*Indian Journal of Fundamental and Applied Life Sciences ISSN: 2231-6345 (Online)*
*An Online International Journal Available at http://www.cibtech.org/jls.htm*
*2012 Vol. 2 (2) April-June, pp. 79 -86 /Selvaraj et al.*
***Research Article***

# NULLIFYING THE TOXICITY OF PLATE MAKING INDUSTRY EFFLUENT USING SEAWEED ULVA LACTUCA

***Selvaraj, K., Sevugaperumal, R. and Ramasubramanian, V.**
*Department of Botany, Ayya Nadar Janaki Ammal College (Autonomous)*
*Sivakasi 626124, Virudhunagar District*
**Author for Correspondence*

**ABSTRACT**
The Plate making industry effluent containing heavy metals that are toxic to plants, reduces the plant yield and even the soil fertility, although these toxic substances could be removed by plants and dried plant materials. The ameliorative effect of *Ulva lactuca* at different concentration viz., 2g, 4g and 6g/L in 60% concentrated Plate making industry effluent treated on *Cyamopsis tetragonoloba* Taub. was analyzed. Impact of effluent was understood by a steep decline in growth characters, pigment content and other biochemical characteristics. The powder of *Ulva lactuca* in 60% concentration of the effluent in different concentrations brought about considerable increase in germination percentage, growth and biochemical characteristics in *Cyamopsis tetragonoloba* Taub than when they were treated with Plate making industry effluent alone. Seaweed dry powder used in this study was found to be efficient in nullifying the toxicity of effluent on growth and biochemical characteristics of *Cyamopsis tetragonoloba* Taub.

***Key Words**: Bioadsorption, Seaweeds, Plant Stress, Plate Making Industry Effluent*

## INTRODUCTION
Water is indispensable and the most precious on the earth. Everything originated in water and everything is sustained by water. The disposal waste water from the industries has a serious havoc as receiving river stream has become coloured. Sivakasi is an industrial town in Virudhunagar district. The town alone has nearly 250 fireworks, 200 litho and offset, 700 match units and 150 other industries including dye, printing ink, chemical cardboard, metal plate making and chemical plate grinding industries. Quite a large number of chemicals have constantly used for manufacturing process (Ramasubramanian *et al*., 2004). The industrial effluents contain especially inorganic content and colour, which impart objectionable colour to the water bodies. Presence of colour reduces the light penetration and photosynthetic activities of water bodies, some of the Plate makings used in the textile industries are found to be carcinogenic (Roshan Poi *et al*., 2000).
These waste effluents can be treated by treatment methods like ozonation, chemical coagulation, adsorption and electrochemical technology. These chemical treatment methods require costly chemicals and also generable hazardous sludge, so use of plants to degrade, assimilate, metabolize or detoxify contaminants is cost effective and ecologically sounds for the restoration and management of our natural water resources. There is an urgent need to apply bioadsorption technology, using dried natural algal biomass to decontaminate the polluted water bodies in the world. This will be effective in bringing new resources and technology to solve environmental problems in India, generated by industries (Selvarathi, 2010).
This study aimed to analyze the characterization of Plate making effluent, the effect of Plate making effluents on morphometric, biochemical and enzymatic characteristics of *Cyamopsis tetragonoloba* Taub. and also study the effect of varying amount of dried natural biomass of *Ulva lactuca* with 60% effluent on the morphometric, biochemical and enzymatic characteristics of *Cyamopsis tetragonoloba* Taub.

## MATERIALS AND METHODS
The Plate making industry effluent was collected from the Plate making industry Sivakasi. The sample for analysis was preserved as per the standard recommended procedure (Rainwater and Thatcher, 1963). The

seaweed *Ulva lactuca* collected from Harberpoint coast near Tuticorin were shade dried and finally powdered by milling. Various concentrations of seaweed powder was prepared with 60% Plate making industry effluent.

Both control and experimental seeds were allowed to grow in uniform mixed red, black and sandy soil in 1:1:1 ratio. After ten days, seedling of *Cyamopsis tetragonoloba* Taub. were treated with various concentration of Plate making industry effluent (20%, 40%, 60%, 80% and 100% v/v). After ten days of effluent treatment, various morphometric, biochemical and enzymatic characteristics were analyzed. In another set 60% of effluent (the concentration at which toxicity was found to be optimum level based on LST analysis (Zar, 1984). was subjected to various concentration of seaweed (*Ulva lactuca* ) powder (2g/L, 4g/L and 6g/L w/v), for 24 hours. Then filtered and the filtrate was used to treat plants. After ten days of treatment, various morphometric, biochemical and enzymatic characteristics were analyzed.

Twenty days old plants of *Cyamopsis tetragonoloba* Taub. were used for measuring the morphometric characters such as root length, shoot length, leaf area, fresh weight and dry weight were measured. The biochemical and enzymatic characters were analyzed by the following methods: chlorophyll and carotenoids (Wellburn and Lichtenthalar, 1984), anthocyanin (Swain and Hills, 1959), Total soluble sugar (Jayaraman, 1981), Protein content (Lowry *et al*., 1951), amino acid content (Jayaraman, 1981), leaf nitrate (Cataldo *et al*., 1978), *in vivo* nitrate reductase activity (Jaworski, 1971), peroxidase and catalase activity (Kar and Mishra, 1976).

**RESULTS AND DISCUSSION**

The results obtained on the analysis of the physico – chemical parameters of Plate making industry effluent, the effect of different concentration of effluent and the effect of effluent + seaweed powder treated plants were summarized and discussed below.

The physico – chemical characters, analysis were tabulated in Table 1. The morphometric characters such as root length, shoot length, leaf area, fresh weight and dry weight decreased (Table 2) with increasing in the concentration of Plate making industry effluent. Similarly, chlorophyll, carotenoids (Table 3), total soluble sugar, protein (Table 4) and nitrate reductase activity (table 5) also showed declining in trend. In contrary, the anthocyanin (Table 3), leaf nitrate, free amino acid, proline contents (Table 4) and the activities of antioxidant enzymes such as peroxidase, catalase (Table 5) were increased.

Plate making industry effluent contained 88.35 mg/L of total dissolved solids and 164 mg/L of total hardness, which leads to root and shoot length inhibition at higher concentration of the effluent. The pronounced inhibition of shoot and root growth and leaf area were the main cause for the decrease in fresh and dry weight of seedlings.

**Table 1: Physico – Chemical analysis of Plate Making Industry Effluent**

| S.No. | Parameters | BSI Standards | Value Characters |
|---|---|---|---|
| 1. | Temperature | - | 29.5$^0$C |
| 2. | pH | 7 – 8.5 | 11.53 |
| 3. | Electric Conductivity (EC) | 400 | 17.49 |
| 4. | Total Dissolved Solids (TDS) | 500 | 88.35 |
| 5. | Total Hardness | 300 | 164 |
| 6. | Biological Oxygen Demand (BOD) | - | 15 |
| 7. | Dissolved Corbandioxide | 22.8 | 79 |

The inhibition of biomass accumulation is directly related to the photosynthetic process. At higher concentration, the effluent showed inhibitory effect on both photosynthetic pigments and total soluble sugar. Similar result was observed by Kumar, (1999) after the irrigations with effluent.

**Table 2: Impact of various concentration of Plate Making Effluent on the Morphometric characteristics of *Cyamopsis tetragonoloba* Taub**

| Growth | Control | 20% | 40% | 60% | 80% | 100% |
|---|---|---|---|---|---|---|
| Root Length (cm) | 12.75 ± 0.091 (100) | 9.32 ± 0.150 (73) | 7.62 ± 0.041 (60) | 6.46 ± 0.094 (51) | 4.58 ± 0.102 (36) | 3.04 ± 0.134 (24) |
| Shoot Length (cm) | 15.12 ± 0.155 (100) | 12.62 ± 0.102 (83) | 9.11 ± 0.106 (60) | 7.53 ± 0.107 (50) | 5.44 ± 0.102 (36) | 4.36 ± 0.097 (29) |
| Leaf Area ($cm^2$) | 11.43 ± 0.109 (100) | 8.93 ± 0.088 (78) | 6.96 ± 0.110 (61) | 4.73 ± 0.039 (41) | 3.78 ± 0.030 (33) | 3.35 ± 0.015 (29) |
| Fresh Weight (gm) | 1.12 ± 0.014 (100) | 0.92 ± 0.050 (83) | 0.77 ± 0.059 (70) | 0.64 ± 0.037 (58) | 0.51 ± 0.013 (46) | 0.37 ± 0.091 (33) |
| Dry Weight (gm) | 0.97 ± 0.040 (100) | 0.79 ± 0.013 (82) | 0.49 ± 0.015 (51) | 0.28 ± 0.015 (29) | 0.15 ± 0.043 (16) | 0.10 ± 0.040 (10) |

*Values in parenthesis indicate percent activity; value represents mean of 10 samples with their standard error (±)*

**Table 3: Impact of various concentration of Plate Making Effluent on the photosynthetic pigments of *Cyamopsis tetragonoloba* Taub**

| Pigments | Control | 20% | 40% | 60% | 80% | 100% |
|---|---|---|---|---|---|---|
| Chlorophyll .a (mg/gLFW) | 1.59 ± 0.080 (100) | 1.16 ± 0.048 (73) | 0.90 ± 0.060 (57) | 0.72 ± 0.016 (45) | 0.53 ± 0.180 (33) | 0.45 ± 0.026 (28) |
| Chlorophyll .b (mg/gLFW) | 0.87 ± 0.016 (100) | 0.65 ± 0.021 (75) | 0.51 ± 0.080 (59) | 0.40 ± 0.90 (46) | 0.30 ± 0.60 (35) | 0.25 ± 0.20 (29) |
| Total.Chlorophyll (mg/gLFW) | 2.45 ± 0.021 (100) | 1.807 ± 0.051 (74) | 1.41 ± 0.014 (57) | 1.12 ± 0.016 (46) | 0.83 ± 0.022 (34) | 0.70 ± 0.046 (29) |
| Carotenoids (mg/gLFW) | 0.483 ± 0.011 (100) | 0.391 ± 0.050 (81) | 0.315 ± 0.016 (65) | 0.247 ± 0.060 (51) | 0.184 ± 0.109 (38) | 0.162 ± 0.010 (33) |
| Anthocyanin (mg/gLFW) | 1.43 ± 0.077 (100) | 1.63 ± 0.015 (114) | 1.75 ± 0.014 (122) | 2.49 ± 0.025 (174) | 3.17 ± 0.088 (221) | 3.75 ± 0.133 (262) |

*Values in parenthesis indicate percent activity; value represents mean of 5 samples with their standard error (±)*

The reduction in sugar content maybe attributed to reduction in chlorophyll content of the leaf and also a decline in protein. This change might have already affected the photosynthetic activity of the plant and hence reduction in contents (Swaminathan *et al*., 1998; Dowton, 1997).
Accumulation of proline has been frequently used as biochemical marker for water stress in plants (Alia and Saradhi, 1991; Schat *et al*., 1997). An increase in the aminoacid and proline content after Plate

making, sugar industrial effluent treated has already been reported (Ramasubramanian *et al*., 1993; Jeyarathi and Ramasubramanian, 2002). The leaf nitrate content was found to be more in effluent treated plants paralleling with the reduction in *in vivo* nitrate reductase activity.

**Table 4: Impact of various concentration of Plate Making Effluent on the Biochemical characteristics of *Cyamopsis tetragonoloba* Taub**

| Parameters | Control | 20% | 40% | 60% | 80% | 100% |
|---|---|---|---|---|---|---|
| Total soluble Sugar (mg/g LFW) | 45.87 ± 0.88 (100) | 34.03 ± 1.245 (74) | 27.54 ± 0.754 (60) | 24.05 ± 0.250 (52) | 19.89 ± 0.145 (43) | 16.69 ± 0.686 (36) |
| Total soluble Protein (mg/g LFW) | 10.81 ± 0.157 (100) | 9.20 ± 0.096 (85) | 8.210 ± 0.168 (76) | 7.25 ± 0.174 (67) | 5.96 ± 0.044 (55) | 4.213 ± 0.125 (39) |
| Amino acid (µM/g LFW) | 1.61 ± 0.040 (100) | 1.93 ± 0.027 (121) | 2.31 ± 0.014 (144) | 2.94 ± 0.038 (184) | 4.50 ± 0.074 (281) | 4.68 ± 0.212 (292) |
| Proline (µM/g LFW) | 25.58 ± 0.060 (140) | 36.32 ± 0.087 (142) | 38.47 ± 0.678 (150) | 42.47 ± 0.566 (166) | 46.85 ± 0.635 (183) | 48.94 ± 0.338 (191) |
| Leaf nitrate (mg/g LFW) | 1.74 ± 0.011 (100) | 2.24 ± 0.015 (129) | 2.53 ± 0.070 (146) | 2.92 ± 0.0475 (168) | 3.52 ± 0.081 (203) | 4.20 ± 0.157 (242) |

*Values in parenthesis indicate percent activity; value represents mean of 5 samples with their standard error (±)*

**Table 5: Impact of various concentration of Plate Making Effluent on the Enzymes activity of *Cyamopsis tetragonoloba* Taub**

| Parameters | Control | 20% | 40% | 60% | 80% | 100% |
|---|---|---|---|---|---|---|
| Nitrate Reductase activity (µMole/g LFW) | 0.54 ± 0.014 (100) | 0.41 ± 0.060 (76) | 0.35 ± 0.051 (64) | 0.29 ± 0.048 (54) | 0.24 ± 0.015 (43) | 0.17 ± 0.085 (32) |
| Catalase activity (µMole/g LFW) | 0.248± 0.068 (100) | 0.307 ± 0.039 (124) | 0.413 ± 0.023 (167) | 0.517 ± 0.094 (208) | 0.560 ± 0.070 (226) | 0.667 ± 0.067 (269) |
| Peroxidase activity (µMole/g LFW) | 4.24 ± 0.017 (100) | 6.94 ± 0.030 (164) | 8.55 ± 0.048 (202) | 9.15 ± 0.020 (216) | 10.55 ± 0.022 (249) | 11.37 ± 0.023 (268) |

*Values in parenthesis indicate percent activity; value represents mean of 5 samples with their standard error (±)*

In the present study an enhanced peroxidase activity was observed with the increase in the concentration of Plate making industrial effluent. Balasimha (1982) reported that peroxidase plays a vital role in IAA and chlorophyll degradation. Thus observed increase in peroxidase activity can be correlated with the observed reduction in chlorophyll content, fresh weight and biomass. Paper industrial effluent also caused similar increase in peroxidase activity of *Eleucine corocana* (Selvarathi *et al*., 2006).

*Indian Journal of Fundamental and Applied Life Sciences ISSN: 2231-6345 (Online)*
*An Online International Journal Available at http://www.cibtech.org/jls.htm*
*2012 Vol. 2 (2) April-June, pp. 79 -86 /Selvaraj et al.*
***Research Article***

Catalase is antioxidant and scavenging enzyme, it was found to be increased with the increasing concentration of Plate making industry effluent. Catalase is special type of peroxidase enzyme which catalyses the degradation of $H_2O_2$, which is natural metabolism and also toxic to plants (Balasimha, 1982).

**Table 6: Effect of Plate Making Effluent and *Ulva lactuca* on the Morphometric characteristics of *Cyamopsis tetragonoloba* Taub**

| Growth | Control (Water) | Control (Plate Making Effluent 60%) | Plate Making Effluent + | | |
|---|---|---|---|---|---|
| | | | 2 gm /L SWP | 4 gm /L SWP | 6 gm /L SWP |
| Root Length (cm) | 12.75 ± 0.091 (100) | 6.46 ± 0.094 (51) | 6.85 ± 0.055 (54) | 9.25 ± 0.132 (73) | 10.96 ± 0.140 (86) |
| Shoot Length (cm) | 15.12 ± 0.155 (100) | 7.53 ± 0.107 (50) | 8.06 ± 0.145 (53) | 11.11 ± 0.317 (73) | 13.49 ± 0.314 (89) |
| Leaf Area ($cm^2$) | 11.43 ± 0.109 (100) | 4.73 ± 0.039 (41) | 5.55 ± 0.112 (49) | 8.31 ± 0.143 (73) | 10.40 ± 0.63 (91) |
| Fresh Weight (gm) | 1.12 ± 0.014 (100) | 0.64 ± 0.037 (58) | 0.743 ± 0.017 (67) | 0.89 ± 0.180 (80) | 1.067 ± 0.072 (96) |
| Dry Weight (gm) | 0.97 ± 0.040 (100) | 0.28 ± 0.015 (29) | 0.41 ± 0.016 (42) | 0.74 ± 0.04 (76) | 0.82 ± 0.079 (84) |

*Values in parenthesis indicate percent activity; value represents mean of 10 samples with their standard error (±)*

**Table 7: Effect of Plate Making Effluent and *Ulva lactuca* on the photosynthetic pigments of *Cyamopsis tetragonoloba* Taub**

| Pigments | Control (Water) | Control (Plate Making Effluent 60%) | Plate Making Effluent + | | |
|---|---|---|---|---|---|
| | | | 2 gm /L SWP | 4 gm /L SWP | 6 gm /L SWP |
| Chlorophyll .a (mg/gLFW) | 1.59 ± 0.080 (100) | 0.72 ± 0.016 (45) | 0.85 ± 0.021 (54) | 1.04 ± 0.044 (65) | 1.45 ± 0.112 (91) |
| Chlorophyll .b (mg/gLFW) | 0.87 ± 0.016 (100) | 0.40 ± 0.90 (46) | 0.57 ± 0.016 (66) | 0.73 ± 0.020 (84) | 0.85 ± 0.028 (98) |
| Total. Chlorophyll (mg/gLFW) | 2.45 ± 0.021 (100) | 1.12 ± 0.016 (46) | 1.42 ± 0.033 (58) | 1.77 ± 0.041 (72) | 2.30 ± 0.084 (94) |
| Carotenoids (mg/gLFW) | 0.483 ± 0.011 (100) | 0.247 ± 0.060 (51) | 0.302 ± 0.023 (63) | 0.404 ± 0.040 (84) | 0.461 ± 0.010 (95) |
| Anthocyanin (mg/gLFW) | 1.43 ± 0.077 (100) | 2.49 ± 0.025 (174) | 2.18 ± 0.084 (152) | 1.85 ± 0.048 (129) | 1.48 ± 0.038 (104) |

*Values in parenthesis indicate percent activity; value represents mean of 5 samples with their standard error (±)*

Bioadsorption studies showed that the morphometric features increased (Table 6) by the application of seaweed powder. The chlorophyll content increased (Table 7) with increasing amount of seaweed powder. This result coincides with the results of Ramasubramanian *et al*., (2006). The total soluble sugar, protein content (Table 8) and nitrate reductase activity (Table 9) also increased after the application of seaweed powder. This may be due to the bioadsorption by plant biomass (*Ulva lactuca* powder) to remove / adsorb toxic elements which are present in effluent (Selvarathi *et al*., 2010). In contrary, leaf

***Research Article***

nitrate, free aminoacid and proline (Table 8) and the activity of enzymes such as catalase and peroxidase (Table 9) were found to be reduced after the application of seaweed in our studies. Our results are in accordance with findings of (Ramasubramanian *et al.*, (2006).

**Table 8: Effect of Plate Making Effluent and *Ulva lactuca* on the Biochemical characteristics of *Cyamopsis tetragonoloba* Taub**

| Parameters | Control (Water) | Control (Plate Making Effluent 60%) | Plate Making Effluent + | | |
|---|---|---|---|---|---|
| | | | 2 gm /L SWP | 4 gm /L SWP | 6 gm /L SWP |
| Total soluble Sugar (mg/g LFW) | 45.87 ± 0.88 (100) | 24.05 ± 0.250 (52) | 28.81 ± 0.182 (63) | 34.76 ± 0.672 (76) | 41.08 ± 0.843 (90) |
| Total soluble Protein (mg/g LFW) | 10.81 ± 0.157 (100) | 7.25 ± 0.174 (67) | 8.13 ± 0.049 (75) | 9.77 ± 0.052 (90) | 10.21 ± 0.168 (94) |
| Amino acid (µMole/g LFW) | 1.61 ± 0.040 (100) | 2.943 ± 0.038 (184) | 2.29 ± 0.181 (143) | 1.82 ± 0.086 (113) | 1.7 ± 0.136 (106) |
| Proline (µMole/g LFW) | 25.58 ± 0.060 (142) | 42.47 ± 0.566 (166) | 39.39 ± 0.399 (154) | 30.08 ± 0.228 (118) | 27.31 ± 0.731 (107) |
| Leaf nitrate (mg/g LFW) | 1.74 ± 0.011 (100) | 2.92 ± 0.0475 (168) | 2.63 ± 0.059 (151) | 2.20 ± 0.105 (127) | 1.70 ± 0.081 (98) |

*Values in parenthesis indicate percent activity; value represents mean of 5 samples with their standard error (±)*

**Table 9: Effect of Plate Making Effluent and Ulva lactuca on the Enzymes activity of *Cyamopsis tetragonoloba* Taub**

| Parameters | Control (Water) | Control (Plate Making Effluent 60%) | Plate Making Effluent + | | |
|---|---|---|---|---|---|
| | | | 2 gm /L SWP | 4 gm /L SWP | 6 gm /L SWP |
| Nitrate Reductase activity (µMole/g LFW) | 0.54 ± 0.014 (100) | 0.29 ± 0.048 (54) | 0.35 ± 0.021 (65) | 0.47 ± 0.017 (86) | 0.56 ± 0.019 (103) |
| Catalase activity (µMole/g LFW) | 0.25 ± 0.068 (100) | 1.25 ± 0.094 (499) | 0.86 ± 0.051 (348) | 0.69 ± 0.036 (279) | 0.37 ± 0.092 (150) |
| Peroxidase activity (µMole/g LFW) | 4.24 ± 0.017 (100) | 9.15 ± 0.020 (216) | 8.54 ± 0.244 (201) | 6.47 ± 0.387 (153) | 4.61 ± 0.191 (109) |

*Values in parenthesis indicate percent activity; value represents mean of 5 samples with their standard error (±)*
*Abbreviation (g – Gram, LFW – Leaf Fresh weight, L – litre, mg – Milligram, SWP – Seaweed powder).*

Conventional methods of removal of toxins present in the Plate making industrial effluent are expensive and hence the use of low cost environment friendly bioadsorbants has been tested. The dried algal biomass used in the present study is available in large quantities in the East Coast area of Indian sub continent. This can be utilized for removal of heavy metal and also found to be a potential, economic and effective safe alternative (Jeyakumar and Ramasubramanian, 2009).

Result of the present study clearly shows that the green algae used *i.e. Ulva lactuca* can efficiently remove the toxicity from effluent. Hence we strongly suggest that *Ulva lactuca* can be used as a bioadsorbant to remove the toxicity of effluent polluted environment for sustainable agriculture.

## REFERENCES

**Alia P and Saradhi PP (1991).** Proline accumulation under heavy metal stress. *Journal of Plant Physiology* **138** 534-538.

**Balasimha D 1982.** Regulation of peroxidase in higher plants a review. *Plant Physiolology and Biochemistry* **9(2)** 130-143.

**Cataldo DA, Garland TR and Wildung RE (1978).** Nickel in plants. I. Uptake kinetics using intact soybean seedlings. *Plant Physiology* and *Biochemistry* **62** 563-565.

**Dowton WJS (1997).** Photosynthesis in salt stressed in grape wines. *Ausralian Journal of Plant Physiology* **4** 183-192.

**Jaworski EG (1971).** Nitrate reductase assay in intact plant tissues. *Biochemistry Biophysics Research Communication.* **43** 1274-1279.

**Jayaraman J (1981).** Laboratory manual in Biochemistry, Willey-Eastern Company Limited, Madras, 1-65.

**Jeyakumar S and RamasubramanianV (2009).** Bioremoval of chromium using seaweeds as biosorbents. *Journal of Basic and Applied Biology* **3**(3&4) 121 – 128.

**Jeyarathi KP and Ramasubramanian V (2002).** Analysis of sugar mill Effluents and its impact on the growth and biochemical characteristics of *Abelmascus esculentus* (L) Mediakus.

**Kar M and Mishra D (1976).** Catalase, peroxidase and polyphenol oxidase activities during rice leaf senescence. *Journal of Plant Physiology* **57** 315- 319.

**Kumar A 1999.** Irrigational impact of industrial effect of chemical constituents of soil and plant. *Addvance in Plant Science* **14** 351 – 358.

**Lowry OH, Rosenbury NJ, Farr AL and Randall (1951).** Protein measurement with folin phenol reagent. *Journal of biochemistry* **193** 262-275.

**Rainwater FH and Thatcher LL (1963). In:** Methods of collection and analysis of water samples (Ed. Thatcher,L.L) US Government print office. Washington 45 -47.

**RamasubramanianV, Ravichandran V and N Kannan (1993).**Analysis of industrial effluents and their impact on the growth and metabolism of *Phaseolus mungo,*L.*Communication Soil Science Plant Annuals*. **24**(17&18) 2241-2249.

**Ramasubramanian V, Jeyaprakash R, Ruby Mallika DA, Ramasubbu R and Mariappan V (2004).** Analysis of physico – chemical characteristics of ground water quality and quality index in and around Sivakasi town. *Indian Journal of Environment and Ecoplan* **8**(1) 171 – 176.

**Ramasubramanian V, Jeyaprakash R and Ramasamy TN (2006).** Assessment of physico-chemical parameters in three industrial effluents. *Indian Journal of Environment Protection* **26**(12)1090-1092.

**Roshan Poi, Binesh P and Malonkar J (2000).** Textile Plate making waste water treatment – an overview. *Chemistry of Indian Digest* 95 – 98.

**Schat H, Sharma SS and Voojis R (1997).** Heavy metal induces accumulation of proline in metal tolerant and non tolerant ecotypes of *Silene Vulgaris*. *Journal of Plant Physiology* **101** 477-482.

**Selvarathi P, Jeyaprakash R, Ramasubramanian V and Veeranan P (2006).** Impact of paper mill effluent on the growth and biochemical characteristics of *Eleucine corocana*. **In**: Proceedings of National Conference on Environmental Pollution Management and Sustainable Development (Ed. Rajan, M.R.) Gandhigram University, Gandhigram 1-9.

**Selvarathi P, Ramasubramanian V and Jeyaprakash R (2010).** Bioremedial effect of *Azotobacter* and *Phosphobacterium* on the growth and biochemical characteristics of paper mill effluent treated *Lycopersicon esculentum* Mill. *Journal of Bioscience Research* **1**(1) 58 – 64.

**Selvarathi P, and Ramasubramanian V (2010).** Phytoremedial effect of *Datura metal* L. on paper mill effluent and its impact on Physicochemical characteristics of *Lycopersicon esculentum* Mill. *Journal of Bioscience Research* **1**(2) 94 – 100.

**SwainT and Hills WE (1959).** The phenolic constituents of *Prunus domestice*,L. The quantitative analysis of phenolic constitution. *Journal of Science and Food Agriculture* **10** 63 – 68.
**Swaminathan K, Arjunan J and Gurusamy R (1998).** Effect of glucose factory effluents on the seed germination and seedling development of groundnut (*Arachis hypogea*,L.). *Envirionmental Biology* **2** 187-189.
**Wellburn AR and Lichtenthaler H (1984). In**: Advances in photosynthesis Research (ed.Sybesma) Martinus Nijhoff, Co., *The Hague* **2** 9-12.
**Zar JK (1984).** Biostatistical analysis. Prentice – Hill international. INC, Engle Wood Cliffs. New Jersey.