CHAPTER - 6

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1. NUTRIENT REMOVAL POTENTIAL OF AQUATIC PLANTS:

(1) TEMPERATURE:

Temperature is one of the important ecological factor, causing many direct and indirect effects. Temperature influences the growth of aquatic plants and controls the solubility of various gases and salts in water. Aquatic plants like *Eichhornia crassipes* and *Pistia stratiotes* are temperature sensitive as found by Clough *et al.* (1987) and Aoi and Hayashi (1996).

In present investigation temperature was estimated before and after the culture of aquatic plants in domestic wastewater. The observed temperature of domestic wastewater had a general conformity with atmospheric temperature; hence higher temperature was recorded in the summer months and lower in the winter months. The observed range of temperature (24.8 - 36.6°C) was quite similar to the range observed by Hosetti and Patil (1986) and Rai *et al.* (1995). The temperature observed by Sooknah *et al.* (2004) for dairy wastewater was also similar to the presently investigated value. The average temperature of domestic wastewater was recorded 30.3°C, higher than the average temperature obtained by Hosetti *et al.* (1986) for sewage. Olga and Alenka (1989) found the luxuriant growth of aquatic plants in domestic wastewater favored by a temperature range of 26°C - 35°C.

The temperature of domestic wastewater was decreased after seven days of culture as also been observed by Zafar (1967) for pond water. The reason for decrease in temperature observed in present investigation was increase in surface area occupied by the aquatic plants in culture, which reduced the direct penetration of sun light in culture. Temperature has been observed to influence

Temperature values before and after the culture exhibited very less variation with the culture of aquatic plants (P1 to P5), with a maximum reduction value of 16.96%. An insignificant change in temperature result was further supported by the 't' test as all the possible pairs between before and after the culture of aquatic plants P1 to P5 indicated an insignificant difference except I - P3.

**2) HYDROGEN ION CONCENTRATION (pH):**

Hydrogen ion concentration is a largely studied ecological parameter, which gives an idea about the concentration of carbonate bicarbonate and CO₂ in water. pH plays an important role for aquatic life (Welch, 1952) hence, cannot be ignored. The pH of domestic wastewater increasing more without the culture of aquatic plants as compared to the increase with the culture of aquatic plants indicates that aquatic plants resist increase in pH of the wastewater. Das (2005) made similar observations for pH in municipal sewage. Insignificant differences between the pH values of wastewater with the culture of aquatic plants P1 to P5 indicate that all of them have almost similar effects on pH values.

The lower increase in pH due to culture of aquatic plants as compared to untreated domestic wastewater maintains pH level suitable for the growth of aquatic plants as Veenstra *et al.* (1995) reported for the treatment of domestic wastewater with duckweed (*Lemna minor*) is impossible at pH level 9.8 and above. Shobha *et al.* (2005) recorded optimum pH requirement to be 6.59 - 7.33 for the growth of *Eichhornia crassipes*. Hosetti and Patil (1986) found a range of pH higher than the presently investigated value.
(3) TURBIDITY:

The colour of domestic wastewater was almost black throughout the year before the culture. Turbidity value was found more before the culture due to presence of various turbidity causing particles like decomposing organic matter as suspended solids. As the aquatic plant absorbed the nutrients during the seven days of culture, hence the turbidity value lowered significantly after the culture. Domestic wastewater had a turbidity value quite similar to the values reported by Sobha and Harilal (2005) for aquatic bodies of the country. Higher value of turbidity was observed during summer because of increase in concentration of turbidity causing particles due to excessive evaporation of water, while lower values were recorded in winter due to lower temperature, which retarded the process of evaporation.

Higher percentage reduction value of turbidity with the culture of aquatic plant P3 suggested a greater efficiency for removal of turbidity. All the aquatic plants had reduced the turbidity after the culture; however, the greater reduction was observed for submerged aquatic plants P3 and P4.

(4) SALINITY:

Salinity is an important parameter of wastewater. It is defined as total solids in the water after the conversion of all the carbonates to oxides; bromides and iodides replaced by chloride and oxidized organic matter. Higher salinity values in summer months (May and June) was due to increase in temperature of domestic wastewater which increased the solubility of solids, while the value lowered in winter months (November and December) due to decrease in temperature which lowered the solubility of solids but contrastingly % reduction potential of aquatic plants was higher during the winter as compared to the summer.
Sooknah *et al* (2004) observed greater potential of *Eichhornia crassipes* than *Pistia stratiotes* for reducing salinity, just reverse observations were made during present study. As there was very less difference in salinity value before and after the culture of aquatic plants, hence ‘t’ test indicated an insignificant difference for all the pairs between before and after the culture of aquatic plants.

(5) ELECTRICAL CONDUCTIVITY:

The measurement of mobile free ions in water sample is expressed as conductivity. It is measured as resistance in mhos. Higher value of electrical conductivity obtained during the summer months was due to increase in concentration of solids, while the value lowered due to dilution of domestic wastewater in rainy months. All the aquatic plants after the culture had lowered the conductivity value, due to the absorption of most of the dissolved solid by the aquatic plants.

Moorhead (1986) found 48% reduction in electrical conductance in wastewater during 22 days of culture; nevertheless, in present investigation maximum of only 25.69% reduction was found with aquatic plant P3 after seven days of culture in domestic wastewater, while other aquatic plants had a closer potential to reduce electrical conductivity. Electrical conductivity value changed significantly with the culture of aquatic plant P3 due to greater rate of absorption of dissolved solids, similar result was shown by the ‘t’ test as significant difference for aquatic plant P3 with value before culture (I) was obtained.

(6) TOTAL DISSOLVED SOLIDS (TDS):

Total dissolved solids is a measure of the materials dissolved in water. These materials include carbonate, bicarbonate, chloride, sulfate, phosphate, nitrate, calcium, magnesium, sodium, organic ions and other ions. A certain level of these ions in water is necessary for aquatic life. Any change in TDS concentration can be harmful because of its effect on the water, which
determines the flow of water in to and out of an organisms cell. Too high or too low TDS concentration may limit the growth of aquatic life. TDS reduces water clarity and decreases the rate of photosynthesis. Some times it combines with toxic compounds and heavy metals and sometimes lead to an increase in temperature. Increase in concentration of TDS observed in the month of May was due to increase in concentration by excessive evaporation, while the minimum TDS value noted in the month of August was due to greater dilution of domestic wastewater.

Maximum percentage reduction potential of aquatic plants to reduce TDS in domestic wastewater culture with aquatic plant P3 and minimum with P5 expresses their difference in rate of absorption of TDS from domestic wastewater. All the aquatic plants exhibited lower absorption during summer, while higher absorption during winter and rainy months. The main reason of lower absorption during summer months was the influence of higher temperature.

Sooknah et al (2004) observed a greater potential of Eichhornia crassipes than the Pistia stratiotes to reduce TDS from wastewater. However, similar results were obtained during present study. Maximum percentage reduction of (22.33%) was obtained with aquatic plant P3 (Hydrilla verticillata).

(7) TOTAL ALKALINITY:

Alkalinity is a measure of buffering capacity of water. Alkalinity is an important parameter indicating ability of water to neutralize acid pollution from wastewater. The buffering materials are primarily the bases bicarbonate and carbonate and occasionally hydroxides, borates, silicates, phosphates, sulfides and organic ligands. Alkalinity not only helps to regulate the pH of water but also the metal content. The value of total alkalinity found very high before the culture of aquatic plants indicated the presence of higher amount of bound CO₂ as carbonate and bicarbonate. In summer months total alkalinity value being
higher as compared to the values for rainy months, due to dilution of wastewater by rainwater or surface run water. In control experiment no change was observed in the value of alkalinity during 7 days interval, but the decrease in alkalinity after the culture of aquatic plants was observed because of partial utilization of bicarbonate ions.

Free floating aquatic plants P1, P2 and P5 had lower reduction potential for alkalinity during the summer months due to influence of temperature, while submerged aquatic plants P3, P4 had no direct influence of atmospheric temperature hence, recorded higher % reduction value. For submerged aquatic plants P3 and P4 lower values for reduction of alkalinity were obtained during the winter months due to decrease in temperature of water. This makes an adverse effect on rate of utilization of carbon dioxide in water by aquatic plants.

The difference in reduction potential between free floating aquatic plants (P1, P2 and P5) and submerged aquatic plants (P3 and P4) was also indicated by the ‘t’ test, in which aquatic plants P3 and P4 had a significant difference with the values of before culture and the values after the culture of aquatic plants P1, P2 and P5.

Total alkalinity value of dairy wastewater was reduced 61.5% and 38.5% by *Eichhonia crassipes* and *Pistia stratiotes* respectively in 31 days of culture (Sooknah et al 2004), however in present study of 7 days of culture in domestic wastewater maximum reduction made by the same aquatic plants are 17.20 % and 20.43 % respectively.

(8) FREE CARBONDIOXIDE:

The higher value of free CO$_2$ in domestic wastewater before culture was due to presence of greater quantity of organic matter. The higher values of free CO$_2$ during summer months was due to higher rate of decomposition of organic matter and evaporation of water, while the reduced value in the month of August was due to dilution of domestic wastewater by rainwater. The free CO$_2$ value
reduced after the culture of all the aquatic plants was due to utilization of CO₂ in photosynthesis by the aquatic plants during seven days of culture.

The lowering in CO₂ values during the month of August had indicated the lower rate of consumption of free CO₂ in photosynthesis because of less availability of sunlight, while higher values during the summer is due to higher rate of decomposition of organic matter resulting in release of more free CO₂. Submerged aquatic plants P3 and P4 had greater potential than the free-floating aquatic plants in % reduction of free CO₂. The % reduction potential of free floating aquatic plant was higher during the winter month, while submerged aquatic plant P3 and P4 had higher % reduction potential during the month of June and October respectively.

Lower free CO₂ reduction potential of Free floating aquatic plants during the summer months was due to adverse effect of temperature on photosynthesis but such trend was not exhibited by submerged aquatic plant P3 and P4 as they did not have any influence of temperature under the water. As there was very little difference in free CO₂ values for before and after the culture of aquatic plants, therefore ‘t’ test indicated an insignificant difference amongst the values before and after the culture of the aquatic plants except I - P3.

(9) TOTAL CARBON DIOXIDE:

Total carbon dioxide is a combined value of free CO₂ and CO₂ in the form of carbonate and bicarbonate ions. In domestic wastewater carbonate ions were found absent, therefore total CO₂ was due to free CO₂ and bicarbonate ions only. The value of free CO₂ was comparatively very less than the bicarbonate ions therefore, bicarbonate ions represented the total alkalinity value and the variation registered for total CO₂ was similar to the total alkalinity value. Total CO₂ was comparatively higher in summer months due to presence of higher concentration of bicarbonate ions while lowered during the rainy months due to dilution of domestic wastewater. After the culture of aquatic plants P1 to P5 the total CO₂

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value reduced because of utilization of carbon dioxide by aquatic plants in photosynthesis.

The submerged aquatic plant P3 had a higher rate of photosynthesis than the other aquatic plants hence, greater reduction in total CO$_2$ was observed with the culture of P3 in domestic wastewater. Aquatic plants P1, P2 and P5 being free floating aquatic plants exhibited slightly lesser reduction of CO$_2$. Percentage reduction was higher in winter months when the conditions were found suitable for photosynthesis. Total CO$_2$ value before culture had a significant difference with the after culture value of P1, P3 and P4, similarly aquatic plant P3 with P1, P3 with P2, P3 with P5 and P4 with P5 had indicated significant difference, similar difference was also obtained in ‘t’ test.

(10) CHLORIDE:

Chloride is one of the major inorganic anions in wastewater. The concentration of chloride is normally higher in domestic wastewater because of sodium chloride commonly used in diet and passes unchanged through the digestive system. Chloride content in very high concentration effects the growth of plants.

The lower values of chloride recorded in the month of August in domestic wastewater before and after the culture of aquatic plants was due to dilution of domestic wastewater by rainwater, while higher values above 100mg/L from January to March. The reason for increase in value was due to gradual increase in concentration as well as change in quality of water influxed. Sudden increase in chloride concentration in the month of July may be due to sudden influx of accumulated chloride with rain.

As the chloride content has no significant role in the metabolism of plants therefore, cultured aquatic plants had absorbed it in very low amount, so a very little change was noted in the value after the culture. Insignificant
difference with t test for all the pairs between domestic wastewater before & after the culture of aquatic plants P1 to P5 confirms the insignificant effect on chloride ion by the aquatic plants.

Free floating aquatic plants (P1, P2 and P5) and Submerged aquatic plants (P3 and P4) had recorded average percentage reduction potential below 6%, this confirms the insignificant role of chloride in these aquatic plants, however the reduction potential of aquatic plants P1, P3, P4 lowers during the winter months as the absorption is retarded by lower temperature, while free floating plant P2 and P5 registered a lower value during the summer months because of higher temperature causes drying of some of the plant parts in culture resulted in to lowering in absorption..

(11) DISSOLVED OXYGEN (DO):

Dissolved oxygen is found as microscopic bubbles of oxygen that are mixed in the water and occur between water molecules. DO is an important component of a water to support aquatic life. Oxygen enters in domestic wastewater by absorption directly from the atmosphere or through aquatic plants photosynthesis. Oxygen is removed from the water by respiration and decomposition of organic matter. The DO in water depends on various physico-chemical and biochemical factors including the partial pressure of gas and temperature.

Dissolved oxygen values were comparatively higher during the winter months October to December in wastewater due to more dissolution of oxygen in colder water, while in summer season from April to June, DO value recorded lower values because of decrease in dissolution of oxygen in domestic wastewater. After the culture of aquatic plants P1 to P5 concentration of DO increased because of photosynthetic activity of aquatic plants in culture. Aquatic plant P5 had a less potential of increasing dissolved oxygen of domestic wastewater due to smaller size of aquatic plant while other submerged and free
floating aquatic plants had increased oxygen according to their respective size and photosynthetic activity in domestic wastewater culture.

The percentage increase in DO concentration of domestic wastewater after the culture of submerged aquatic plant P3 and P4 was higher during the summer month because of the suitable temperature of water for photosynthesis and submerged nature of plants prevent drying in direct sunlight, while free floating aquatic plants (P1, P2 and P5) starts drying in summer due to direct exposure to higher temperature of sunlight. As the growth of free floating aquatic plants in culture flourished in the winter, subsequently resulted increased the rate of photosynthesis and DO of the culture.

Moorhead and Reddy (1988) observed increase in oxygen level after the culture of aquatic plants in domestic wastewater due to exchange of oxygen from aerial tissue in to root zone, similarly Debusk and Reddy (1987) found aquatic plants capable of transporting atmospheric oxygen from the foliage in to root and the amount not required for root respiration diffused in to water system lifts the level of oxygen.

There was a significant difference in oxygen concentration before and after the culture of aquatic plants. Aquatic plant P5 had registered a significant difference with after culture value of aquatic plants P3 and P4, as has also been confirmed by the ‘t’ test.

(12) PERCENTAGE OXYGEN SATURATION:

It provides a better comparison of dissolved oxygen value. The saturation of domestic wastewater with oxygen is one of the most variable phenomenon; changing with the rate of photosynthesis by aquatic plants. The aquatic plant P5 produced less oxygen due to its smaller size than the other aquatic plants; hence percentage saturation value was recorded lower than other aquatic plants cultured in domestic wastewater. The percentage saturation of oxygen value indicated same trend as observed for dissolved oxygen. Percentage oxygen
saturation recorded higher values during the winter due to greater dissolution of oxygen in water while, lower values were obtained during summer months because of lower dissolution rate, before the culture, but after the culture of aquatic plants increase in saturation was found during the rainy and winter months as cultured aquatic plants had a higher rate of photosynthesis in those months, while lower increase was noted during the summer months except with aquatic plant P3 in February because of lower rate of photosynthesis due to less suitable temperature. Another reason had influenced the dissolution of oxygen and successive increase in percentage oxygen saturation was difference in atmospheric pressure.

The presence of dissolved solids in domestic wastewater also influenced the rate of oxygen dissolution. After the culture of aquatic plants value of total dissolved solids lowered which promoted the grater dissolution of oxygen in domestic wastewater. The variation in quantity of dissolved solids changes the percentage oxygen saturation. The ‘t’ test indicated similar results for percentage oxygen saturation as was observed for dissolved oxygen.

(13) CHEMICAL OXYGEN DEMAND (COD):

Chemical oxygen demand is an indicator of oxidizable matter present in domestic wastewater. COD values were higher during the summer months and lower in rainy months. These results were obtained because of excessive evaporation causing higher concentration of organic matter, while the value lowered in the rainy months due to dilution of domestic wastewater by rainwater. The COD values decreased in similar range after the culture of all the presently investigated aquatic plants but except for P5 (Lemna minor). Korner et al. (1998) have observed faster reduction ability to C.O.D. by duckweed (Lemna minor) but during present investigation Lemna minor exhibited only about 50% reduction ability to C.O.D. as compared to C.O.D. reduction ability of other investigated aquatic plants in the wastewater. Percentage reduction in COD value after the culture of aquatic plants in domestic wastewater was lowered
during the summer months because of less availability of oxygen in domestic wastewater during the summer, while rainy and winter months had a higher reduction value due to more availability of oxygen for oxidation of organic matter.

Sooknah et al (2004) and Das (2005) observed Eichhornia crassipes as more efficient plant than Pistia stratiotes and Hydrilla verticillata to remove COD after the culture but reversed results were obtained during the present study. All the aquatic plants throughout the year reduced the COD value in domestic wastewater after the culture; however, significant reduction in value between before and after the culture of aquatic plants was indicated only by aquatic plant P3 by ‘t’ test.

(14) TOTAL HARDNESS:

Hardness is a measure of the concentration of polyvalent cations like calcium and magnesium. Hardness affects the amount of soap that is needed to produce foam or leather. Other hardness causing ions like Iron and Manganese are found in very low concentrations.

Higher value of total hardness recorded in the month of March in the wastewater, before and after the culture of aquatic plants was because of more evaporation in the month of March due to increase in temperature, while the value lowered in the month of May due to an excepted rain in the month diluted the water considerably to lower value. The ‘t’ test analysis indicated that the total hardness value before culture had significant difference with the value after the culture of aquatic plant P1 to P4, while P5 had an insignificant difference with value before culture. Insignificant difference between the hardness values after the culture of aquatic plants P1 to P5, but except for between P1 and P3 indicates similarity in hardness reduction ability of all the presently investigated aquatic plants. The temperature in the month of February was found suitable for the absorption, resulting in higher potential of percentage reduction with aquatic...
plants P1, P2, P4 and P5 was observed, while the higher temperature of month of May had increased the rate of absorption by the aquatic plant P3.

(15) CALCIUM HARDNESS:

Calcium hardness is the major determinant of total hardness in domestic wastewater. The maximum value of calcium hardness was in the month of April before and after the culture of aquatic plants but in very next month of May the value lowered to minimum due to dilution of domestic wastewater by unexpected rains.

The calcium hardness value before the culture was always below 200 mg/L except in the month of April, due to excessive evaporation of water, while the value decreased in the months of July and August due to dilution of water. All the aquatic plants had reduced the calcium hardness value after the culture. This was due to absorption of calcium ions by the aquatic plants. All the aquatic plants had a maximum percentage reduction potential in the month of February except the aquatic plant P3 that had its maximum in the month of May. This was due to suitable growth conditions for the aquatic plants in respective months, while lower values obtained during the rainy months for aquatic plants P1 to P4, was due to temperature and less availability of sunlight reducing the growth of aquatic plants, therefore absorption was also retarded, but aquatic plant P5 which is comparatively smaller free floating aquatic plant recorded minimum value of hardness reduction in the month of May due to adverse effect of temperature.

Percentage reduction potential of aquatic plants P3 and P5 registered a significant difference between them, while rest of the aquatic plants had an insignificant difference with respect to reduction potential for hardness. This is confirmed by the result of ‘t’ test where except aquatic plant P5; all the other aquatic plants had a significant difference with values of hardness recorded before culture.
(16) CALCIUM:

The calcium content, as expected exhibited similar fluctuation as was recorded for calcium hardness. This was due to the same reasons as described for the fluctuation of calcium hardness value before and after the culture, however, the recorded values were comparatively lower than the calcium hardness. All the aquatic plants had reduced the calcium content after the culture. The higher and lower percentage reduction potential in calcium value exhibited similar pattern as was observed for calcium hardness.

Das (2005) found double potential of *Eichhornia crassipes* than *Hydrilla verticillata* to remove calcium content after the seven days of culture in sewage, however reverse results were obtained in present study. The submerged aquatic plant (P3 and P4) had a significant difference of percentage reduction with the value for free floating aquatic plant P5, as was indicated by “t” test.

(17) MAGNESIUM:

Magnesium is a constituent of natural water and a contributor of hardness in water but in concentrations lesser than the calcium. The higher value of magnesium content was recorded in the month of March for the culture of free floating aquatic plants P1 and P2; while plant P5 had its maximum value along with submerged aquatic plants P3, P4 in the month of January. The lower value before and after the culture was recorded in the month of August due to dilution of domestic wastewater. All the aquatic plants had similar reduction potential for magnesium therefore; the average value of magnesium recorded after the culture of aquatic plant was similar.

Das (2005) recorded comparatively higher reduction of magnesium content in sewage after the seven days of culture of *Eichhornia* than the *Hydrilla*. This is different from the results obtained during the present study. The ‘t’ test indicating insignificant difference in between aquatic plants P1 to P5 for magnesium reduction value after the culture indicates similarity in properties of
the aquatic plants for Mg reduction. The maximum reduction potential was observed in the month of December for free floating aquatic plant P1 and P2, while for submerged plant P3, P4 maximum potential was noted during the month of August with an exception for aquatic Plant P5.

All the aquatic plants after the culture had reduced the magnesium concentration in domestic wastewater. It was indicated by the ‘t’ test as significant difference was found for magnesium concentration before and after the culture of aquatic plants between P1 to P4 but with exception of aquatic plant P5.

(18) AMMONICAL NITROGEN (NH$_4$- N):

Ammonia is an inorganic form of Nitrogen, least stable in domestic wastewater. Ammonia is quickly transformed to nitrate in water. The higher value of ammonical nitrogen was observed in the month of July, while lower in the month of November before and after the culture of aquatic plants in domestic wastewater. The higher of ammonical - N observed presently was lower to the value obtained by Hosetti et al. (1986) for sewage.

The ammonical-N value before and after the culture of aquatic plants had an insignificant difference, because ammonical form of nitrogen is less absorbed by the aquatic plants in culture as compare to nitrite and nitrate form, The similar result was obtained in ‘t’ test. Aquatic plants were found to be very useful in treatment of domestic wastewater with higher ammonia concentration as long as pH level doesn’t exceed 8 pH. Alaerts et al. (1996) obtained such results while treating domestic wastewater by duckweed (*Lemna minor*).

Percentage reduction in ammonical nitrogen value after the culture of aquatic plants being higher in the month of November as compared to the lower reduction value in the month of July with the exception for aquatic plant P2 was because of difference in absorption rate in respective months. Hosetti et al.
(1986) observed 92.85% removal of ammonical nitrogen from sewage, in ten
days culture of *Lemna minor*, while in present investigation maximum value of
reduction was obtained to be 47.93% during seven days of culture.

(19) NITRITE NITROGEN (NO$_2$ - N):

In domestic wastewater nitrogen is found in nitrate, nitrite, ammonia and
organic Nitrogen forms representing different levels of reduction. All these
forms of Nitrogen are biochemically inter-convertible. Nitrite is an intermediate
oxidation state, both in oxidation of ammonia to Nitrate and in the reduction of
Nitrate. These oxidization and reduction reactions are common in domestic
wastewater. Nitrogen is commonly a limiting factor and is rarely present in
concentration optimal for biotic requirements. Of all the forms of nitrogen nitrite
and nitrate are comparatively more stable in domestic wastewater.

All the aquatic plants reduced the nitrite value after the culture. Aquatic
plant P3 had a greater rate of reduction of nitrite concentration than other aquatic
plants. Higher value of nitrite nitrogen was observed in the month of August,
except for aquatic plant P3 and P4 for which higher values were obtained in the
month of May. The lower value of nitrite nitrogen was noted in the summer
months for aquatic plants, but except for P2 and P5, which had their minimum in
the month of December.

The percentage reduction potential of nitrite-N was higher in the month of
April for aquatic plant P1 and P3, December for P2 and P5, while P4 in the
month of June. It was due to suitability of aquatic plants to absorb higher
quantity during these months for their growth and the higher values were
obtained due to higher rate of oxidation at higher temperature, while lower value
was obtained due to lowering in temperature, which decreased the rate of the
oxidation. Nitrite-N value before and after the culture had a significant
difference due to absorption of Nitrite-N by the aquatic plants from water. The
't' test also indicated the similar result. The absorption potential of aquatic plant

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P2, P3, P4 had significant difference with aquatic plant P5 because of its minimum reduction potential.

(20) NITRATE NITROGEN (NO₃-N):

Nitrate nitrogen is highly soluble in water and remains stable for longer period. In water ammonical and nitrite forms oxidize in to nitrate form, hence, was recorded comparatively higher value than the ammonia and nitrite forms of nitrogen. The higher value of nitrate nitrogen was recorded in the month of May except for the plant P3 in the month of February after the culture. The lower values were obtained in the month of August for P1, December for P2, P5 and June for plant P3, P4. The higher values were obtained due to greater rate of oxidation in higher temperature, while lower value was obtained due to lowering in temperature, which reduced the rate of the oxidation. All the aquatic plants had reduced the nitrate nitrogen significantly after the culture.

The percentage reduction in nitrate nitrogen was recorded higher for submerged plant than the free-floating aquatic plants, because of difference in requirement for the growth. In the months when aquatic plants had luxuriant growth the value of reduction was higher, while lower reduction potential was observed when the poor growth was observed for the aquatic plants.

PHOSPHORUS:

Phosphorus occurs in wastewater as phosphate, which is one of the essential macronutrient for the growth of plants. It is the nutrient that limits the productivity of plants in water. In domestic wastewater phosphate can be classified in to Ortho-phosphate, Condensed phosphate and organic phosphate. Normally they occur in solution, in particles or detritus or in the bodies of aquatic organisms. Phosphate in water limits the growth and photosynthesis of plants; therefore absorbed by the plants in larger quantity. Kaul et al (1980) observed submerged aquatic plants as more efficient than the free-floating aquatic plants in the removal of phosphate from water.
(21) TOTAL ORTHO PHOSPHATE:

This is the soluble form of phosphorous mainly contributed through detergents and soaps widely used for domestic purposes. It occurs in both filterable and non-filterable form. Ortho phosphate is a reactive phosphorous which respond to spectrophotometric test without any preliminary treatment.

All the aquatic plants in domestic wastewater culture had reduced the total orthophosphate concentration because of absorption by the aquatic plants. Percentage reduction potential of total orthophosphate was similar for aquatic plants P1 and P3 while; P2 had a similarity with P4. The minimum percentage reduction noted for aquatic plant P5 was due to its smaller size as compared to other aquatic plants used in domestic wastewater culture.

All the aquatic plants absorbed significant amount of total ortho phosphate, therefore ‘t’ test indicated significant difference between the value of total ortho phosphate before and after the culture of aquatic plants. Aquatic Plant P5 absorbed less amount of total ortho phosphate in culture as compared to aquatic plant P2, P3, and P4, therefore significant difference in the total ortho phosphate value was recorded between P5 with P2, P3 and P4.

(22) ACID HYDROLYZABLE PHOSPHATE:

Higher values of acid hydrolysable phosphate was noted because of less settlement of condensed phosphate, while lower values were obtained due to more settlement of condensed phosphate at the bottom. All the aquatic plants absorbed acid hydrolyzable phosphate hence, quantity lowered after the culture.

Percentage reduction potential of all the aquatic plants had a similarity; therefore ‘t’ test indicated insignificant difference in the values for acid hydrolyzable phosphate among the aquatic plants experimented presently. The higher and lower reduction potential was related with the respective growth period of the aquatic plants. Free floating aquatic plants (P1, P2 and P5) had a higher growth rate during winter, while submerged aquatic plants (P3, P4) in
summer, therefore, higher reduction was observed in those season, as aquatic plant absorbed much amount of phosphorus than the other months. All the aquatic plants absorbed significant amount of acid hydrolyzable phosphate so, the value before and after the culture exhibited a significant difference by 't' test.

(23) TOTAL PHOSPHATE:

Total phosphate includes condensed, particulate, organic and inorganic forms of phosphorus together with the dissolved or ortho phosphate phosphorus; hence, this form of phosphorus was released by rigorous digestion of water with acid. Total phosphate value exhibited a random monthly variation in values, which could not be explained but probably was due to variation in the influx of phosphate.

All the aquatic plants had reduced the total phosphate content in domestic wastewater significantly due to absorption, in culture; therefore significant difference was indicated by 't' for the value before and after the culture of aquatic plants. Aquatic plant P5 had a minimum potential of total phosphate reduction in domestic wastewater because of its lowest rate of net primary productivity and comparatively less requirement of phosphorus for the growth as compared to other aquatic plants.

(24) ORGANIC PHOSPHATE:

Organic Phosphate exists in solution or as loose fragments, therefore is released only by the strong acid hydrolysis. This is the tightly bound phosphorous within larger organic matter. Contrastingly both higher and lower values of organic phosphate contents were observed in subsequent months of January and February with all the aquatic plants but except for aquatic plant P1.

Temperature had also played a role in the process of absorption therefore; submerged aquatic plants (P3 and P4) removed more organic phosphate during summer as compared to free-floating aquatic plants (P1, P2 and P5) in winter. Significant difference in the value of organic phosphate before and after the
culture of aquatic plant P3 and P4 was due to higher absorption by these two aquatic plants, indicated by ‘t’ test. Aquatic plant P5 had a minimum removal potential due to its lower productivity than others.

In present study all the aquatic plants were found suitable to grow and remove the nutrients considerably from domestic wastewater, however submerged aquatic plants *Hydrilla verticillata* Casp (P3) and *Ceratophyllum demersum* L (P4) were found to have higher potential for the nutrient removal than the free floating aquatic plants *Eichhornia crassipes* Solms (P1), *Pistia stratiotes* L (P2) and *Lemna minor* L (P5).

2. NET PRIMARY PRODUCTIVITY (NPP) OF AQUATIC PLANTS:

The free floating aquatic plants P1, P2, P5 and the submerged aquatic plant P3 and P4 had exhibited difference in net primary productivity values. Shobha *et al.* (2005) reported that the climate and water quality influences the productivity of aquatic plants. During present investigations net primary productivity of both free floating and submerged aquatic plants were almost similar but except for the aquatic plant P5 which had almost half to other aquatic plants used in culture. Reddy *et al.* (1983) obtained higher NPP value (2.47 gm m⁻² day⁻¹) for *Eichhornia crassipes* and lower value for *Pistiaia stratiotes* (1.0 gm m⁻² day⁻¹) in domestic wastewater as compared to the presently obtained values. The higher rate of biomass production was observed in winter months for aquatic plants P1, P2 and P5, while submerged aquatic plant recorded maximum production during the summer months. Free floating aquatic plants recorded lower value in the month of August for P1, May for P2 and April for P5, while submerged aquatic plants recorded lower values during the winter months. Lower values in summer months were due to adverse effect of higher temperature on free-floating aquatic plants, while in rainy months reduction in Net Primary Productivity of free floating aquatic plant P1, was because of lower availability of sunlight. The lower value in winter months for submerged aquatic
plants P3 and P4 was because of lower temperature of water, which retarded the growth rate of submerged aquatic plants. When temperature of water increased during the summer, productivity values also increased for submerged aquatic plant P3 and P4.

Free floating aquatic plants received sufficient quantity of sunlight and suitable temperature during the winter months, hence had maximum productivity value during the winter season. Kaul *et al.* (1980) had also observed lower values of NPP for submerged aquatic plant.

Net primary productivity of aquatic plants in culture will not be of any use in future, if techniques are not developed to convert even non-utilizable parts of aquatic plants into some useful products. (Westlake 1963). If the plant parts are made useful then only the culture techniques will become useful for the economic exploitation of aquatic plants. Aquatic plants are important for mankind as they contribute to biomass. The more important property of these aquatic plants are that they can be grown in raw domestic wastewater, where they absorb nutrients. Greaf *et al.* (1981), Reddy *et al.* (1983) and Gopal *et al.* (1978) have also observed the absorption of nutrients by the aquatic plants from polluted water bodies. In this way these aquatic plants can be used as one of the cheapest method for nutrient removal from domestic wastewater as well as beneficial cultivation for biomass production. In present investigation except aquatic plant P5 all other aquatic plants were found to have good potential for being used as nutrient remover from domestic wastewater.