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MATHEMATICAL APPROACH TO ASSESS PHYTOREMEDIATION POTENTIAL OF LEMNA MINOR FOR PULP AND PAPER MILL EFFLUENT-A CASE STUDY

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ABSTRACT

The Phytoremediation of Pulp and Paper Mill Effluent employing Lemna minor has been assessed in terms of reduction in pH, EC,BOD, COD, TS,TSS and TDS. The effluent has been treated for 60 days. A significant reduction in all the selected parameters of Pulp and Paper Mill Effluent over zero day value has been observed. A maximum reduction in pH of the effluent (81.81%), whilst minimum reduction in TSS content (19.01%) is observed. A model for studying the Phytoremediation Potential of Lemna minor against Pulp and Paper Mill Effluent has been developed and analyzed. All parameters exhibited exponential decrease from the start up to 45 days and thereafter showed negligible decrease till the termination of the experiment. The value of absorption coefficient (μ) is calculated from the observed values of all parameters. The proposed phytoremediation model establishes that this technique can be profitably employed for the abatement of pollution from industrial waste water.

Keywords: Lemna Minor, Phytoremediation, , Pulp And Paper Mill Effluent.

I. INTRODUCTION

Pollution affects plants and animals alike but there are some plants that possess the ability to tackle water pollution to a large extent. The industrial pollution has spoiled the three wealths of life, namely water, air and soil. The industrial effluents have caused havoc for human living on earth and therefore there is a need for the treatment of industrial effluents before disposal. The traditional physic-chemical processes employed for treatment involve high energy and large capital investment. A new approach for cleaning up of contaminated water and soil based upon the use of plants has emerged. Certain plants species function like scavengers and help in environmental clean up by retention of toxic pollutants in their bodies. Such plants are known as pollution mitigators and the process is known as Phytoremediation[1,2].

Pulp and Paper mill, categorized as one of the most polluting industries in india, releases environmentally hazardous[3] liquid effluent containing pollutants. This industry releases about 80% of the used water back into the streams[4].Studies on metal biosorption of pulp and paper mill effluent by Water hyacinth[5],Water lettuce[6] and Channel grass[7] have been carried out by many researchers.

Several comprehensive reviews[8-13] summarizing important aspects of this novel plants based technology are available. Phytoremediation potential of Vallisneria spiralis for pulp and paper industry effluent has been investigated by V.P. Singh[14] and a mathematical model for monitoring the pollution treatment by this technique has been presented by J.P.N.Rai[15].The authors[16] have already developed a mathematical model to assess the Phytoremediation potential of E.crassipes with respect to distillery effluent. Efforts have already been made to develop mathematical models of physical and chemical means of waste water treatment[17-18].Lemna minor was used to treat Romi stream of Nigeria[19]. Bianconi et al investigated the toxic effects of Cd and its bioaccumulation on *L.* minor[20].Mark R. Apelt observed that lemna minor lowered the copper concentration by 55% [21].Biosorption study of acid red dye by lemna minor have been done by Balark et al.[22].Lemna minor is suitable for cleaning of freshwaterresources containing small amounts of oil contaminants [23]. Moreover, duckweeds are used for treatment of wastewater, municipal effluents, herbicides, heavy metals and textile effluents[24-28].

It would be worthwhile to study the Phytoremediation Potential of Lemna minor with respect to Pulp and Paper mill Effluent. In the present paper attempt has been made to develop a Phytoremediation Model for the predication of pollution load abatement form Pulp and Paper Mill Effluent employing Lemna minor as a Phytoremediator.

II. METHODOLOGY

Pulp and Paper Mill Effluent was collected from the exit point of Ruchira Paper Mill , Kala-Amb (Himachal Pradesh) in Sep,2014. The effluent collected in clean plastic containers from effluent drain was stored at 4ºC until further experimentation. Lemna minor plants were collected from a natural pond along the road side. They were washed thoroughly with running tap water followed by distilled water to avoid any surface contamination.

Experiment was performed in plastic tubs (capacity 10 litre). One tub was filled with 5 litres of distilled water and the other with 5 litres of Ruchira Paper Mill Effluent. Lemna minor plants were immersed in each tub. The plants were allowed to grow and analyzed for different pollution load parameters at intervals of 15 days each between 0 to 60 days. 50ml of the samples were withdrawn from each tub at the specified interval and analysed for various physico-chemical parameters. The lost effluent on account of its analysis was made good by adding as amount of distilled water equal to the amount withdrawn from each tub.

Analysis of the chosen pollution parameters of the effluent drawn after experimental treatment was carried at 0, 15, 30, 45, 60 days of the start of the experiment using standard methods outlined in APHA[29].

III. RESULTS AND DISCUSSION

The effect of Lemna minor on physico-chemical characteristics of Paper Mill Effluent phytoremediated for different durations in respect of observed and estimated parameters have been summed up in table I & II respectively.

TABLE I: Effect of Lemna minor on Observed Physico-chemical parameters of Pulp and Paper Mill Effluent phytoremediated for different durations

Phytoremediation duration in days						
Effluent Parameter	**0**	**15**	**30**	**45**	**60**	**% reduction**
pH	8.19	7.90	7.56	7.16	6.7	81.81%
EC	974.8	683.3	457.3	404.0	236.8	24.29%
BOD	303.2	190.5	114.1	83.24	78.7	25.95%
COD	786.1	489.7	284.8	194.5	178.9	22.75%
TSS	359.8	275.6	198.5	130.0	68.4	19.01%
TDS	620.7	379.5	224.1	142.7	134.5	21.66%
Na	19.17	15.76	13.28	11.90	11.5	59.98%
K	39.25	31.3	25.71	22.61	22.64	57.68%

TABLE II: Effect of Lemna minor on Estimated Physico-chemical parameters of Pulp and Paper Mill Effluent phytoremediated for different durations

Phytoremediation duration in days						
Effluent Parameter	**0**	**15**	**30**	**45**	**60**	**% reduction**
pH	8.16	7.71	7.52	6.91	6.6	80.89%
EC	973.8	721.8	600.86	421.01	250.55	25.71%
BOD	303.12	213.18	144.68	119.24	93.12	30.72%
COD	789.11	598.12	450.39	267.17	206.33	26.40%
TSS	359.78	264.60	191.2	105.06	63.4	17.62%
TDS	620.71	489.80	350.58	197.66	260.49	41.92%
Na	19.71	14.98	14.09	12.47	11.01	57.43%
K	32.25	32.18	27.01	23.18	22.37	56.99%

It is clear that with increasing time, the concentration of the pollutants is decreased. However, beyond attainment of equilibrium Lemna minor ceases to contribute towards pollution removal. The variation in parameters caused by phytoremediation of industrial effluents cannot exceed beyond finite limit and is maximum at the first day of experiment.

IV. PHYTOREMEDIATION MODEL

Let A be the phytoremediation potential of Lemna minor at time *t* from initial day of the experiment. Then the rate of change in *A* with respect to *t* from start upto the time when plants attain equilibrium is directly proportional to A, at that time.

$$\frac{dA}{dt} \alpha A$$

$$\frac{dA}{dt} = \mu A \qquad \text{………………... (1)}$$

Where μ= Phytoremediation Absorption constant.

Integrating Eq. (1), we get

$$\ln A = \mu t + I \qquad \text{……..………… (2)}$$

Where I = Integration Constant.

At start t = 0; A will be maximum, let it be A_0.

Then, $\ln A_0 = \mu\, 0 + I$

$I = \ln A_0$

Putting the value of I in equation (2),

$\ln A = \mu t + \ln A_0$

Or $\ln A - \ln A_0 = \mu t$

Or $\ln A / A_0 = \mu t$

$$\text{Or } A = A_0 \exp(\mu t) \qquad \text{…………..... (3)}$$

Now, when plants attains equilibrium after 45 days, change in A with respect to t tends to zero,

$$\frac{dA}{dt} = 0,$$

$$\text{Which implies that } A = K \qquad \text{……………. (4)}$$

Where k = Constant.

Now combining equation (3) and (4),

$A = A_0 \exp(\mu t)$ (before attaining equilibrium)

$A = K$ (after attaining equilibrium)

The model derived is valid only for t > 0 days. The values of μ will be positive if the curves between various parameters and T are increasing, otherwise negative.

From equation (3),

$$\mu = \frac{\{\ln (A/A_0)\}}{t} = \frac{2.303\log (A/A_0)}{t}$$

Now we take t at equal interval, let these be $t_1, t_2, t_3 \ldots\ldots, t_N$. Then we calculate the values of μ

$$\mu_i = \frac{\{\ln (A/A_0)\}}{t_i} \qquad \text{where } i = 1,2,3\ldots..N.$$

Thus $\mu = \sum^N \mu_i$

1

N

Then by putting the values of μ in equation (3), One can predict the activity of phytoremediator.

For application of the model to the observed data, observations corresponding to three equidistant time intervals i.e. 0, 15, 30 and 45 days were made. The values of μ for all time intervals have also been calculated and summarized in table III & IV.

TABLE III: Calculations of $\mu = (\ln A/A_0)/t$ for the observed parameters selected for study

Observed Values of Phytoremediation Absorption Coefficient (μ)								
Days	**μ for pH**	**μ for EC**	**M for COD**	**μ for BOD**	**μ for TSS**	**μ for TDS**	**μ for Na**	**μ for K**
0	-----	----	----	----	----	----	----	----
15	-0.00236	-0.0240	-0.0323	-0.0317	-0.0179	-0.0392	-0.01324	-0.01539
30	-0.00255	-0.0248	-0.0334	-0.0326	-0.0198	-0.0395	-0.01221	-0.01409
45	-0.00293	-0.0258	-0.0312	-0.0290	-0.0228	-0.0329	-0.01056	-0.01186
Mean μ_i	-0.00261	-0.0244	-0.0323	-0.0311	-0.0201	-0.0328	-0.0328	-0.0137

Table-IV Calculations of μ $(\ln A/A_0)/t$ for the estimated parameters selected for study

Estimated Values of Phytoremediation Absorption Coefficient (μ)								
Days	**μ for pH**	**μ for EC**	**μ for COD**	**μ for BOD**	**μ for TSS**	**μ for TDS**	**μ for Na**	**μ for K**
0	-----	----	----	----	----	----	----	----
15	-0.00378	-0.01996	-0.01822	-0.0235	-0.0204	-0.0158	-0.0164	-0.01324
30	-0.00272	-0.01609	-0.01856	-0.0246	-0.0210	-0.0190	-0.0102	-0.01245
45	-0.00369	-0.01863	-0.02398	-0.0207	-0.0273	-0.02543	-0.0955	-0.01170
Mean μ_i	-0.00339	-0.01823	-0.02025	-0.02025	-0.02297	-0.02080	-0.02098	-0.02103

Phytoremediator plant almost stopped functioning after 45 days of phytoremediation, hence data collected beyond 45 days has been omitted from calculating μ.

All parameters exhibited potential decrease in activity of Lemna minor from the start of the experiment upto 45 days, and thereafter showed negligible decrease. This pattern of take up of nutrients from industrial waste could be attributed to carrying capacity of phytoremediator plants[30].

A comparison between the estimated values and observed values of a given parameter of the effluent shows minimum variation which is evident from the values of μ and also from the percentage reduction of different parameters in respect of the observed and estimated values. With increase in phytoremediation duration, estimated values of the parameter exceed observed values excepting pH which decreased, especially beyond 45 days. This supports that with increase in phytoremediation period, the phytoremediator has attained equilibrium level of absorption of the pollutants present in the effluent and beyond that stage the reduction in parameters studied was stopped.

V. CONCLUSION

The proposed model can be employed for predicting the trend of phytoremediation potential of Lemna minor for Pulp and Paper Mill Effluent at any time interval. It opens a way to develop models in respect of other similar industrial effluents using other Phytoremediating plant besides Lemna minor. Rapid monitoring of industrial pollution treatment using plants can be done from the proposed model. It establishes the fact that Phytoremediation ia a cost effective, eco-friendly technique which can be profitably employed for the abatement of pollution from industrial waste water[31].

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