Removal of Heavy Metals from the Contaminated Soil using Soil Washing Technique with Biosurfactant

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***Abstract*— Heavy metal removal from the contaminated soil is significant because they are not only contaminating the soil but also affect the human being and animal. Various technologies were employed from the some years to remove the heavy metals from the contaminated soil. In the present study, soil washing is one of the ex-situ techniques which is cost effective and easy in operation. This study focuses on the modified bench scale model or rotating soil washing unit was constructed to remove the Copper and Chromium from the contaminated soil. A biosurfactant solution is used as a washing solution and the reaction is carried out for 3 hours. Results supported with the effectiveness of bench scale soil washing model in Copper and Chromium removal from the contaminated soil at open dumping site. The removal efficiency for Copper and Chromium is found to be minimum and maximum on the use of biosurfactant.. This soil washing process can remove heavy metals from the contaminated soil efficiently as well as reasonably.**

Keywords*— *MSW disposal site, Bench Scale Soil washing, Biosurfactant as an additive

I. INTRODUCTION

Due to pollution, soils are contaminated and various types of contamination occurs from the accumulation of toxic heavy metals which are emitted from the solid waste disposal, industrial areas, chemical fertilizer, animal manures, pesticides, decomposition of high metal waste. The concept related to soil contamination is a significant due to associated risk related to the human health and surrounding environment in the form of direct transmission with soil and secondary transmission from the soil with water. Soil is a major source at which the heavy metal contaminants are being dumped due to anthrogenic activities.

Heavy metals are one of the major contaminants of the soil. Heavy metals are defined as any kind of metals which is of environmental concern due to its dangerous concept ad its harmful effects. It constitutes of inorganic chemical elements. Most of the types of heavy metals are present in the contaminated soil such as chromium (C_r), lead (P_b), arsenic (Ar), Copper (C_u), cadmium (Cd), mercury (H_g) and nickel (Ni). Organic contaminants are better than the inorganic pollutants because it oxidized to CO_2 and disintegrated by the microbial activities. Hence they are washed from the soil after some duration. However inorganic contaminates takes longer time because they did not interact with microbial activities as well as chemical disintegration. Heavy metal contaminates directly affect the human health and ecosystem directly or indirectly.

In current situation, removal of heavy metal from the contaminated soil is very important mainly at the near by places where the disposal of solid waste is running. Characteristics of soil provide the clear cut situation about the sources of contamination, chemical properties of contamination. Based on the characterization of soil, proper selection of remediation technologies can be applied. Selection of remediation technologies of contaminated soil depends on the type, properties, concentration of pollutants.

Research of this technology is going to happened which are most cost effective and toxicity reduce techniques. Combination of two or more techniques may be easiest solution but it also increases the cost of the techniques. Soil washing is a sustainable technique for chemical transformation of the pollutants to the non-hazardous materials by the physico-chemical process which leads to physical separation, segregation and reduction of volume of hazardous material. This technique is used to eliminate the heavy metals, polluted contaminants, volatile organic compounds, pesticides, and herbicides. This process is done on the excavated soil (ex situ) or on-site (in-situ). Hence, in this paper soil washing technique is studied for the removal of heavy metals using biosurfactant as an additive.

The aim of this study is to design a bench scale model soil washing which could efficiently remove the contaminants from at least 2.5 kg of a soil at a time and to determine the soil fertility of a soil using wash solution as Tween -80 from the soil by the soil washing process.

II. METHODOLOGY

It is a systematic and various views analysis of the methods applied to a various field of study like descriptive study, an experimental study in which a treatment, procedure is intentionally introduced and a result or outcome is observed.

A. Sample collection

Soil samples were collected from dumping site (sample 1), near dumping site (sample 2), urali devachi (sample 3), hadapsar stretch (sample 4). The detail information are as follows;

Study Area

Pune is spreading in the western Indian State of Maharashtra includes an area around 700 km² and population

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is around 3.115 million, but still is an arising and expanding city .Pune region is situated at 18° - 19.2° latitudes and 73.2° - 75.1° longitudes. In developing cities such as Pune (PMC), more than 1600 – 1700 Tonnes of daily Solid Waste generated. From 1981, the Municipal Solid Waste is disposed at Urali Devachi by open dumping yard by PMC authority. In present scenario, around 200 kg of daily solid waste is disposed at Urali Devachi through PMC. The Urali Devachi village, dumping yard for Pune city has about 120 acres of land for disposal and remediation of contaminated soil is necessary because it creates serious problems to the environment and human health. The site was selected to study the heavy metal contamination in a soil and impact of MSW contamination at the Urali Devachi site.

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Fig.1. Dumping Site showing heap of solid waste Pune

B. Experimental Design of Bench Scale Model

An improved bench scales model set up is prepared at the Engineering lab. This model is designed to check the remedial efficiency of soil washing process, and reduced the concentration of heavy metal such as chromium and copper from the soil by using bio surfactant (Tween -80). This bench scale model can process up to 2.5 kg of contaminated soil at a time. This model is cost operative, simple and simple in operating. Fig. shows the actual presentation of bench scale model fabricated and designed.

Fig.2. Bench scale model design for Soil Washing

B. Model Specification

This bench scale model involves a tumbler composed of PVC material. The tumbler is 7 inch in diameter and 3ft in length. And this tumbler can be capped at the both ends. The bottom cap is completely sealed and has a PVC valve attached to the cap for the effluent removal. The top cap of tumbler is removable hence the soil and wash solution can be placed into the tumbler.

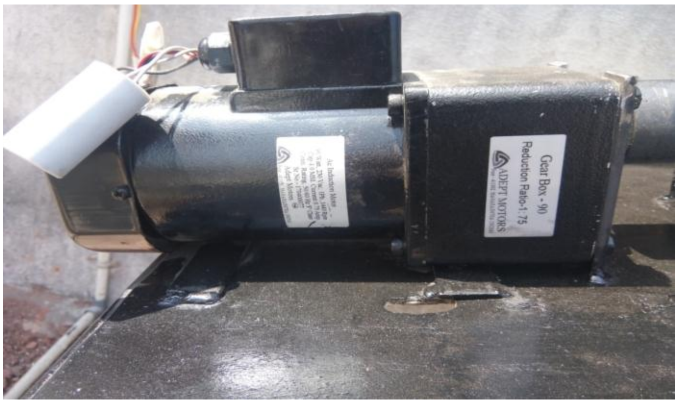

Fig.3.AC motor connected with gearbox

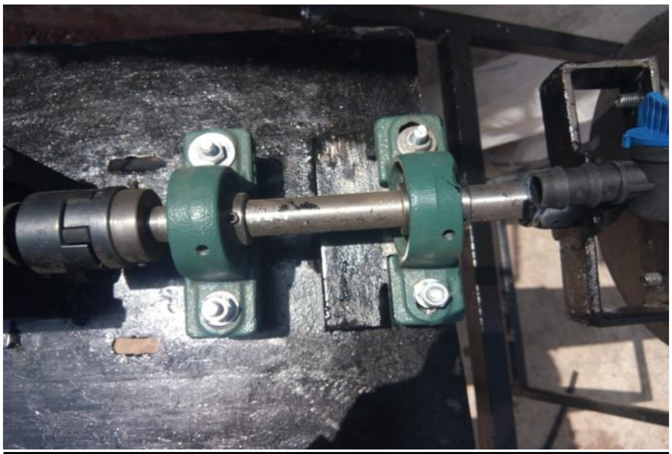

Fig .4. Shaft Arrangement between the motor and PVC pipe

Size specification:

There are various parts includes in the model design.

a. PVC material pipe – 3 ft in length and 7 inch in diameter
b. Angle of inclination – 30°
c. Motor specification - AC induction Motor , 90 v , 0.75 HP, 1440 rpm speed with adjustable gear box
d. Shaft size – 20 mm diameter
e. Stand – M.S. Steel Material, 2.5 ft in height , width and 3 ft in length
f. No. of roller support - 2

For the removal of effluent, the knob is attached to the bottom end of the PVC material. The purpose of filter is for collection of volatiles. The tumbler is placed on stand at an angle of 30° for doing safe operations. The stand is constructed of aluminium steel. Additional tumbler support is supplied by a rotating wheel which is attached to the frame. This is driven by variable speed of AC motor. During operation, it allows the mixing tumbler to be adjusted.

C. Experimental setup and wash solution

Contaminated soil and wash solution mixed together in a rotary apparatus i.e. tumbler which rolled over soil solution with a speed of 23 rpm for 3 hours time. Tween 80 solution was chosen the wash solution for this model. The wash solution is added as 0.5% for 1litre of water. Treatment is continued up to all the leachate collected.

After some time, the washing soil sample is removed and effluent is separated at the outlet which is connected to the bottom cap of tumbler. In wet condition, the soil is removed by hand after removing the top cap of tumbler and placed in container for the further process.

D.Testing procedure and analytical testing

a. Without washing solution

The samples were taken from the different areas at the various depths. The wash solution is not added in the soil. Only mixing is done with soil and water. The bottom cap of tumbler is permanently fixed. Tumbler was designed atleast 2.5 kg of soil and 12 L of wash solution. This tumbler is rotated at 23 revoluions per minute for 3 hours for the proper mixing of contaminated soil and water. At the end of this process, the effluent is separated and soil filtered and dried at its atmospheric temperature.

b. With washing solution

The wash solution is added in the soil up to 25 ml with water solution. The wash solution used for the testing was the mixture of 25 ml of TWEEN 80 and water for 2.5 kg of soil.

The tumbler is rotated at 23 revolutions per minute for approximately 3 hours for interaction of the wash solution and contaminated soil. At the end of this process, the effluent is separated, filtered and soil was dried at its atmospheric temperature.

III. RESULTS AND DISCUSSION

A. Analysis of Leachate Sample

The parameters of leachate samples are as follows

Table 1 Physio-chemical characteristics of Leachate Sample

SR. NO.	PARAMETERS	UNIT	RESULTS
1.	pH	-	7.00
2.	Electrical Conductance	ms/cm	Not detected
3.	Turbidity	NTU	65
4.	Suspended solids	mg/lit	Not detected
5.	Total dissolved solids	mg/lit	Not detected
6.	BOD @ 27° C for 3 days	mg/lit	9270
7.	COD	mg/lit	22713
8.	Hardness	mg/lit	4000
9.	Chromium	mg/lit	23.4
10.	Copper	mg/lit	34.7

From the above results, the characteristics of the leachate were high. A heavy metal concentration of Copper and Chromium in leachate was very high.

B. Analysis of soil sample

a. pH

The pH value of any liquid or solid particles indicates negative log of hydrogen ions concentration in the soil. It was carried out by pH scale meter.

Table 2 1st pH variation in soil

Sr. No.	Initial pH	Final pH without Biosurfactant	Final pH with Biosurfactant
Sample 1	8.5	8.45	8.31
Sample 2	8.31	8.03	8.2
Sample 3	8.74	8.65	8.18
Sample 4	8.9	8.37	8.35

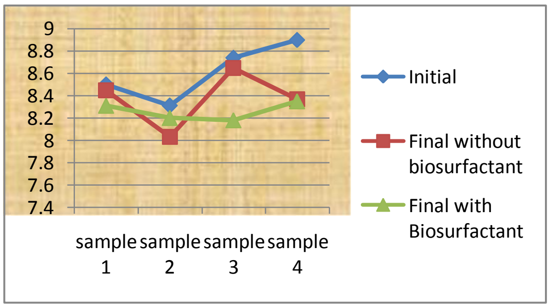

Fig.6 1st pH variation in soil

Table 3 2nd pH variation in soil

Sr. No.	Initial pH	Final pH without Biosurfactant	Final pH with Biosurfactant
Sample 1	8.3	8.4	8.3
Sample 2	8.3	8.0	8.22
Sample 3	8.7	8.62	8.16
Sample 4	8.91	8.3	8.3

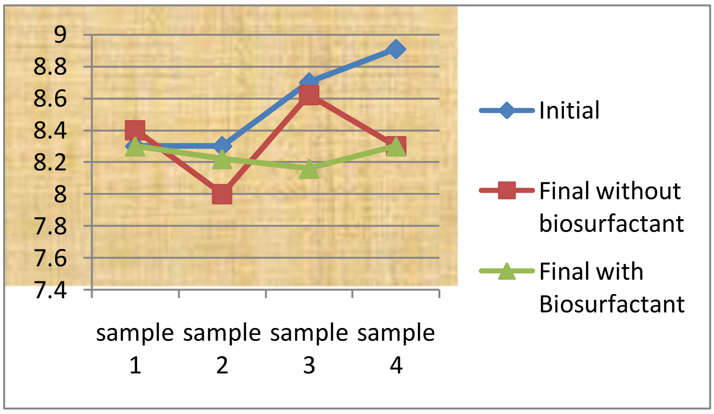

Fig.7 2nd pH variation in soil

From the above results the pH variation in soil differs from various locations. According to the pH scale, the pH ranges from 8 to 8.6. The untreated soil pH ranging from 8.3 to 8.9.Also the pH range for treated soil without biosurfactant is from 8.0 to 8.6 as well as using biosurfactant from 8.1 to 8.35.

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b. Electrical conductivity

It is the reciprocal of electrical resistivity and measures ability to conduct a current. It is measured by conductivity meter. The average range between the soils is from 0.05 to 3.94 for untreated soil.

Table 4 1st Electrical conductance variation in soil (mhsos/cm)

Sr. No.	Initial Electrical Conductivity	Final Electrical Conductivity without Biosurfactant	Final Electrical Conductivity with Biosurfactant
Sample 1	1.94	1.42	1.43
Sample 2	0.65	0.33	0.33
Sample 3	0.30	0.33	0.27
Sample 4	0.47	0.41	0.5

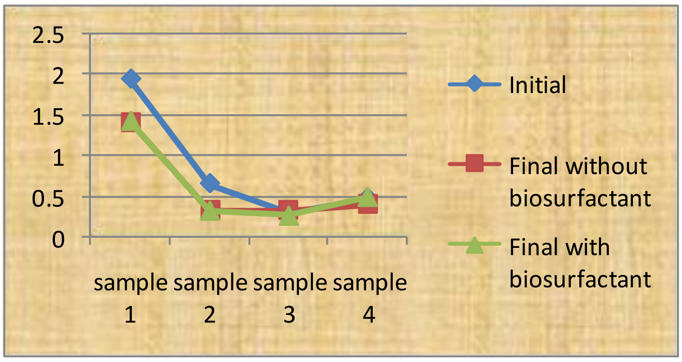

Fig.8 1st Electrical conductance variation in soil (mhsos/cm)

Table5 2nd Electrical conductance variation in soil (mhsos/cm)

Sr. No.	Initial Electrical Conductivity	Final Electrical Conductivity without Biosurfactant	Final Electrical Conductivity with Biosurfactant
Sample 1	3.91	1.43	1.44
Sample 2	0.64	0.31	0.33
Sample 3	0.31	0.35	0.27
Sample 4	0.45	0.4	0.45

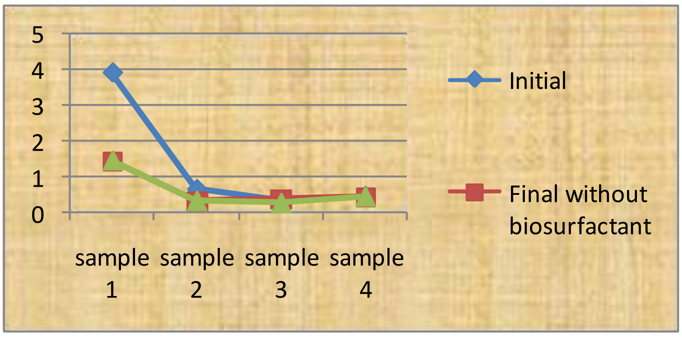

Fig.9 2nd Electrical conductance variation in soil (mhsos/cm)

From the above results of electrical conductance, the maximum variation in soil was in sample 1 (Dumping site). With the help of bench scale soil washing model, electrical conductance were decreased. And for treated soil without using the biosurfactant is ranges from 0.23 to 1.43 also for treated soil using biosurfactant is ranges from 0.27 to 1.44.

c. Organic matter content

It is the component of soil which consists of plants and animals residues at various stage including decomposition of cells and tissues of microorganisms. It is expressed in percentage. Organic matter controls many of the physical, chemical and biological properties of soils.

Table 6 1st Organic matter content variation in soil (%)

Sr. No.	Initial organic content	Final organic content without Biosurfactant	Final organic content with Biosurfactant
Sample 1	2.40	0.40	0.50
Sample 2	1.24	0.30	0.33
Sample 3	1.15	0.40	0.4
Sample 4	0.42	0.50	0.42

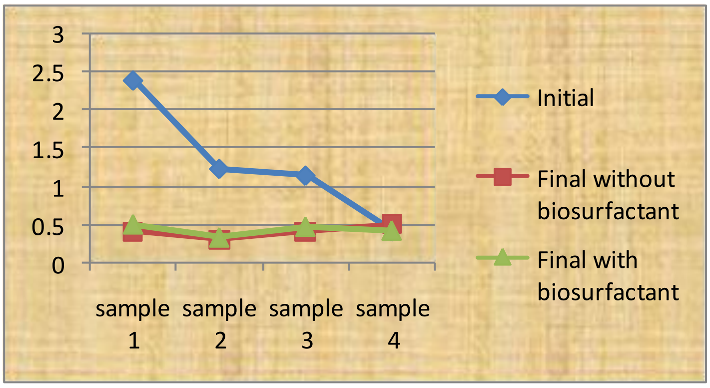

Fig.10. Organic matter content variation in soil (%)

Table 7 2nd Organic matter content variation in soil (%)

Sr. No.	Initial organic content	Final organic content without Biosurfactant	Final organic content with Biosurfactant
Sample 1	2.36	0.42	0.50
Sample 2	1.22	0.34	0.31
Sample 3	1.15	0.36	0.42
Sample 4	0.43	0.51	0.40

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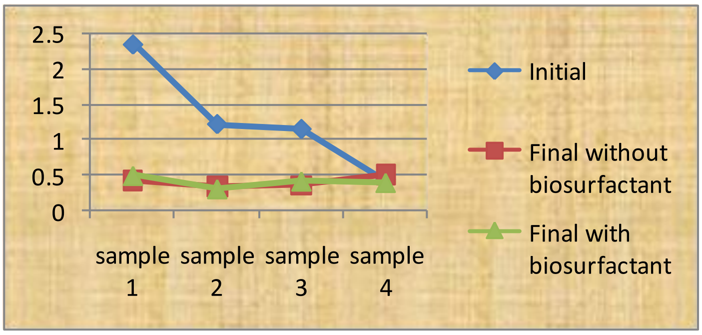

Fig.11. 2nd Organic matter content variation in soil (%)

The organic matter content depends on the type of soil, minerals, heavy metal concentration. Organic matter content in untreated soil ranges from 0.42 to 2.4. Treated soil without biosurfactant is ranges from 0.3 to 0.51 and with biosurfactant ranges from 0.33 to 0.5.

d. Moisture content

It is the ratio of weight of water to the weight of soil in a given mass of soil. This is based on removing soil moisture by oven dried soil sample until the wight remains constant. The moisture content (%) is calculated from the sample weight before and dried soil. The moisture content of a soil was determined using the formula:

$$Mc = (W_2 - W_3) / (W_3 - W_1) * 100 \qquad (1)$$

Where: W_1 = weight of tin (g)
W_2 = weight of moist soil + tin (g)
W_3 = weight of dried soil + tin (g)

Table 8 1st Moisture content variations in soil (%)

Sr. No.	Initial moisture content	Final organic content without Biosurfactant	Final organic content with Biosurfactant
Sample 1	19.85	20	20.6
Sample 2	13.48	20	20.10
Sample 3	13.66	12.2	13
Sample 4	10.1	12.2	11.9

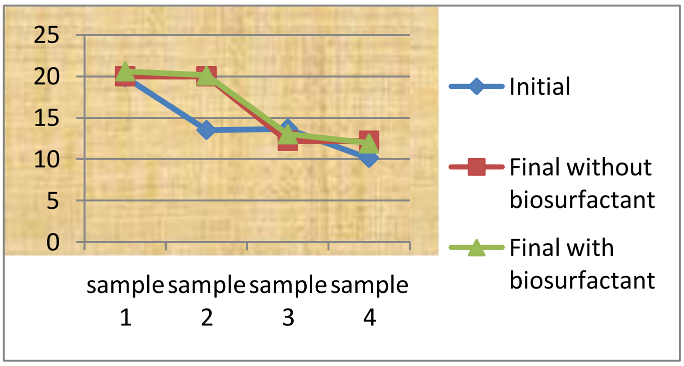

Fig.12.1st Moisture content variation in soil (%)

Table 8 1st Moisture content variations in soil (%)

Sr. No.	Initial moisture content	Final organic content without Biosurfactant	Final organic content with Biosurfactant
Sample 1	19.85	20.1	20.62
Sample 2	13.44	20.1	20.13
Sample 3	14	12	13.1
Sample 4	10	12	11.5

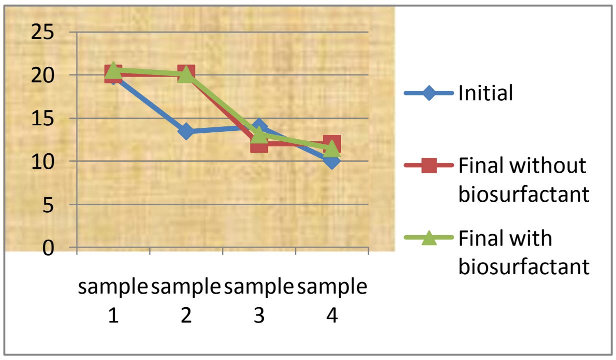

Fig.13. 2nd Moisture content variation in soil (%)

In untreated soil, it ranges from 10 to 19 and for treated soil ranges from 12.2 to 20, and using biosurfactant ranges from 11.50 to 20.6.

e. Removal efficiency of copper

A removal efficiency of heavy metal is determined as follows:

$$\% \text{ removal efficiency of metal} = I_0 - F_0 / I_0 * 100 \qquad (1)$$

Where I_0 = Initial concentration of copper (mg/kg)
F_0 = Final concentration of copper(mg/kg)

A final removal efficiency without biosurfactant ranges from 19.39 to 24.71 and with biosurfactant ranges from 16.67 to 42.59.

Table 6 1st Removal efficiency of copper (%)

Sr. No.	Final removal efficiency without biosurfactant	Final removal efficiency biosurfactant
Sample 1	24.71	18.53
Sample 2	22.65	19.14
Sample 3	20.48	37.15
Sample 4	19.39	42.42

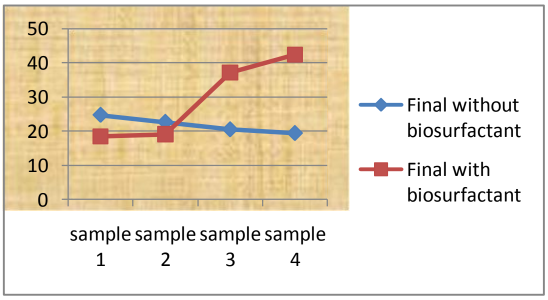

Fig.14 1st Removal efficiency of copper (%)

Table 10 2nd Removal efficiency of copper (%)

Sr. No.	Final removal efficiency without biosurfactant	Final removal efficiency biosurfactant
Sample 1	23.61	16.67
Sample 2	22.92	19.14
Sample 3	20	36.5
Sample 4	19.75	42.59

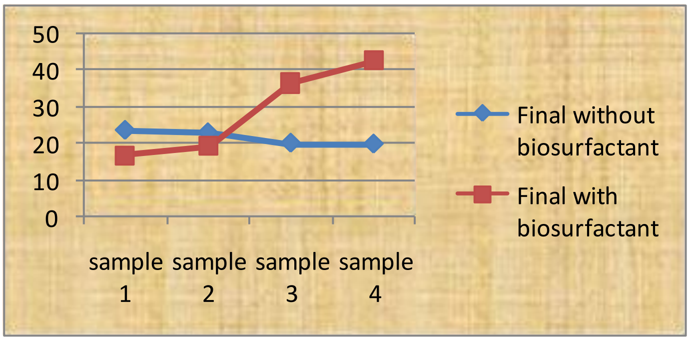

Fig.15 2nd Removal efficiency of copper (%)

f. Removal efficiency of chromium

A removal efficiency of heavy metal is determined as follows:

% removal efficiency of metal = $I_0 - F_0 / I_0 * 100$ (1)

Where I_0 = Initial concentration (mg/kg)

F_0 = Final concentration (mg/kg)

A final removal efficiency without biosurfactant ranges from 16.00 to 32.72 and with biosurfactant ranges from 33.39 to 56.14.

Table 11 1st Removal efficiency of Chromium (%)

Sr. No.	Final removal efficiency without biosurfactant	Final removal efficiency biosurfactant
Sample 1	32.72	33.93
Sample 2	23.91	33.47
Sample 3	16.20	40.68
Sample 4	19.29	56.14

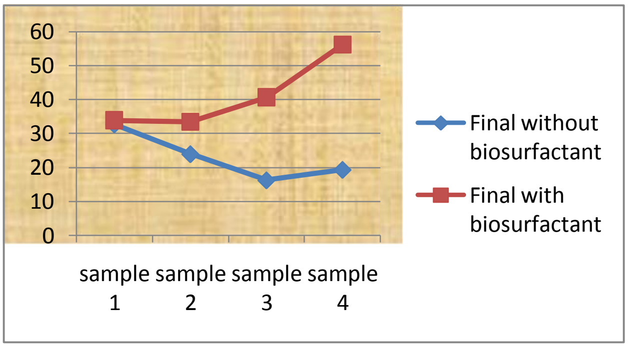

Fig.16 1st Removal efficiency of Chromium (%)

Table 12 2nd Removal efficiency of Chromium (%)

Sr. No.	Final removal efficiency without biosurfactant	Final removal efficiency biosurfactant
Sample 1	32.68	34.39
Sample 2	20	32.38
Sample 3	16	42.18
Sample 4	18.68	55.70

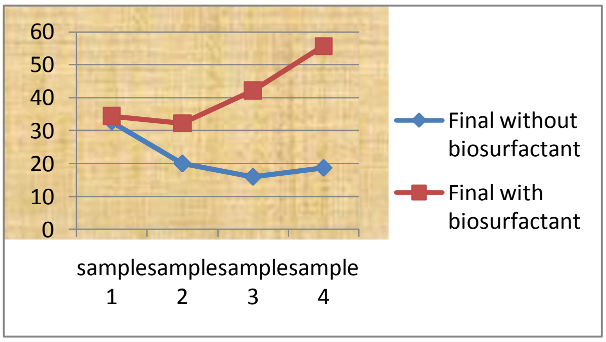

Fig.17 2nd Removal efficiency of Chromium (%)

From the results, a maximum removal efficiency removal is carried out at Hadapsar stretch and Urali devachi and minimum removal efficiency is at dumping site and near dumping site. Removal efficiency of copper and chromium depends on the type of soil, constituents of metal, leachate percolation at various depths. Also it depends on the physio-chemical characteristics of leachate formation.

IV. CONCLUSION

In present study, the technique of soil washing with the addition of biosurfactant is used for remediation of contaminated site. The samples required for the study where collected from various locations near open dumping area at Urali Devachi which is the solid waste dumping site for PMC. The sampling points chosen to analyze the level of contamination due to MSW disposal. The soil samples where procured from the location at a depth 1m and 2m. The soil samples were tested to analyze the removal efficiency of copper and chromium. The samples were also tested to observe the effect on various parameters like pH, Electrical Conductance, Organic matter content, Moisture content.

The results obtained during experimentation programme shows considerable increase in removal efficiency of copper and chromium with addition of biosurfactant. Soil washing and soil washing with biosurfactant was done. The properties of soil also get improved due to addition of biosurfactant. Hence it can conclude that addition of biosurfactant is helpful to enhance the effectiveness of soil washing.

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