ISSN: 0974-2115
www.jchps.com Journal of Chemical and Pharmaceutical Sciences

Influence of fungi species for reducing chromium in tannery industry wastewater

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ABSTRACT

The present study focused to isolate the different fungi species from soil samples of municipal solid waste dumping yard site located on the Ambattur Industrial Estate and reduced the Cr(VI) from tannery industry wastewater of Nagalkeni, Chennai using those isolated fungi species. The experiments were conducted against the effect of pH, fungi biomass and different Cr(VI) concentration (different dilution ratio) to know the effectiveness of fungi for removing Cr(VI) ions from tannery industry wastewater. The results showed that the order of maximum removal of Cr(VI) by the fungi at an optimum pH of 3, an optimum fungi biomass of 3g and an optimum dilution ratio of 3 was Aspergillus niger (98.6 %) > Rhizopus arrhizus (93.77 %) > Mucor racemosus (91.27 %). The maximum removal of Cr(VI) ions from the tannery industry wastewater was achieved by Aspergillus niger than other fungi species. Also, the study focused on validating the removal of Cr(VI) ions from tannery industry wastewater with the removal of Cu ions in an aqueous solution by the same isolated fungi species.

KEY WORDS: fungi, chromium, tannery.

1. INTRODUCTION

Development of rapidly increasing industry and population growth, utilization of water for various purposes increases tremendously, as a result, sources of water are polluted by discharging wastewater from both industry and domestic sectors. When compared to water pollution caused by domestic sector, pollution caused by industry sector contributes more. The controlling the effect of pollutant from an industrial wastewater is problematic issue, since, surface water and groundwater is contaminated due to percolation of wastewater when it is not treated and discharged properly (Sivakumar Durairaj, 2013c; Sivakumar, 2011).

Today, the heavy metals like Cu, Zn, Ni, Pb, Cd, and Cr into various sources of drinking water pose a great threat to public health. Among these heavy metals, pollution by chromium is of major concern as the metal is used in electroplating, leather tanning, metal finishing, and chromate preparation. Chromium occurs in aqueous systems in trivalent and hexavalent forms (Fabianil, 1996). However, the latter form is of particular concern due to its greater toxicity. Human is facing the problems like gastric system, epigastric pain, nausea, vomiting, severe diarrhoea, corrosion of the skin, respiratory tract and lung carcinoma when consumed the chromium polluted water. Due to this reason, the chromium in contaminated water has to be removed. Removal of Cr(VI) ions from industrial wastewater (Donmez and Aksu, 2002) is achieved principally by the application of several conventional processes such as reduction followed by sedimentation (Song, 2000), physico-chemical method (Kurniawan, 2006), chemical precipitation, adsorption (Sivakumar and Nouri, 2015; Sivakumar, 2014c; Sivakumar, 2014f; Sivakumar, 2014g; Sivakumar, 2014k; Shankar, 2014a; Sivakumar, 2013b; Sivakumar and Shankar, 2012; Karaca, 2008), electrochemical processes (Oda and Nakagawa, 2003), ion exchange, biological operations (Kapoora, 1999), cementation, coagulation / flocculation ((Hoda Roushdy Guendy, 2010; Song, 2004), filtration and membrane processes (Hafez, 2002), bioremediation (Shankar, 2014b; Sivakumar, 2014d; Sivakumar, 2014e), constructed wetland (Sivakumar, 2013a; Sivakumar, 2014h; Sivakumar, 2015), electrochemical method (Lin, 1994), electro deionization process (Lu, 2010) and electro-dialysis (Sivakumar, 2014i; Sivakumar, 2014j) and solvent extraction.

Detoxification of Cr(VI) by naturally occurring microorganisms provides a viable option to protect the environment from chromium toxicity. Bacteria, fungi, yeast and algae are abundantly available in nature are a potential alternative to conventional methods that are used to decontaminate liquid wastes. Fungi offer the advantage of having cell wall material, which shows excellent metal-binding properties (Gupta, 2000). Similarly, it can adapt and grow under various extreme conditions of pH, temperature, nutrient availability and high metal concentrations. Thus, the present study focuses to isolate the different fungi species from soil samples of municipal solid waste dumping yard site located on the Ambattur Industrial Estate. The isolated different fungi species are used to remove the Cr(VI) from tannery industry wastewater. Further, the results of experiments were validated by conducting the same experiments for the removal of Cu in an aqueous solution by the same isolated fungi species.

2. MATERIALS AND METHODS

2.1. Study Area: Ambattur is a town in the Ambattur Taluk of the Thiruvallur District of Tamil Nadu. Ambattur is a part of Chennai Corporation. Closer to Anna Nagar, Padi and Avadi. Ambattur is a fast developing residential locality and IT hub of Chennai. It covers an area of 45 km². In olden days, Ambattur was a village with large

extents of agricultural farmlands irrigated by sprawling Ambattur Lake. Presently, due to evaluation of different types of industries, Ambattur Lake was polluted by the wastewater generated from various industries. Further, solid wastes generated from the Ambattur industrial estate was dumped nearer to Ambattur Lake, as a result, the soil and groundwater in the Ambattur industrial estate was contaminated due to the influence of contaminated Ambattur Lake water and leachate of solid waste from dumping yard.

Nagalkeni is situated in Kanchipuram District, Tamil Nadu. Nagalkeni with 12.96 Latitude and 80.13 Longitude. Nagalkeni is where the leather industry once thrived. The groundwater was polluted by tannery industries situated in Nagalkeni. In addition, the area continues to be an industrial center; one noted the company is the Tag Corporation, which manufactures heavy electrical equipment. The contaminated soil due to solid waste of Ambattur industrial estate was used for isolating the different fungi, which in turn used to remove the Cr(VI) from tannery industry wastewater of Nagalkeni.

2.2. Soil Sample Collection: For this purpose, soil samples were collected from soil samples from municipal solid waste dumping yard site located on the Ambattur Industrial Estate, where all untreated sewage and industrial wastewater was disposed off, results, heavy metals and toxic chemicals contaminate Ambattur Industrial Estate. Soil samples were collected by randomly at 5 places around the Ambattur Industrial Estate site and composite soil sample was prepared by mixing of soil samples from 5 sites and it was taken for laboratory and stored at 4 °C to ensure minimal biological activity. The isolation of fungi was carried out within 24 h of sample collection for further investigation.

2.3. Wastewater Sample Collection: Totally, 5 wastewater samples were collected without the presence of bubbles using cleaned air tight plastic bottles at Nagalkeni, Pallavaram, Chennai, where clusters of tannery industries are available. The sampling locations were randomly selected throughout the study area. The collected samples took to the environmental engineering laboratory for various physico-chemical analyses.

Various physico-chemical parameters such as pH, total dissolved solids (TDS), total solids (TS), chemical oxygen demand (COD), biochemical oxygen demand (BOD), and sulphate (SO_4^{2-}) in the wastewater samples were analyzed before and after treating with fungi by using standard procedures prescribed by APHA, AWWA, and WEF, 2005. The chromium (Cr^{6+}) was also measured before and after treating with fungi with the help of UV spectrophotometer. The physico-chemical parameters of tannery industry wastewater are given in Table 1.

Table.1.Physico-chemical characteristics of tannery industry wastewater

Characteristics	Values
pH	7.6
TDS	12350 mg/L
TS	16625 mg/L
COD	8256 mg/L
BOD	5689 mg/L
Sulphate	852 mg/L
Chromium	90.2 mg/L

Table.2.The isolated fungi from soil samples

Fungi Symbol	Isolated Fungi	Sample Code
F1	*Aspergillus niger*	S1,S2,S3,S4
F2	*Aspergillus fumigatus*	S5,S6,S7
F3	*Aspergillus flavus*	S8,S9,S10
F4	*Rhizopus arrhizus*	S11,S12
F5	*Saccharomyces cerevisiae*	S13,S14
F6	*Mucor racemosus*	S15,S17,18

2.4. Sterilization of Apparatus: Petri plates, media bottles, distilled water, McCartney bottles and syringes were sterilized in an autoclave for 60 min. at 120°C. After autoclaving all sterilized material dried in oven at 100°C.

2.5. Media Preparation: Potato Dextrose Agar (PDA) media were used for the isolation of fungi. For the preparation of PDA, potatoes (200 g) were peeled, sliced and boiled, and then sieved through a clean muslin cloth to get a broth in which agar (10 g) and dextrose sugar (10 g) was added. The media was then autoclaved for 30 minutes at 120°C.

2.6. Isolation of Fungi: Fungi were isolated on Potato Dextrose Agar (PDA) by the soil dilution method. Poured the media in Petri-dishes and allowed to solidify for 48 hours. To suppress the bacterial growth, 25 mg/L of streptomycin was added to the medium. After solidification, the plates were filled with diluted soil solution (different proportion). The plates were incubated at 28°C for 72 hours. After incubating at 28°C for 72 hours, the prominent colonies were picked and inoculated individually in other PDA plates for further purification.

2.7. Identification of Fungi: After incubation, the distinct colonies were counted and identified. The fungal cultures were identified on the basis of macroscopic (colonial morphology, colour, texture, shape, diameter and appearance of the colony) and microscopic (septation in mycelium, presence of specific reproductive structures, shape and structure of conidia, and presence of sterile mycelium) characteristics (Table 2).

2.8. Sorption Experiment: In this study, various fungi isolated from municipal dumping yard of the Ambattur industrial estate was used to remove the Cr(VI) ions from the tannery industry wastewater of Nagalkeni than other parameters. In order to remove the Cr(VI) in a tannery industry wastewater, 100 ml of tannery industry wastewater was collected in a 250 ml flask and the experiments were conducted against the effect of pH, fungi biomass and different Cr(VI) concentration (different dilution ratio) to know the effectiveness of fungi for removing Cr(VI) ions

from tannery industry wastewater. The results for the incubation period of 7 days only presented below. Since, 7 day incubation gave the maximum Cr(VI) removal from the tannery industry wastewater by different fungi than another incubation period of 1 day to 6 days and hence, the results of the removal percentage of Cr(VI) for the incubation period of 1 day to 6 days were not presented in this study.

3. RESULTS AND DISCUSSION

The experiments conducted against the effect of pH, fungi biomass and different Cr(VI) concentration (different dilution ratio) to know the effectiveness of fungi for removing Cr(VI) ions from tannery industry wastewater are presented below.

3.1. Effect of pH: Fig. 1 shows the removal of Cr(VI) by 1.0 g of each fungal biomass against initial Cr(VI) concentration of 90.2 mg/L (dilution ratio 1 part of wastewater : 0 part of deionized water) as a function of incubation time at pH of 2.0, 3.0, 4.0 and 5.0. The metal removal was found to be varied for different fungi and for incubation time. It can be observed from Fig. 1, the uptake of Cr(VI) increases up to the pH of 3 and decreases with increase pH values of 4 and 5. The Cr(VI) adsorption by different fungi have shown similar trend and the optimum pH found from this study is 3.0 and the decrease in sorption capacity to increase in pH may be attributed to the changes in metal speciation and the dissociation of functional groups on the fungi. From Fig. 1, the order of maximum removal of Cr(VI) by the fungi at an optimum pH of 3 was *Aspergillus niger* (92.5 %) > *Rhizopus arrhizus* (88.4 %) > *Mucor racemosus* (86.9 %).

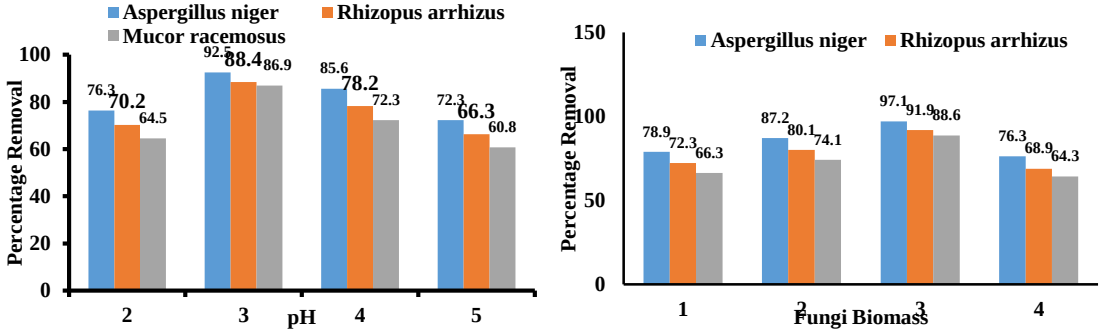

Fig. Effect of 1) pH 2) fungi biomass on removal percentage of Cr(VI) for different fungi

3.2. Effect of Fungi Biomass: The influence of fungi biomass in the removal capacity of Cr(VI) was depicted in Fig. 2. Fig. 2 shows the removal of Cr(VI) for an initial Cr(VI) concentration of 90.2 mg/L (dilution ratio 1 part of wastewater : 0 part of deionized water) as a function of incubation time at an optimum pH of 3.0 against each fungi biomass of 1 g, 2 g, 3 g and 4 g. It can be observed from Fig. 2, the uptake of Cr(VI) increases up to the fungi biomass of 3g and decreases with increase fungi biomass of 4g. Higher the removal is due to more binding sites in the fungi biomass. The Cr(VI) adsorption by different fungi have shown similar trend and the optimum fungi biomass found from this study is 3 g. From Fig. 2, the order of maximum removal of Cr(VI) by the fungi at an optimum fungi biomass of 3g was *Aspergillus niger* (97.12 %) > *Rhizopus arrhizus* (91.93 %) > *Mucor racemosus* (88.63 %). This showed the similar results with removal of Cr(VI) against the effect of pH.

3.3. Effect of Initial Cr(VI) Concentration: The influence of initial concentration Cr(VI) against optimum pH of 3, optimum each fungi biomass of 3 g against the dilution ratio of 0, 1, 2, and 3 at various incubation times (Fig. 3). It can be observed from Fig. 3, the uptake of Cr(VI) increases up to the dilution of 3. Higher the removal is due to more binding sites in the fungi biomass, which able to adsorb and absorb the Cr(VI) ions in the tannery industry wastewater. The Cr(VI) adsorption by different fungi have shown similar trend and the optimum dilution ratio found from this study is 3. As similar to the effect of pH and fungi biomass, the order of maximum removal of Cr(VI) by the fungi at an optimum dilution ratio of 3 was *Aspergillus niger* (98.6 %) > *Rhizopus arrhizus* (93.77 %) > *Mucor racemosus* (91.27 %) (Fig. 3). From the Figs. 1 to 3, it may be found that long time exposure (7 days) of soil fungi to heavy metals can lead to physiological adaptation or considerable modification of their microbial populations, reducing their activity and their number, and such changes may be associated with increased metal sorption capacity. Similarly, it may be found from the Figs. 1 to 3 that the maximum removal of Cr(VI) ions from the tannery industry wastewater was achieved by *Aspergillus niger* than other fungi species.

3.4. Verification Experiment: In order to verify the experimental results for the reduction of Cr(VI) in a tannery industry wastewater by the isolated fungi species namely *Aspergillus niger*, *Rhizopus arrhizus*, and *Mucor racemosus*, a separate experiment has been performed with an optimum pH of 3, optimum each fungi biomass of 3 g against the optimum dilution ratio of 3 for Cu reduction in an aqueous solution by the same isolated fungi species. The maximum removal percentage of Cr(VI) in a tannery industry wastewater and Cu removal in an aqueous solution by the isolated fungi species is shown in Fig. 4. The initial concentration of Cu in an aqueous solution is 100 mg/l and the test was carried out as similar to that of Cr(VI) determination in a tannery industry wastewater (APHA, 2005). The results (Fig. 4) showed that the maximum removal percentage of Cu in an aqueous solution by *Aspergillus niger*, *Rhizopus arrhizus*, and *Mucor racemosus* respectively is 99.2, 95.6 and 94.2 %. As

similar to the effect of pH, fungi biomass and concentration on reduction of Cr(VI) in a tannery industry wastewater, the order of maximum removal of Cu by the isolated fungi species at an optimum values for an aqueous solution was *Aspergillus niger* (99.2 %) > *Rhizopus arrhizus* (95.8 %) > *Mucor racemosus* (94.2 %) (Fig. 4).

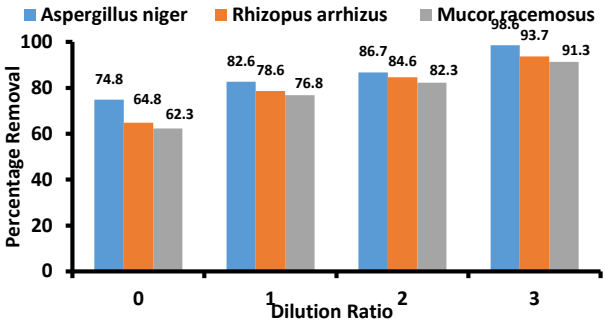

Fig. 3 Effect of dilution ratio on removal percentage of Cr(VI) for different fungi

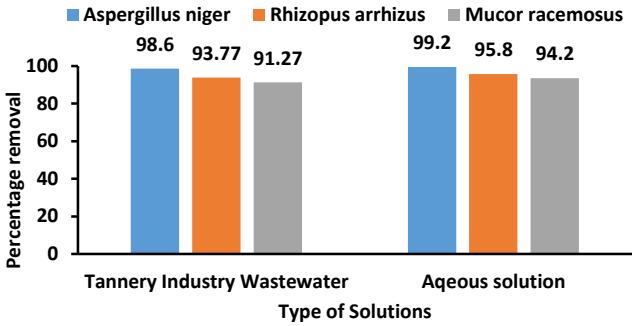

Fig.4 The Percentage Reduction of Cr(VI) in a tannery industry wastewater and Cu reduction in an Aqueous solution using isolated fungi species against an optimum parameters value

It may be observed from Fig. 4 that the result of the removal percentage of Cu in an aqueous solution is greater than the removal percentage of Cr(VI) in a tannery industry wastewater by the isolated fungi species. The reason for maximum removal of Cu in an aqueous solution is due to there are no competitive ions present in the aqueous solution than in a tannery industry wastewater, where other several competitive ions like TDS, EC, BOD, COD, chloride, sulphate and etc. are available. These ions are coming from usage of various chemicals used in various processes. Based on the results, it may be found that *Aspergillus niger* removed Cr(VI) more than the *Rhizopus arrhizus,* and *Mucor racemosus* in a tannery industry wastewater. Though the *Aspergillus* niger removed maximum of Cr(VI) in a tannery industry wastewater, the other two isolated fungi species along with *Aspergillus niger* may be used as sorbents for removing Cr(VI) in a tannery industry wastewater.

4. CONCLUSION

The present study indicated that different fungi isolated from the Ambattur industrial estate have the ability to resist higher concentrations of Cr(VI) from the tannery industry wastewater of Nagalkeni. The experiments were conducted against the effect of pH, fungi biomass and different Cr(VI) concentration (different dilution ratio) to know the effectiveness of fungi for removing Cr(VI) ions from tannery industry wastewater. The results showed that the order of maximum removal of Cr(VI) by the fungi is at an optimum pH of 3, an optimum fungi biomass of 3 g and an optimum dilution ratio of 3. The maximum removal of Cr(VI) ions from the tannery industry wastewater was achieved by *Aspergillus niger* than other fungi species. The variation of removal rate of the different fungi species was due to the development and adaptation of different fungus. Further, the results of experiments were validated by conducting the same experiments for the removal of Cu in an aqueous solution. The validation results showed that maximum removal of Cu from an aqueous solution was 99.2, 95.8 and 94.2 % respectively for the isolated fungi species *Aspergillus niger*, *Rhizopus arrhizus,* and *Mucor racemosus,* which was obtained for the same optimum pH of 3, an optimum fungi biomass of 3 g and an optimum dilution ratio of 3. Thus, this study was concluded that the isolated fungi spices might be used as sorbents for removing Cr(VI) not only in a tannery industry wastewater but also remove any other contaminants from any industry wastewater.

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