Mathematical Approach to Assess Phytoremediation Potential of Water Hyacinth (E Crassipes) For Distillery Effluent-A Case Study

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Abstract

The Phytoremediation of distillery effluent employing water hyacinth as a phytoremediator has been assessed in terms of reduction in pH, EC,BOD, COD, TSS, TDS, Na and K. the effluent has been treated for 60 days. A significant reduction in all the selected parameters of distillery effluent over zero day value has been observed. A model for studying the phytoremediation potential of water hyacinth (E. crassipes,) against distillery 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) calculated from the observed as well as estimated values of all parameters have been found comparable. The proposed phytoremediation model establishes that this technique can be profitably employed for the abatement of pollution from industrial waste water.

Keywords: Phytoremediation, Eichhornia Crassipes, distillery effluent.

Introduction

Rapid urbanization and industrialization has led to increased disposal of pollutants such as heavy metals, agrochemicals and various types of organics and inorganics into the aquatic environment. All industries in general and distilleries in particular release environmentally hazardous effluent containing several harmful contaminants and other toxicants.

Distilleries manufacture rectified spirit and extra neutral alcohol for human consumption and for industrial utilization. Looking to its wide use, it can be inferred that demand of alcohol will increase in the country and so will the number of distilleries producing alcohol. Most of the Indian distilleries use molasses as raw material for producing ethylalcohol from the fermentable sugars contained in molasses. The distilleries produce waste water, commonly known as spent wash which is characterized by its high percentage of dissolved organic and inorganic matter, dark brown colour, high temperature, low pH and high ash content. Therefore, the treatment of distillery waste water is essential prior to its disposal on land, river, lakes etc. If disposed untreated on land, it reduces alkalinity of the soil, the crops may be destroyed and ground water gets contaminated. Due to its colour the distillery waste water behaves much more hazardous when disposed into water bodies, since it will result in the complete depletion of D.O. and aquatic life will be destroyed.

The dark brown colour of distillery waste water is caused by phenolic, caramel & melanoidin compounds. Out of these mainly melanoidin is responsible for imparting the characteristic colour to the distillery waste water. Studies on its chemical properties and possible molecular structure revealed that melanoidin is negatively charged. Melanoidins resemble humic substances in their chemical properties being acidic, polymeric and highly dispersed colloids, which are negatively charged due to the dissociation of carboxylic and hydroxylic groups. So treatment of distillery waste water disposal is very important. The conventional physico-chemical processes employed in industrial waste water treatment involve high energy and large capital investments.

In recent years, it has been found that several plants are capable of reducing heavy metals, metalloids, pesticides, petroleum hydrocarbons and other organic and inorganic chemicals. The process of restoration of quality of environment by the application of plants is called phytoremediation and the plants used for this purpose are called phytoremediators. Several comprehensive reviews summarizing important aspects of this novel plant based technology are available. The development of phytoremediation into a promising, cost effective and environment friendly technology is due to a series of fascinating scientific discoveries combined with an interdisciplinary research approach.

The basic idea of that plants can be used for environmental remediation has been around for the long time. There have been numerous reports on
aquatic plants such as duckweed, water hyacinth that can accumulate various toxicants. Studies on assessment of phytoremediation potential of water hyacinth (E. Crassipes) and Trapa bispinosk of pulp and paper mill waste water have been carried out9-10. Similar studies on phytoremediation of pulp and paper and distillery effluent by channel grass (Vallisneria spiralis) have been reported11. Phytoremediation technologies have gained considerable momentum in the last one decade and currently in process of commercialization12-15.

Mathematical models for the assessment of pollution load removal by physico-chemical techniques have also been developed by some researchers16. Efforts have already been made to develop mathematical models of physical and chemical means of waste water treatment17-18. In the present paper attempt has been made to develop a phytoremediation model for the predication of pollution load abatement form distilleries effluent employing water hyacinth as a phytoremediator.

Methodology

Distillery effluent was collected from the exit point of Haryana Distillery, Yamuna Nagar (Haryana) in Nov,2009. The effluent collected in clean plastic containers from effluent drain was stored at 4ºC until further experimentation. Young water hyacinth plants collected from a natural pond along the road side 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 distillery effluent. Equal number of uniform size water hyacinth plant roots 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.

Results and Discussion

The effect of E. crassipes on physico-chemical characteristics of distillery 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 Water Hyacinth on observed physico-chemical parameters of distillery effluent phytoremediated for different durations

<table>
<thead>
<tr>
<th>Effluent Parameter</th>
<th>Phytoremediation duration in days</th>
<th>0</th>
<th>15</th>
<th>30</th>
<th>45</th>
<th>60</th>
<th>% reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td></td>
<td>6.20</td>
<td>6.08</td>
<td>6.00</td>
<td>5.98</td>
<td>5.8</td>
<td>6.45%</td>
</tr>
<tr>
<td>EC</td>
<td></td>
<td>5154.40</td>
<td>4164.06</td>
<td>3453.26</td>
<td>3127.78</td>
<td>3002.53</td>
<td>41.74%</td>
</tr>
<tr>
<td>BOD</td>
<td></td>
<td>9780.24</td>
<td>8279.92</td>
<td>7054.50</td>
<td>6054.20</td>
<td>5428.86</td>
<td>44.49%</td>
</tr>
<tr>
<td>COD</td>
<td></td>
<td>14552.60</td>
<td>12010.28</td>
<td>10284.96</td>
<td>10109.18</td>
<td>9579.86</td>
<td>34.17%</td>
</tr>
<tr>
<td>TSS</td>
<td></td>
<td>7164.78</td>
<td>5640.06</td>
<td>4934.82</td>
<td>4422.48</td>
<td>4180.16</td>
<td>41.65%</td>
</tr>
<tr>
<td>TDS</td>
<td></td>
<td>15386.60</td>
<td>12844.20</td>
<td>11771.86</td>
<td>10696.44</td>
<td>10375.20</td>
<td>32.56%</td>
</tr>
<tr>
<td>Na</td>
<td></td>
<td>572.46</td>
<td>367.12</td>
<td>264.78</td>
<td>212.46</td>
<td>190.68</td>
<td>65.29%</td>
</tr>
<tr>
<td>K</td>
<td></td>
<td>820.80</td>
<td>568.08</td>
<td>444.36</td>
<td>366.12</td>
<td>320.88</td>
<td>60.96%</td>
</tr>
</tbody>
</table>

Table II: Effect of Water Hyacinth on observed physico-chemical parameters of distillery effluent phytoremediated for different durations
It is clear that with increasing time, the concentration of the pollutants is decreased. However beyond attainment of equilibrium water hyacinth 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.

**Phytoremediation Model**

Let \( A \) be the phytoremediation potential of water hyacinth 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.

\[
\frac{dA}{dt} = \mu A
\]

where \( \mu \) is a constant. Integrating Eq. (i),

\[
\ln A = \mu t + I \quad \text{...(ii)}
\]

Where \( I \) is the constant of integration. At start \( t = 0 \); \( A \) will be maximum, let it be \( A_0 \). Then,

\[
\ln A_0 = \mu 0 + I \quad \text{or} \quad I = \ln A_0
\]

Putting the value of \( I \) in equation (ii),

\[
\ln A = \mu t + \ln A_0
\]

Or

\[
\ln A - \ln A_0 = \mu t
\]

Or

\[
\ln A / A_0 = \mu t \quad \text{or} \quad A / A_0 = \exp (\mu t)
\]

Or

\[
A = A_0 \exp (\mu t) \quad \text{...(iii)}
\]

Now when plants attain equilibrium after 45 days, change in \( A \) with respect to \( t \) tends to zero,

\[
\frac{dA}{dt} = 0,
\]

which implies that \( A = K \)  

... (iv)

where \( k \) ia s constant. Now combining equation (iii) and (iv),

\[
A = A_0 \exp (\mu t) \quad \text{(before attaining equilibrium)}
\]

\[
= k \quad \text{(after attaining equilibrium)} \quad \text{...(v)}
\]

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

From equation (iii),

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

Now we take \( t \) at equal interval, let these be \( t_1, t_2, \ldots, t_N \). Then we calculate the values of \( \mu \)

\[
\mu_i = \frac{\ln (A/A_0)}{t_i} \quad \text{where} \quad I = 1,2,3, \ldots, N.
\]

Thus

\[
\mu = \frac{\sum_{i=1}^{N} \mu_i}{N}
\]

Then by putting the values of \( \mu \) in equation (iii) 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 \( \mu \) for all time intervals have also, been calculated and summarized in table III & IV.

**Table-III Calculations of \( \mu (\ln A_0/A_0) / t \) for the observed parameters selected for study**

<table>
<thead>
<tr>
<th>Effluent Parameter</th>
<th>0</th>
<th>15</th>
<th>30</th>
<th>45</th>
<th>60</th>
<th>% reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>6.17</td>
<td>6.02</td>
<td>5.98</td>
<td>5.69</td>
<td>5.54</td>
<td>10.2%</td>
</tr>
<tr>
<td>EC</td>
<td>5154.40</td>
<td>4219.08</td>
<td>3543.84</td>
<td>3238.52</td>
<td>3113.10</td>
<td>39.48%</td>
</tr>
<tr>
<td>BOD</td>
<td>9775.23</td>
<td>8359.81</td>
<td>7136.39</td>
<td>6250.93</td>
<td>5678.51</td>
<td>41.90%</td>
</tr>
<tr>
<td>COD</td>
<td>14542.52</td>
<td>12138.20</td>
<td>10992.86</td>
<td>10217.50</td>
<td>9662.88</td>
<td>33.55%</td>
</tr>
<tr>
<td>TSS</td>
<td>7158.84</td>
<td>5684.12</td>
<td>4985.74</td>
<td>4596.10</td>
<td>4287.78</td>
<td>42.89%</td>
</tr>
<tr>
<td>TDS</td>
<td>15380.64</td>
<td>13337.86</td>
<td>12325.44</td>
<td>11417.12</td>
<td>10804.80</td>
<td>29.75%</td>
</tr>
<tr>
<td>Na</td>
<td>568.63</td>
<td>384.29</td>
<td>296.04</td>
<td>220.76</td>
<td>198.34</td>
<td>66.52%</td>
</tr>
<tr>
<td>K</td>
<td>805.86</td>
<td>601.54</td>
<td>492.97</td>
<td>397.55</td>
<td>335.12</td>
<td>62.13%</td>
</tr>
</tbody>
</table>
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 water hyacinth from the start of the experiment upto 45 days, and thereafter showed negligible decrease. This pattern of take up of pollutants from industrial waste could be attributed to carrying capacity of phytoremediator plants. As has been reported earlier26.

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 40 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.

Conclusion

The proposed model can be employed for predicting the trend of phytoremediation potential of water hyacinth for distillery effluent at any time interval. It opens a way to develop models in respect of other similar industrial effluents using other Phytoremediating plant besides water hyacinth. 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.

Acknowledgement

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References

2. Kumar S. and Vishvanatham L., Production of


