous and total nitrogen measurement was done using UV/Vis Spectrophotometer (UVmini-1240). Methodology flow chart for experimental procedures were as shown (figure 2.1).

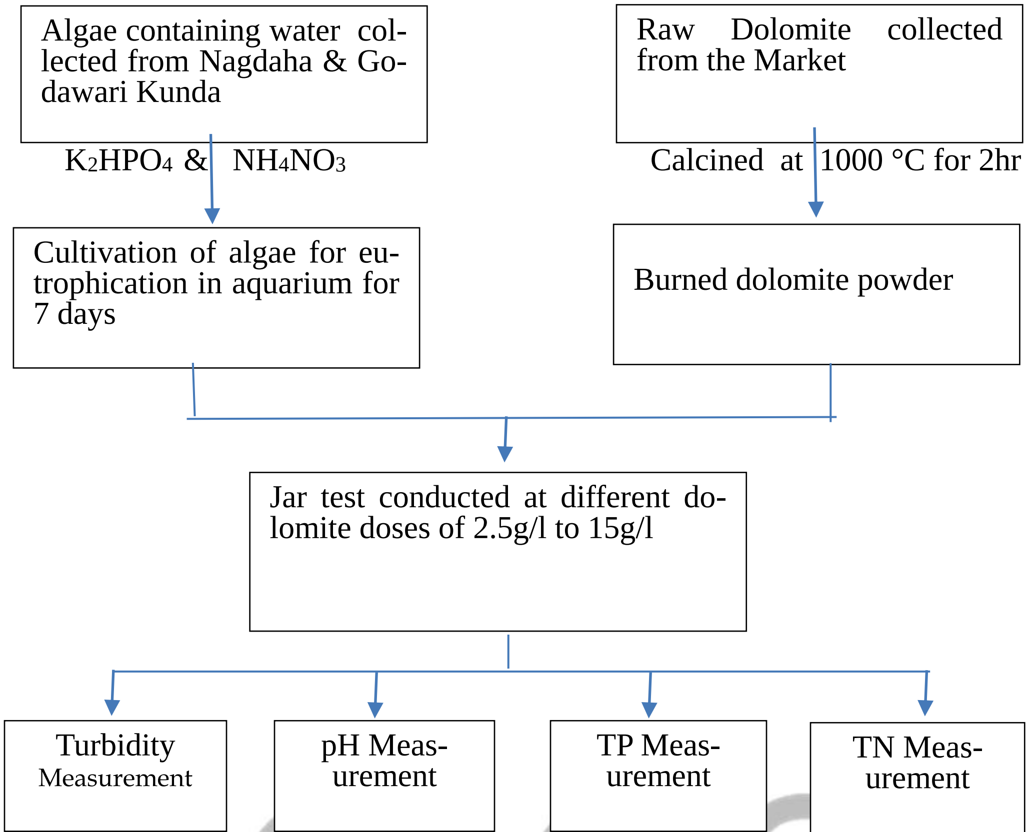

Figure 2.1 Methodology flow chart for experimental procedures

The efficiency of algae and nutrients removal from eutrophic water was tested in several rounds of batch experiments. Four rounds of experiments were tested. In the first and second round of experiment the water sample collected from Nag Daha were performed without dilution. In the third round experiment water sample was collected from Nag Daha and 500ml of raw sample was diluted in 5000ml distilled water and after placing chemical placed in aquarium for 7 days for eutrophic condition. In fourth round experiment eutrophic water sample was collected from Godawari Kunda and adding chemical and without dilution placed in aquarium & additional nutrients were placed for eutrophic condition.

3. Results and Discussions

Treatment Result Analysis

Comparative results of all four rounds of experiments done on algae and phosphorus removal using dolomite powder are analyzed here. The parameter analyzed were as follows

- Turbidity removal
- pH effect
- Total Phosphorus Removal
- Total Nitrogen Removal

3.1 Turbidity Removal

The measurement for turbidity were observed at raw sample and at different amount of dolomite powder were shown in figure 3.1. From the figure it showed that the turbidity of the solution diminished proportionally to the amount of dolomite powder adde. Refering to figure 3.1 in case of low turbidity at experiment first and second round a dolomite dose of 2.5 g/l was sufficient for removal turbidity after increasing dose dolomite itself causes turbidity beyond 2.5 g/l. But in case of high turbidity caused by algae in experiment three and four round, from 5 g/l the turbidity of solution dropped sharply upto 7.5 g/l.

After the reaction turbidity of solutions diminished proportionally to the amount of dolomite doses. For the elimination of algae, cation source play an important role for the precipitation by ionic bonding with phosphorous ion. The phenomenon of algae turbidity removal was due to fact that the relatively less soluble $Mg(OH)_2$ of hydrated dolomite. (Nam *et al.,* 2017)

Algae particle that are suspended on the water surface exist in form of anionic colloids and the use of dolomite powder as inorganic coagulant that has cationic van der waals bonds causes algal particles to come into contact with one another, which causes their volume and weight increase & eventually leads to a settling process by gravity. (Huh *et al.,* 2017)

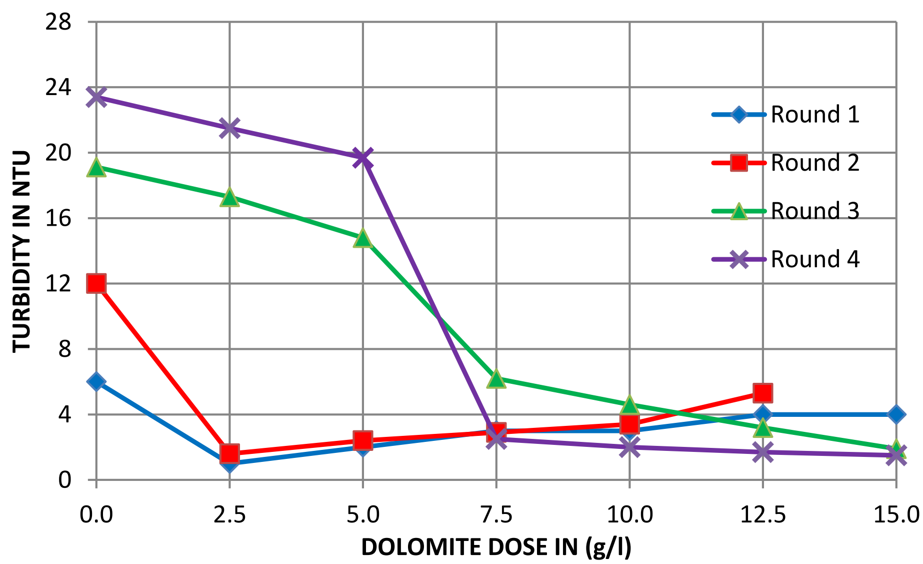

Figure 3.1 Turbidity removal at different dolomite doses

3.2 pH Effect

To find out the pH changes of algal solution different doses of dolomite were added to algal solution. With increase in doses of dolomite the pH of the sample was increased upto 12 as shown in Figure 3.2. The reason that pH was increased with raised amount of slurry is due to, the hydrated $Ca(OH)_2$ and $Mg(OH)_2$ from dolomite exists as Ca^{++} ,Mg^{++} and OH^{-} in the solution. Then Ca^{++} and Mg^{++} cation flocculate with some species, such as CO_2 or CO_3^{2-} on the surface of algae or react with phosphorous and nitrogen ions in solution, in which concentration of remaining OH^{-} ions are increased, which brings pH to be increased upto approximate 13 as shown in graph. In the algae solution the rise of pH was higher than that of low turbidity solution.

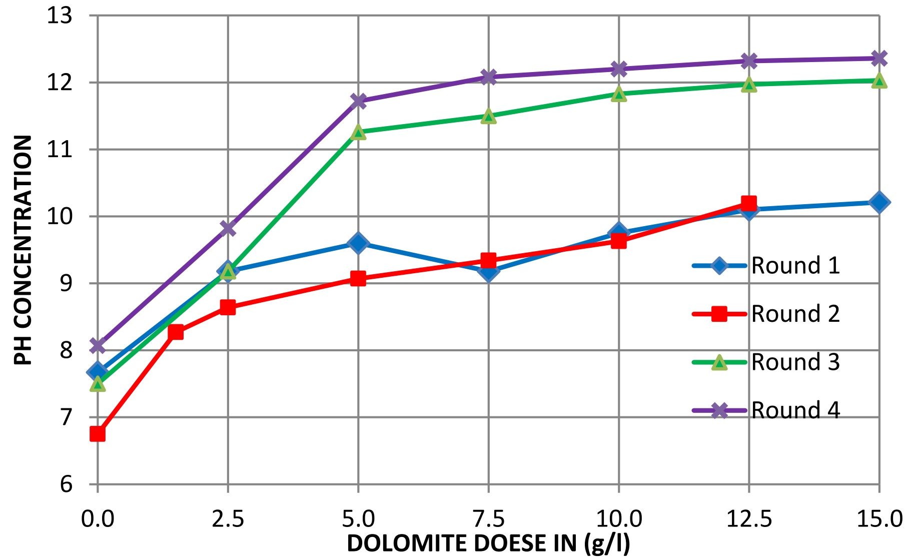

Figure 3.2 pH effect on different doses

3.3. Total Phosphorous Removal

The total phosphorous removal from algae containing water in different experiment cycle is presented in figure 3.3 & figure 3.4. As shown in figure. As the added amount of dolomite doses the concentration of TP was diminished. TP was rapidly decreased from 5 to 7.5 g/l and resulted in elimination of almost all concentration of phosphorous in algal solution. At dolomite dose of 2.5 g/l it shows little removal effect.

The phosphorous removal is due to fact that the Ca^{2+} and Mg^{2+} ions in dolomite can be crystallized with phosphorous ion as form $Ca_3(PO_4)_2$ or $Ca_5(PO_4)_2OH$ by shown below equation.

$$3Ca^{2+}(aq) + 2PO_4^{3-}(aq) \leftrightarrow Ca(PO_4)_2\ (s,aq)$$

$$5Ca^{2+}(aq) + OH^{-}\ (aq) + 3PO_4^{3-}(aq) \leftrightarrow Ca_5(PO_4)_3OH\ (s,aq)$$

From literature, In case of oyster shell CaO a major phase of oyster shell was changed to $Ca(OH)_2$ by hydration process with H_2O. Slurry after reaction, any diffraction peaks for $Ca(OH)_2$ was not detected but new large peak at near 32° was observed which represents $Ca_5(PO_4)_3OH$. (Nam *et al.*, 2017)

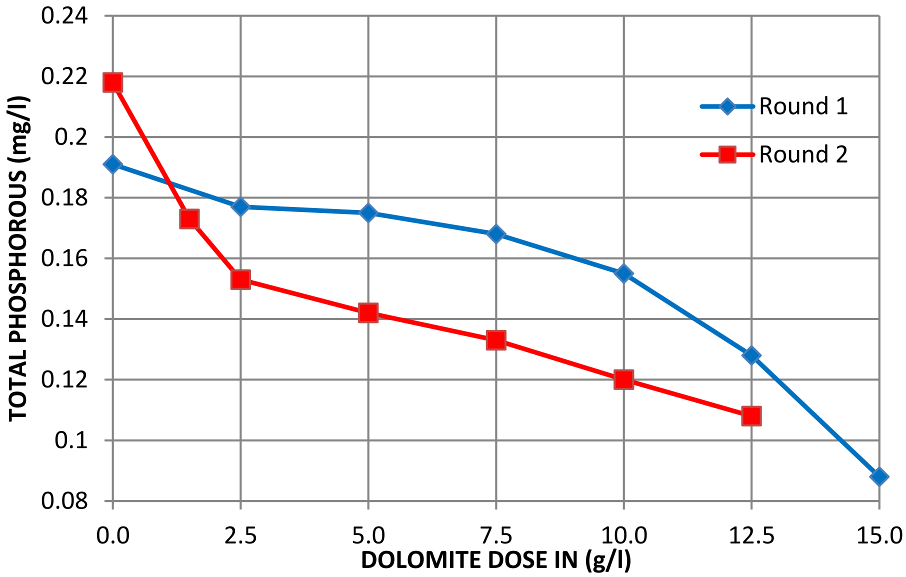

Figure 3.3 Total phosphorous removal at different dolomite dose for round 1 &2.

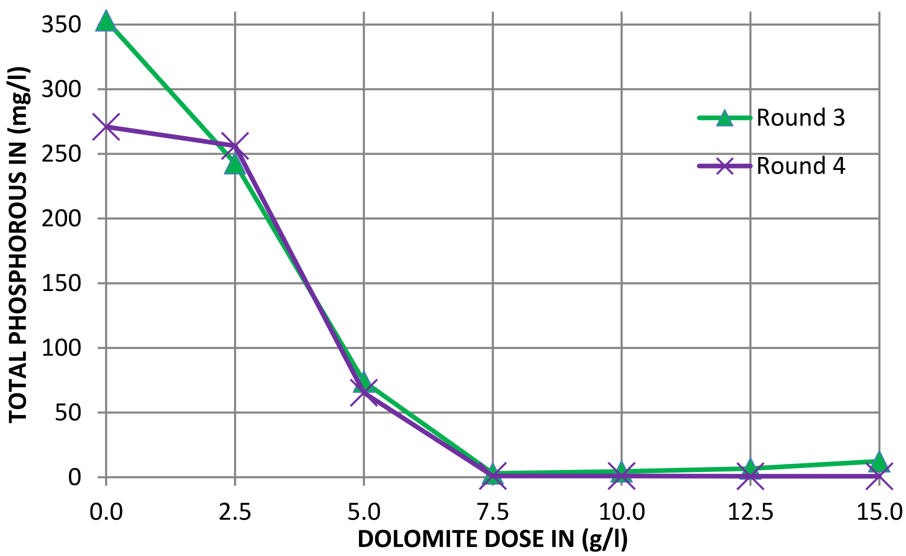

Figure 3.4 Total phosphorous removal at different dolomite doses for round 3 & 4

3.4 Total Nitrogen Removal

The total nitrogen removal from algae containing water in different experiment cycle is presented in figure 3.5 & 3.6. Refering to figure, as added amount of dolomite the concentration of TN was not affected.

NAM (2017) mentioned two mechanism that the no obvious effect of concentration of TN observed were, First, nitrogen exist as an NO_3^- ion reacts with Ca^{2+} ion to form $Ca(NO_3)_2$. However $Ca(NO_3)_2$ posses good solubility and exists as a form of an ion as Ca^{2+} and NO_3^- in aqueous solution and thus concentration of nitrogen seems to remain without any changes in solution.

Second, nitrogen also can exist as ammonium (NH_4^+) ion in the solution and react with other cations such as Ca^{2+} and reacts with anions such as OH^- ion in water forming NH_4^+OH compound. However, since the NH_4^+OH compound is also soluble in water, the NH_4^+ ion remain as it is in solution. Although dolomite did not treat nitrogen element in algal solution.

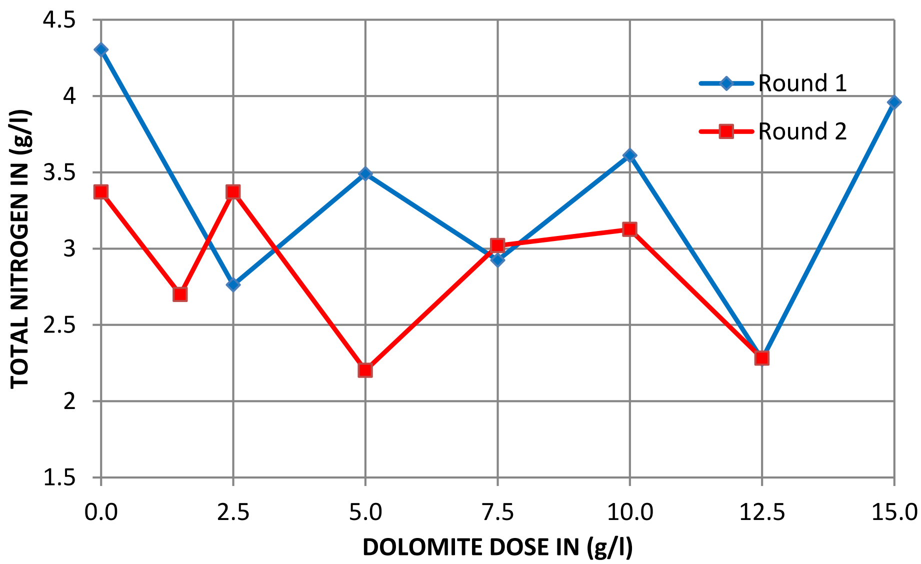

Figure 3.5 Total nitrogen removal at different dolomite dose for round 1& 2.

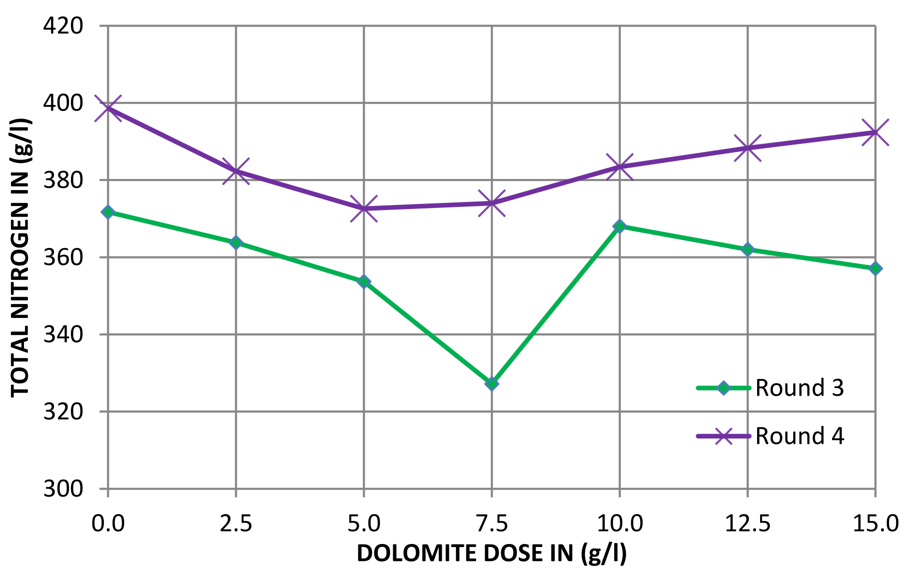

Figure 3.6 Total nitrogen removal at different dolomite doses for round 3 & 4

4. Conclusions and Recommendations

4.1 Conclusions

From the test results, calculations and analysis the following conclusions can be finally drawn

i. From the results of turbidity measurement, we can conclude that algae were coagulated and precipitated proportionally to added amount of dolomite dosages.

ii. From the results of phosphorous removal, addition of dolomite dose of 7.5g/l to the eutrophic algal solution removed almost phosphorous element.

iii. On the other hand, the nitrogen removal due to dolomite dose observed no obvious effect on removal due to high solubility nature of the nitrogen compound.

iv. In context to Nepal, due to easily available, cheap and ecofriendly. Dolomite can be considered as a significient coagulant for the removal of algae and phosphorous.

4.2 Recommendations

The following points are recommended for further research.

i. A continueous flow system can be done instead of batch process.

ii. For the removal of total nitrogen, a suitable composite material can be tried as a coagulant.

iii. Dolomite rock granules can also be tried in filtration system as a filter media.

iv. Other material with high rich in calcium and magnesium can replace dolomite because Ca^{++} ion can flocculate the algae by forming an ionic bond with CO_2 or CO_3^- on the surface of algae or can be crystallized with PO_4^{--} or NO_3^- ions to form a few ionic compound in the solution

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