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Discovery

Phytoremediation of Cyanide and Phenol from wastewater by *Zea Mays (Maize)* plants

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ABSTRACT

The constituents of waste water from coke industry have various pollutants, but cyanide and phenol are more toxic pollutants in the environment. In this study the treatment of waste water was done by the maize plants using phytoremediation method. The experiment was processed in a phytoremediation chamber at 25 ℃ temperature and 75 % relative humidity. The presence of cyanide and phenol in the waste water was effected the Normalized relative transpiration and the percentage removal of cyanide and phenol. The effect of initial concentration and pH on the percentage removal was observed. The metabolic properties of Maize plants change with the different concentration of cyanide and phenol. The experimental data were fitted in the Langmuir and Temkin isotherm and the best suited model for the maize plants was Langmuir isotherm for the cyanide and phenol.

Keywords: Cyanide, Normalized Relative Transpiration, Phenol, Phytoremediation.

1. INTRODUCTION

The toxicity of cyanide to humans is of well known topic in these days. The mean lethal dose for an adult human is 50-200 mg [Sridhar et.al 2002]. Cyanide is a strong molecule which can complex with any heavy metal. Hence cyanide can be used as an agent for metal finishing and treatment and also as a reagent for leaching of metals, especially in the case gold and silver [Kuhn et.al

1974]. Phenol is also considered as major pollutants in wastewater discharges from coal conversion processes and also in wastewater from fungicides, herbicides and insecticide production and can become a major risk to the health of human. But both cyanide and phenol are found in significant amount in the coke industry wastewater. Hence the treatment of cyanide and phenol is considered as a major problem in current days. USEPA, WHO and CPCB set the maximum contaminant limit of cyanide and phenol is 0.2 mg/l and 0.5 mg/l for the wastewater discharge [Vedula et.al 2011]. Various physiochemical methods, oxidation methods, electricity based methods have been found in these for the removal of cyanide and phenol such as adsorption, leaching, ion exchange, oxidization, membrane separation and precipitation [Busca et.al 2008]. These methods have various advantages for the treatment of wastewater, but a few disadvantages make these methods less efficient in the treatment process. Hence phytoremediation method is introduced to overcome these advantages of present wastewater treatment methods. Phytoremediation method is a wastewater treatment method which utilizes plants and associated rhizosphere micro-organisms to remove, transform the toxic pollutants present in soils, sediments, surface waters, ground waters and also the atmosphere. Phytoremediation methods are utilized plants for the remediation process; hence it is a low cost waste water treatment method. For high concentration of pollutants phytoremediation is initial treatment method, but for low concentration of pollutants, the phytoremediation is alone become the most economical and effective remediation process [Mathias et.al 2007].

In the present study the removal of cyanide and phenol by Zea Mays plants has been studied and the toxicity of cyanide and phenol for these plants has been observed. By assuming the phytoremediation experiment as the batch experiment with a single component, the sorption isotherms such as Langmuir and Temkin isotherms were applied to the experimental data.

Normalized Relative Transpiration (NRT)

Transpiration, Biomass Growth, Root growth and Stem growth are expressed as the measure of the toxicity of pollutants in the plants.. Transpiration can be calculated easily and directly by measuring the weight of the plant with pot.The transpiration is normalized with respect to initial transpiration and also with respect to the initial transpiration. The mean normalized relative transpiration (NRT) is calculated by [Trapp et.al 2000]

$$NRT(C,t) = \frac{\frac{1}{n}\sum_{i=1}^{n}\frac{T_i(C,t)}{T_i(C,0)}}{\frac{1}{m}\sum_{j=1}^{m}\frac{T_j(0,t)}{T_j(0,0)}} \quad (1)$$

Where C is the concentration of pollutants in mg/l, it is the time period in h till the end of the experiment, T is the absolute transpiration in g/h and n and m are the number of replicates for exposed and control plants. Water use efficiency of production is defined as the inverse of transpiration and can be calculated by the ratio of biomass growth of plants (g) and the transpired water.

Study of Metabolic Parameters

In this study the metabolic parameters taken are Chlorophyll a, Chlorophyll b, Protein, Carbohydrates and starch [Pdamapriya et.al 2012].

Chlorophyll Measurement

Chlorophyll measurement in leaves was calculated after the experiment by the spectrophotometer. The content of chlorophyll a and b in leaves of plants was calculated with the help of given formula [Maclachalam et.al 1963].

$$C_a = \frac{(12.3D_{663} - 0.86D_{645})V}{100*d*W} \quad (2)$$

$$C_b = \frac{(19.3D_{645} - 3.60D_{663})V}{100*d*W} \quad (3)$$

Where C_a is the concentration of chlorophyll a (mg/g FW), C_b is the concentration of chlorophyll b (mg/ g FW), D is the optical density (OD) at the specific wavelength indicated, V is the final volume mL), W is the fresh weight of leaf materials (g), and d is the length of the light path (cm) [30].

Biosorption Studies

The phytoremediation experiment of cyanide and phenol were done on the healthy *Zea Mays* (Maize) plants of different biomass. Effect of pH and initial concentration has been observed on the percentage removal of cyanide and phenol. The initial concentration of cyanide and phenol were taken are 5, 15, 25 and 35 mg/l.

Adsorption Isotherms

The amount of pollutants per unit Biosorbent can be obtained with the following expression [Pdamapriya et.al 2012].

$$q_e = \frac{(C_i - C_e)V}{g} \quad (4)$$

Where C_i and C_e Are the initial and final concentration, V is the volume of solution and g is the weight of plants. In the present study the plants are considered as the biosorber. In this study the Langmuir and Temkin isotherm are applied to the experimental data to verify the fit of the model.

Langmuir Isotherm

The Langmuir isotherm is applied for the monolayer adsorption on the surface with a finite number of binding sites [Langmuir 1918]. The linearized form of Langmuir isotherm is

$$\frac{C_e}{q_e} = \frac{1}{Bq_m} + \frac{C_e}{q_m} \quad (5)$$

Where q_m Is the maximum absorptive capacity for a monolayer adsorption, B is the Langmuir coefficient defines the affinity between sorbet and Sorbent. These parameters are determined from the slope and the intercept of the graph drawn between C_e/q_e and C_e Which is given in the figure. Where C_e is the equilibrium concentration (mg/l) and q_e is the amount of biosorbed pollutants (mg/g). Dimensionless constant R_L which is calculated by the following formula is an important characteristic of Langmuir isotherm and explains the nature of the isotherm. This formula is given by [McKay et.al 2012].

$$R_L = \frac{1}{1+BC_i} \quad (6)$$

Where B is the Langmuir constant and C_i is the initial concentration. The nature of the Langmuir isotherm at different values are taken as R_L=0 as Irreversible, R_L=1 as Linear, R_L>1 as unfavourable and 0< R_L<1 as favourable [Dawodu et.al 2012].

Temkin Isotherm

Temkin isotherm explains the interaction between the sorbent and the sorbed pollutants and is based on the sorption that the free energy of sorption as the function of surface coverage [KKH et.al 1999]. The linearized form of Temkin isotherm is given as

$$q_e = B \ln A + B \ln C_e \quad (7)$$

Where A and B are the Temkin isotherm [Dawody et.al 2012].

2. MATERIALS AND METHODS

Zea Mays (Maize) plants were germinated in 8 days to get a required length of the roots of each seed. After the growth of each seed to a well developed plant, every plant was planted in Hoagland solution with different concentration of cyanide and phenol such as 0, 5, 15, 25 and 35 mg/l. Then all plants were transferred in the phytoremediation chamber with 18h light period and 25℃ temperature and 75% relative humidity.

3. RESULTS AND DISCUSSIONS

Normalized Relative Transpiration (NRT)

Figure 1(a) and 1(b) shows the variation in % NRT with time for the removal of Cyanide and Phenol respectively. Plants with 35 mg/l concentration of cyanide show lowest percentage of NRT i.e. 49% and plants with 5 mg/l concentration of phenol show highest percentage of NRT i.e. 83%. This variation is because of the sickness of the plants after 2 days.

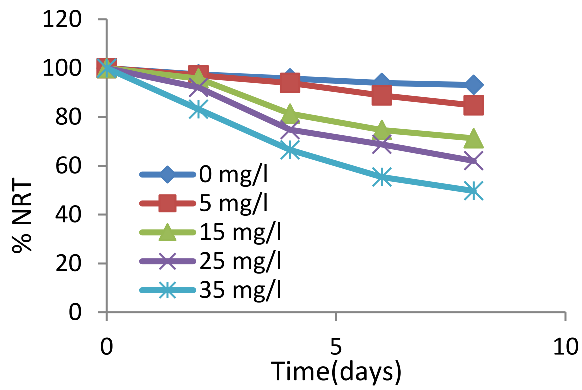

Fig.1(a) Variation in % NRT with time for cyanide

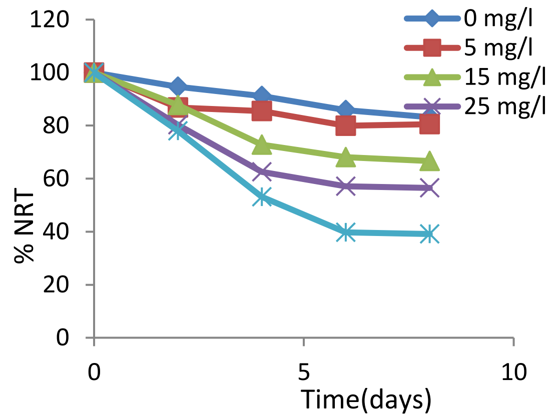

Fig.1(b) Variation in % NRT with time for phenol

Percentage Removal

Figure 2 represent the percentage removal of cyanide and phenol at different concentration respectively. The percentage removal of cyanide with maize plants was reduced from 44% to 32% at the concentration 5 mg/l and 35 mg/l but in the case of phenol the percentage removal was reduced from 43% to 30% at 5 mg/l and 35 mg/l concentration.

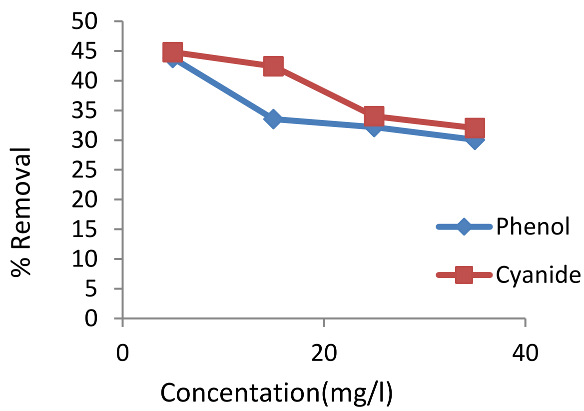

Fig.2 % Removal of cyanide and phenol at diffrent concentration

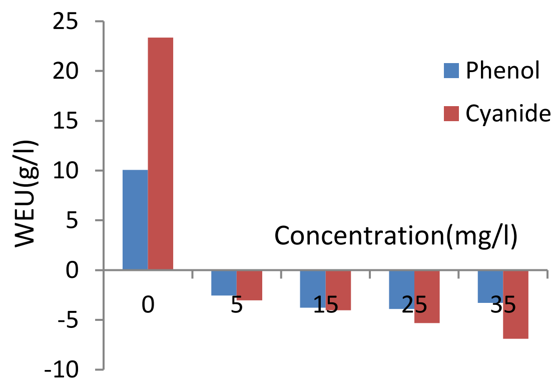

Fig.3 Water Use Effieciency at diffrent concetration of cynaide and phenol

Water Use Efficiency

The water use efficiency of maize plants at different concentration of cyanide and phenol is depicted through the figure 3. The biomass growth of control plant is positive, hence the water use efficiency of control plants has also a positive value, but plants with the cyanide and phenol concentration has a negative value of water use efficiency. When plants became pale after 3 days, then the efficiency of plants in water use reduces.

Metabolic Changes in plants

Chlorophyll Measurement

Fig.4 shows the Chlorophyll content of maize plant at different concentration of cyanide and phenol [Pramod et.al 2011].

Protein content in plants

Fig.5 Shows the protein content of maize plant at different concentration of cyanide and phenol [Lowry et.al 1951].

Carbohydrate content in plants

Fig.6 Shows the Carbohydrate content of maize plant at different concentration of cyanide and phenol [Dubois et.al 1956].

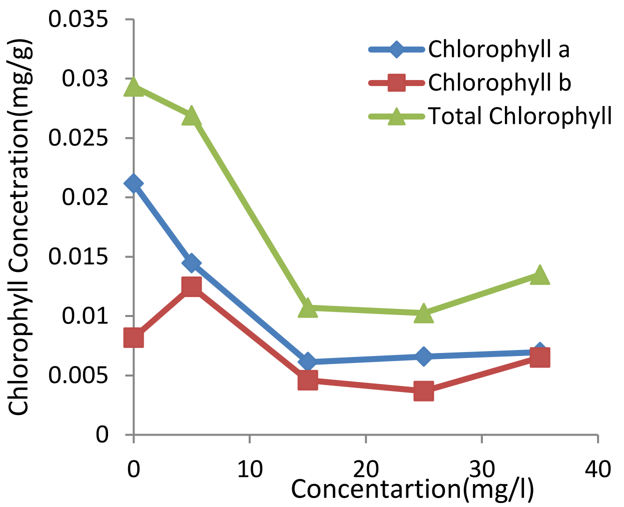

Fig.4(a) Chlorophyll concentration of plant at different concentration of cyanide

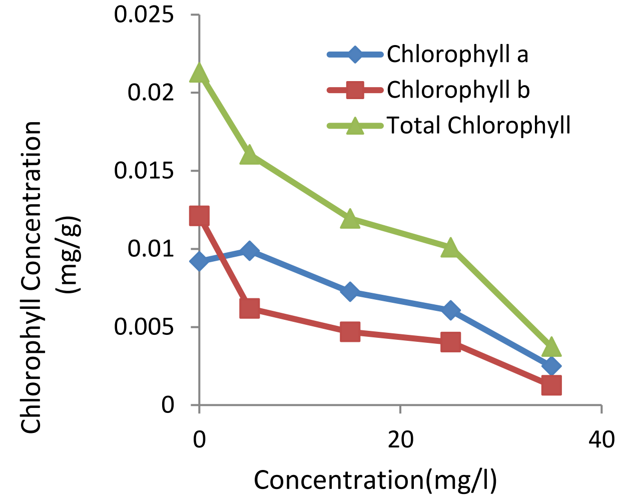

Fig.4(b) Chlorophyll concentration of plant at different concentration of phenol

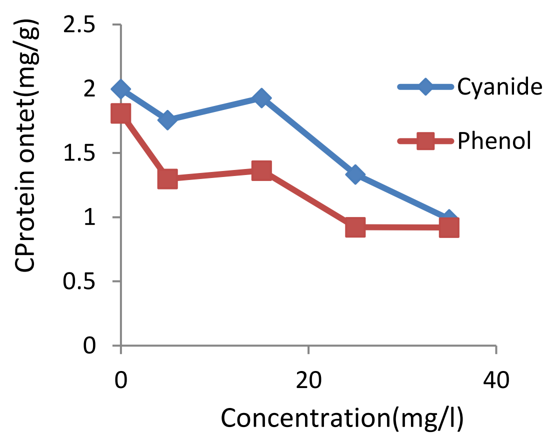

Fig.5 Protein content at different concntration of cyanide and phenol

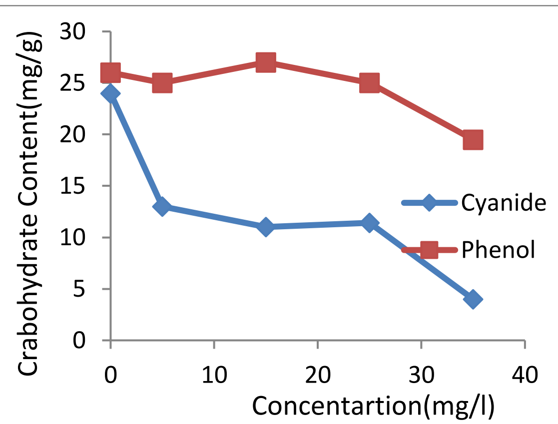

Fig.6 Carbohydrate content at different concntration of cyanide and phenol

Starch content in plants

Fig.7 Shows the Starch content of maize plant at different concentration of cyanide and phenol [Dubois et.al 1956].

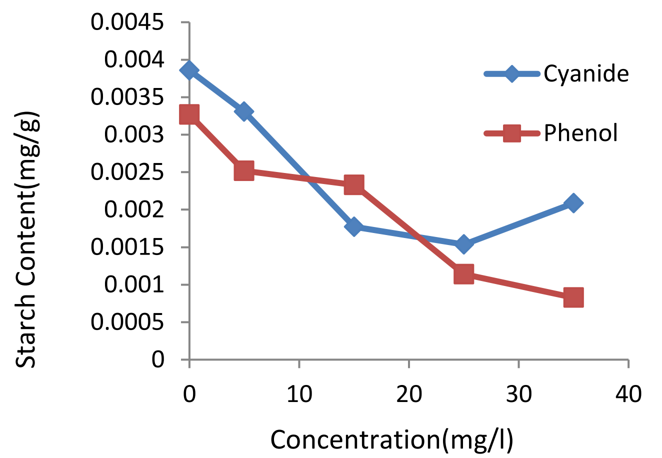

Fig. 7 Starch content at different concentration of cyanide and phenol

Isotherm Modelling

Fig.8 and 9 shows the Langmuir and Temkin isotherm of maize for cyanide and phenol respectively. The parameters of both models and correlation coefficients are tabulated in the table 1. From these data it was observed that the experimental data of phytoremediation of cyanide and phenol was best fitted into Langmuir isotherm. The value of R_L explains that the Langmuir isotherm was favourable to the experimental data.

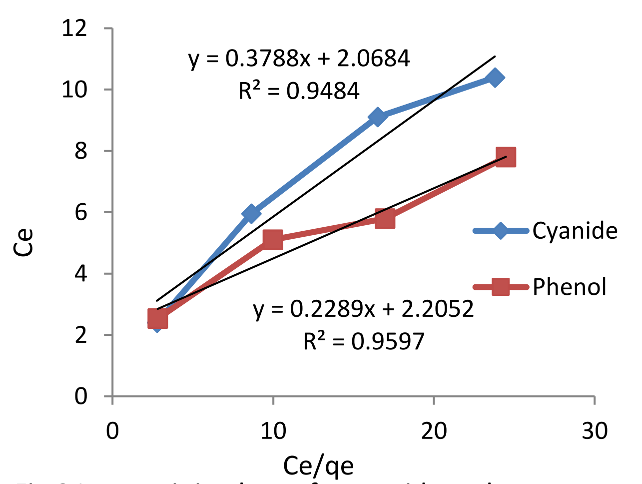

Fig.8 Langmuir isotherm for cyanide and phenol

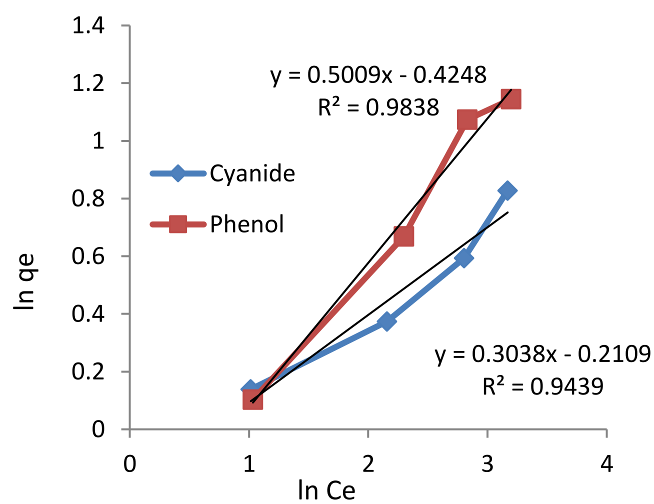

Fig.9 Temkin isotherm for cyaide and phenol

Langmuir Isotherm

Temkin Isotherm

Table 1 Constant and correlation coefficient of Langmuir and Temkin isotherm for phytoremediation of phenol and cyanide in Zea Mays plants

Model	Parameters	Cyanide	Phenol
Langmuir isotherm	R^2	0.9484	0.959
	q_m	0.4834	0.4534
	B	0.2491	0.5047
	R_L	0.4453	0.2837
Temkin Isotherm	R^2	0.8876	0.9535
	B	0.489	0.9675
	A	3.1270	1.018

4. CONCLUSIONS

The results of the phytoremediation of cyanide and phenol indicate that the removal of cyanide and phenol by maize plants is insignificant amount and the cyanide and phenol were also accumulated in the plants. The maize plants have a minimum life in the presence of cyanide and phenol but its immediate the wastewater, but if nutrients are added in the aqueous solution then maize plants can survive for more days. Maize plants can also be used as biosorbent for the removal of cyanide and phenol. The Langmuir and Temkin isotherm models were used for the comparison of experimental data and best fitted model is Langmuir isotherm. The metabolic property of maize plants also reduces by the effect of cyanide and phenol concentration. But maize plants are also used as a food for the animal and if these plants are used as a Remediator for cyanide and phenol then it can be harmful to the environment.

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