J. Soils and Crops 32 (2) 388-392, December 2022

ISSN 0971-2836 (Print)
ISSN 2582-2756 (Online)

# STRATEGY FOR CHROMIUM (Cr) REMOVAL FROM CONTAMINATED SOIL DUE TO TEXTILE EFFLUENTS THROUGH BIOAUGUMENTATION

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## ABSTRACT

**Textiles are among the basic needs of human being. The textile industries therefore have great economic significance by virtue of its contribution to overall industrial output and employment generation. Heavy metal such as chromium can bio-accumulate and through the food chain, to toxic levels in man. A study was conducted in 2016-17 on eastern part of the State; Yavatmal, which is bordered by Amravati district on the north, Wardha district on the northeast, Chandrapur district on the east, the State of Andhra Pradesh on its south, Nanded on its southwest, to its west, Parbhani district and the district of Akola on its north west. Yavatmal district stretches over an area of 13584 Sq. Km This sector has wide spectrum of industries ranging from small scale units that use traditional manufacturing process, to large integrated mills using modern machineries and equipment. Based on the wastewater characteristics and the prevailing vegetation, the experimental work was carried out in 2017 at 3 site of effluent. The experiment was designed by using the principles of design of experiment. The role of organic amendments (Farm yard manure and microorganisms like *Actinomycete*, *Azotobacter* and *Rhizobium*) in enhancing bioremediation of textile industry effluent contaminated soil was assessed. The COD of textile industry wastewater showed decline over a period of 10 days after treated with the plants. The field experimental data indicated the highest chromium uptake rate was observed with the plants, such as *Bacopamonnieri* (Brahmi), *Alternanthera sessilis*, *Typha angustata* (Lesser Indian Reed Mace), *Kyllinga tenuifolia* (Cyprus grass) and it was highest with *Typha angustata* when bio-augmented with Azotobacter, Rhizobium and FYM.**

**(Key words:Textiles effluent, microorganisms, phytoremediation and bioremediation)**

## INTRODUCTION

Textiles are among the basic needs of human being. The textile industries therefore have great economic significance by virtue of its contribution to overall industrial output and employment generation. This sector has wide spectrum of industries ranging from small scale units that use traditional manufacturing process, to large integrated mills using modern machineries and equipment. There are 2324 textile industries in the country including composite and process houses.

A study was conducted in 2017 eastern part of the State; Yavatmal, which is bordered by Amravati district on the north, Wardha district on the northeast, Chandrapur district on the east, the State of Andhra Pradesh on its south, Nanded on its southwest, to its west, Parbhani district and the district of Akola on its north west. Yavatmal district stretches over an area of 13584 Sq. Km.

Textile industries transform fibers into yarn; convert the yarn into fabrics or related products, and dye and finish these materials at various stages of production. In processing of textiles, the industry uses a number of dyes, chemicals, auxiliary chemicals and sizing materials. As a result, contaminated waste water is generated which can cause environmental problems unless properly treated before its disposal.

The main environmental problems associated with textile industry are typically those associated with water body pollution caused by the discharge of untreated effluents. Other environmental issues of equal importance are air emission, notably Volatile Organic Compounds (VOC) and excessive noise or odour as well as workspace safety.

Textile effluents are often contaminated with non-biodegradable organics termed as refractory materials. Detergents are typical example of such materials. The presence of these chemicals results in high chemical oxygen demand (COD) value of the effluent.

Organic pollutants, which originate from organic compounds of dye stuffs, acids, sizing materials, enzymes, tallow etc. are also found in textile effluent, such impurities are reflected in the analysis of bio-chemical oxygen demand (BOD) and COD. These pollutants are controlled by use of biological treatment processes. In many textile units, particularly engaged in synthetic processing, low BOD/COD ratio of effluent is observed which makes even biological treatment not a ready proposition. The waste water of cotton

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based textile units is usually alkaline, whereas synthetic and woolen fabric processing generates acidic effluent.

The textile industry actually represents a range of industries with operations and processes as diverse as its products. It is almost impossible to describe a "typical" textile effluent because of such diversity. Fabrics, after its manufacturing, are subjected to several wet processes collectively known as "finishing" and it is in these finishing operations that the major waste effluents are produced (Abo-Elela *et al.,* 1988).

While a number of methods are currently being used for sewage treatment and industrial waste water treatments at sewage treatment plants, effluent treatment plants, these are very expensive methods that rely on high-cost chemicals and heavy inputs of energy. With an emphasis on sustainable wastewater treatment throughout the world. The industries are keen on pursuing a method that can be cost effective and can provide a sustainable, long-term solution for treatment of waste water and sewage.

# MATERIALS AND METHODS

Based on the wastewater characteristics and the prevailing vegetation, the experimental work was carried out from three different sites of Textile factory. The experiment was designed by using the principles of design of experiment. The role of organic amendments (Farm yard manure and microorganisms like *Actinomycete*, *Azotobacter* and *Rhizobium*) in enhancing bioremediation of textile industry effluent contaminated soil was assessed. The experiment was carried out for the duration of one year i.e in 2017.*In-situ* land treatment with limited by the depth of soil that can be effectively treated. In most soils, effective oxygen diffusion sufficient for desirable rates of bioremediation extends to a range of only a few inches to about 12 inches into the soil. Usually when it is desired to treat soil *In-situ* to despite greater than 12 inches, the surface layer of soils is first treated to the desired contaminated levels, and then removed, or tilled so that lower layers are moved to the surface for treatment. Most tractor mounted tilling devices can still only to a depth of about 12 inches. Experiment was planned with contaminated soil brought from effluent site with 24 plant pits of each species i.e *Bacopa monnieri* (Brahmi), *Alternanthera sessilis*, *Typha angustata* (Lesser Indian Reed Mace) and *Kyllinga tenuifolia* (Cyprus grass).

Chemical Oxygen Demand (COD) test determine the oxygen required for chemical oxidation of organic matter with the help of strong chemical oxidant. The test can be employed for the same purpose as the BOD test taking into accounts its limitations.

The intrinsic limitation of the test lies in its inability to differentiate between the biologically oxidizable and biologically inert material.

COD determination has an advantage over BOD determination in that the result can be obtained in about 5 hours as compared to 5 days required for BOD test. Further, the test is relatively easy, gives reproducible results and is not affected by interferences as the BOD test.

The organic matter gets oxidized completely by $K_2Cr_2O_7$ in the presence of $H_2SO_4$ to produce $CO_2 + H_2O$. The excess $K_2Cr_2O_7$ remaining after the reaction is titrated with Fe $(NH_4)_2(SO_4)_2$. The dichromate consumed gives the $O_2$ required for oxidation of the organic matter.

**Chromium of textile wastewater**

Most rocks and soils contain small amounts of chromium. The commonest one is chromite in which the metal exists in the trivalent form. Hexavalent chromium also exists naturally but in frequently, chromium in its naturally occurring state is in a highly insoluble form but can be converted into more soluble form by the action of weathering, oxidation and bacteria. Because of the low solubility, the levels found in water are usually low. However, there are examples of contamination of water, in some cases serious, in which effluents containing chromium compounds have been discharged to rivers. The valency of the chemical form in natural water is influenced by the acidity of the water. The levels of chromium in finished water entering the public supply are normally about the same as or perhaps slightly lower than those in raw sources of water. The Chromium was estimated by spectrometric studies as given and established by Nagaraj (2009).

Based on the wastewater characteristics and the prevailing vegetation, the experimental work was carried out. The experiment was designed by using the principles of design of experiment. The role of organic amendments (Farm yard manure and microorganisms like *Actinomycete*, *Azotobacter* and *Rhizobium*) in enhancing bioremediation of textile industry effluent contaminated soil was assessed.

# RESULTS AND DISCUSSION

Based on the data obtained from the experimental work, a model was developed (on pilot scale) for textile wastewater treatment. The details are presented hereunder. Phytoremediation is the use of certain plants to clean up soil, sediment and water contaminated with metals and/or organic contaminants such as crude oil, solvents, and polyaromatic hydrocarbons. Plants can be used to contain, remove, or degrade contaminants. It is a name for the expansion of an old process that occurs naturally in ecosystems as both inorganic and organic constituent's cycle through plants.

In the present study, the plant physiology, agronomy, microbiology, hydrogeology and engineering are combined to select the proper plant and conditions for a specific site. Phytoremediation mechanism can be used in several ways prominent amongst them are *Phytovolatillization* (Plants take up water and organic contaminants through the roots, transport them to the leaves, and release the contaminants as a reduced or detoxified vapor into the atmosphere), *Microorganism* *stimulation* (Plants excrete and provide enzymes and organic substances from their roots that stimulate growth of microorganisms such as fungi and bacteria. The microorganisms in the root zone then metabolize the organic contaminants). *Phytostabilization* (Plants prevent contaminants from migrating by reducing runoff, surface erosion, and ground water flow rates. Hydraulic pumping can occur when tree roots reach ground water, take up large amounts of water, control the hydraulic gradient, and prevent lateral migration of contaminants within a ground water zone). *Phytoaccumulation/extraction* (Plant roots can remove metals from contaminated sites and transport them to leaves and stems for harvesting and disposal or metal recovery smelting processes) (Hajare and Kulkarni, 2020).

Though there are different phytoremediation mechanisms, in this study a model was prepared for the possible treatment of the heavy metal containing textile industry wastewater. The process used combination of *Phytostabilization and Phytoaccumulation/ extraction* concepts.All the plant species prevalent in vicinity of wastewater discharge were collected and used for assessing their potential for COD removal. The textile industry wastewater was poured in the pits (of dimension 0.6 m x 0.6 m x 0.5 m) prepared for the experiment. The COD of the soil solution on initial day as well as that on each day was determined by following standard method. The results of the experiment are as follows

| Day | Date | COD (mg $l^{-1}$) |
|---|---|---|
| **1** | 02.07.2017 | 680 |
| **2** | 03.07.2017 | 654 |
| **3** | 04.07.2017 | 620 |
| **4** | 05.07.2017 | 562 |
| **5** | 06.07.2017 | 510 |
| **6** | 07.07.2017 | 474 |
| **7** | 08.07.2017 | 412 |
| **8** | 09.07.2017 | 382 |
| **9** | 10.07.2017 | 344 |
| **10** | 11.07.2017 | 308 |

The result in Table 1 shows that the COD of textile industry wastewater declined over a period of 10 days. The initial COD value was 680 mg $l^{-1}$. On the $10^{th}$ day, the COD was 308 mg $l^{-1}$. In all the COD removal of 45.2% was achieved in 10 days of treatment. Hence, it can be concluded that the phytoremediation model involving the four plant species has a good potential for use for treatment of textile industry wastewater.

## Table 2. Heavy metal (chromium) concentration in textile industry waste water

| Parameter | Textile Industry Waste Water from Sampling Site | | |
|---|---|---|---|
| | **Site 1** | **Site 2** | **Site 3** |
| Chromium (mg $l^{-1}$) | 0.06±0.02 (0.02 to 0.09) | 0.04±0.01 (0.02 to 0.06) | 0.061±0.01 (0.02 to 0.08) |

It was also evident from Table 3 that the average chromium content of wastewater sample collected from site 1 was 0.06±0.02mg $l^{-1}$ (varied between 0.02 mg $l^{-1}$and 0.09 mg $l^{-1}$), the average chromium content of waste water sample collected from site 2 was 0.04±0.01mg $l^{-1}$(varied between 0.02 mg $l^{-1}$ and 0.06 mg $l^{-1}$) and the average chromium content of waste water sample collected from site 3 was 0.06±0.01mg $l^{-1}$(varied between 0.02 mg $l^{-1}$and 0.08 mg $l^{-1}$).

Tzanakakis *et al.* (2003) established slow rate systems in order to develop the appropriate technology required, at Skalani (a small village in Greece). The slow rate systems were planted with four plant species *Eucalyptus, Acacia*, poplars and reeds to evaluate their effects on wastewater treatment and produced biomass. They reported that in terms of plant species used, there were no significant differences in treatment efficiency among the four slow rate systems.

In view of these results, our results showed that there was difference in the phytoremediation ability of different plant species used, which indicates that further research efforts are warranted to arrive at more specific conclusions. Aubert and Schwitzguébel (2004) had reported that Sulphonated anthraquinones (known to be recalcitrant to biodegradation) are not eliminated by traditional wastewater treatment plants, leading to their accumulation in fresh water. Upon treatment they reported that, under hydroponic conditions plant species *Rheum rabarbarum* (rhubarb) showed the most promising results for its ability to treat model effluents contaminated with mono- and disulphonated anthraquinones. However, the authors further indicated that the role of transpiration stream in phytoremediation should be further explored then exploited, which can be studied in this investigation (Saikia *et al.*,2021).

Nilratnisakorn *et al.* (2007) expressed a need to study role of salinity in the phytoremediation potential of various plant species. Based on the promising results obtained in this study, similar studies (wherein role of salinity) can be assessed in future investigations. Besides, its role in the dynamics of dye transformation can also be studied. The results of the study by Bulc and Ojstršek (2008) proved that constructed wetlands could offer an optimal solution to meet the environmental legislation as well as requirements for effective and inexpensive textile wastewater treatment. Similar study using the plant species prevalent in the vicinity of textile industry in Yavatmal can also be planned. Carias *et al*. (2008) had reported that antioxidant and detoxification enzymes of *Phragmite saustralis* are helpful in the degradation of an azo dye, acid orange. However, situational demand with respect to the pollution mitigation needs to be studied in more details with respect to the plant species investigated in this study.

Kagalkar *et al.* (2011) observed that cell cultures of *Blumea malcolmii* Hook rapidly decolorized textile industry effluent along with a variety of dyes with diverse structural properties. The textile industry wastewater treated in this study also had dyes in it, however, the potential of plant species to remove it (dye) was not studied in details, which can form a worthwhile future study of phytotransformation. Khandare *et al.* (2011) had reported that wild and tissue cultured plants of *Portulaca grandiflora,* Hook have shown to be able to decolorize a Sulphonated diazo dye Navy Blue $HE_2R$ ($NBHE_2R$) up to 98% in 40 h. This shows that the plants used in this study can also be used to study their potential for removing various dyes present in the textile industry wastewater. Further, they have also explored the potential of *Aster amellus,* Linn. to decolorize a Sulphonatedazo dye Remazol Red (RR), a mixture of dyes and a textile effluent.

They reported that BOD of textile effluent and mixture of dyes were reduced by 75% and 48% respectively, COD of industrial effluent and mixture of dyes was reduced by 60% and 75% and TOC was reduced by 54% and 69% respectively after the treatment by *A. amellus* for 60 h. Similar to this results, our results also showed promising phytoremediation potential of heavy metal contaminated soils.

Laboratory studies have shown phytoremediation is a feasible method for remediating sludge contaminated with heavy metals. Latif *et al.* (2012) have reported that plants (*Cyperus kyllingia-Rasiga, Asystassia intrusa* and *Scindapsus Pictus Var Argyaeus*) have ability to hydroponically digest industrial sludge contaminated with aluminum, cadmium, chromium, copper, iron, lead, nickel, manganese and zinc. Our study results also showed that *Cyperus kyllingia* has a lot of potential to be used as a promising phytoremediation agent, especially, for treatment of textile industry wastewater.

As a result, research activity concerning control (especially biological control) and utilization (especially wastewater treatment or phytoremediation) has boomed up in the last few decades which was reported by Jiwtani *et.al* (2016). However, such boom has not been witnessed in the Indian context. From the study it was concluded that the plant species used were able to significantly absorb the metals present in industrial sludge. Hence, this study offers valuable inputs for the scientific community in the area of phytoremediation.

**Table 3. Uptake of Cr present in the textile industry waste water by different plant species**

| Plant species | Treatments | Initial Cr Conc. (mg $kg^{-1}$ of soil) | After 3 months |
|---|---|---|---|
| ***Bacopa monnieri*** | Control | 10 | 8.9±1.7 |
| | Soil amended with microorganisms (*Azotobacter* + *Rhizobium*) | 10 | 7±1.4 |
| | Farm Yard Manure | 10 | 5.2±1.1 |
| ***Alternanthera sessilis*** | Control | 10 | 8.7±2.4 |
| | Soil amended with microorganisms (*Azotobacter* + *Rhizobium*) | 10 | 7.6±1.9 |
| | Farm Yard Manure | 10 | 7.8±2.8 |
| ***Typha angustata*** | Control | 10 | 8.7±2.4 |
| | Soil amended with microorganisms (*Azotobacter* + *Rhizobium*) | 10 | 5.1±1.2 |
| | Farm Yard Manure | 10 | 3.8±0.6 |
| ***Kyllinga tenuifolia*** | Control | 10 | 8.7±1.3 |
| | Soil amended with microorganisms (*Azotobacter* + *Rhizobium*) | 10 | 4.4±1.9 |
| | Farm Yard Manure | 10 | 7.3±2.1 |

**Chromium (Cr) uptake by different plant species (N=3)**

The information pertaining to the soil Cr concentration as a function of growth of different plant species grown in textile industry waste water effluent affected land under experimental conditions. It was evident from the information that for the control set where *Bacopa monnieri* was planted the soil Cr concentration was 8.9±1.7 mg $kg^{-1}$after 3 months period, however, for *Bacopa monnieri* grown in soil amended with microorganisms (*Azotobacter* and *Rhizobium*) it was 7±1.4 mg $kg^{-1}$after 3 months, whereas for *Bacopa monnieri* grown in farmyard manure it was 5.2±1.1 mg $kg^{-1}$ after 3 months.

Moreover, it was observed that for the control set of *Alternanthera sessilis* plantation the soil Cr concentration was 8.7±2.4 mg $kg^{-1}$after 3 months, for the *Alternanthera sessilis* grown in soil amended with microorganisms (*Azotobacter* and *Rhizobium*) it was 7.6±1.9 mg $kg^{-1}$after 3 months, whereas for the *Alternanthera sessilis* grown in farmyard manure it was 7.8±2.8 mg $kg^{-1}$ after 3 months.

Furthermore, it was evident that for the control set planted with *Typha angustata* the soil Cr concentration was 8.7±2.4 mg $kg^{-1}$ after 3 months' time period, however, for the *Typha angustata* grown in soil amended with microorganisms (*Azotobacter* and *Rhizobium*) it was 5.1±1.2 mg $kg^{-1}$after 3 months, in addition to this for *Typha angustata* grown in farmyard manure the soil Cr concentration was 3.8±0.6 mg $kg^{-1}$ after 3 months.

In addition to above, it was apparent that for the control set where the *Cyprus sps* was planted the soil Cr concentration was 8.7±1.3 mg $kg^{-1}$ after 3 months, moreover, for the *Cyprus sps.* grown in soil amended with microorganisms (*Azotobacter* and *Rhizobium*) it was 4.4±1.9 mg $kg^{-1}$after 3 months and for the *Cyprus sps.* grown in farmyard manure it was 7.3±2.1 mg $kg^{-1}$after 3 months (Table 3).

The field experimental data indicated that highest heavy metal uptake rate was observed with the plants, such as *Bacopa monnieri* (Brahmi), *Alternant herasessilis*, *Typha angustata* (Lesser Indian Reed Mace)**,** *Kyllinga tenuifolia* (Cyprus grass) and it was highest with *Typha angustata* bioaugmented with *Azotobacter, Rhizobium* and FYM. The results obtained in this study confirm the beneficial role of the phytoremediation strategy, especially by using the locally available herbaceous plant species for cleaning the contaminated site.

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**Rec. on 27.06.2022 & Acc. on 06.07.2022**