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

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Abstract— Heavy metal removal is important 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. Soil washing is one of the ex-situ techniques which are 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. In case of mixed contaminants such as pesticides, volatile organic compounds, this bench scale model can be used.

Index Terms— MSW disposal site, Bench Scale Soil washing, Biosurfactant as an additive

1 Introduction

Heavy metals present in the contaminated soil are lead (Pb), chromium (Cr), arsenic (As), zinc (Zn), cadmium (Cd), copper (Cu), mercury (Hg), and nickel (Ni). Natural pollutants are superior to the inorganic pollutants for the reason that they are oxidized to carbon oxide and degraded by the microbial activities thus they are wash away from soil after some period. Inorganic pollutants such as heavy metals go on in soils intended for the longer duration as they did not suffer microbial and chemical degradation. Soil contamination increase their toxicity in the proper food series such as soil-plant human or soil-plant-animal-human, consuming water and land water which reduce human environmental safety and marketability of food, properties of drinking water and land reused for agriculture purpose. These types of factors increase their risk to various diseases in humans.

In present scenario, it is required to remediate the contaminated soil or remove the heavy metals from the polluted soil. Soil characterization and appropriate remediation technologies for contaminated soil is accommodating towards the removal of heavy metal from the polluted soil. Selection of remediation technology for heavy metal removal depends on the type of soil, characteristics of soil, concentration of the pollutants.

There are various technologies to remediate the contaminated soil which includes the removal of heavy metals and their impacts on the soil fertility.

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However, mainly two types of remediation carry on for the metal contaminated soil: 1) removes the metal in a soil by immobilization of the contaminants and decrease their movement like vitrification, solidification/stabilization 2) by transferring the contaminants to liquid phase desorption and solubilisation like soil washing and soil flushing 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 as well as increases their soil fertility using biosurfactant as an additive.

The aim of the 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.

2 Methodology

It is a systematic and different 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.

2.1 Sample Collection

While collecting sample, it is necessary to analyze the study area, characteristics and analysis of soil sample. Soil samples were collected from dumpng site (sample 1), near dumping site (sample 2), urali devachi (sample 3), hadapsar stretch (sample 4). The detail information is as follows;

2.2 STUDY AREA

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 is selected to study the heavy metal contamination in a soil and impact of MSW contamination at the Urali Devachi site.

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

Government allotted 43 acres of land in verdant Urali Devachi. In 2003, 120 acres of land waste disposal demands at Phu sungi site. This depot is an old dumping site and contaminated site hence it is necessary to remediate the soil and land.

Fig.2. MSW dumping area which shows leachate pond Pune India

2.3. EXPERIMETAL DESIGN OF BENCH SCALE MODEL

An enhanced 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.3. Bench scale model design for Soil Washing

2.4. MODEL SPECIFICATION

This bench scale model consists of of 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.4.AC motor connected with gearbox

Fig.5. Shaft Arrangement between the motor and PVC pipe

Size specification:

There are various parts includes in the model design.
1. PVC material pipe – 3 ft in length and 7 inch in diameter
2. Angle of inclination – 30°
3. Motor specification - AC induction Motor , 90 v , 0.75 HP, 1440 rpm speed with adjustable gear box
4. Shaft size – 20 mm diameter
5. Stand – M.S. Steel Material, 2.5 ft in height , width and 3 ft in length
6. 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.

2.5 EXPERIMENTAL SET UP 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 is 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 was separated by 5 μm pore size 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.

2.6 TESTING PROCEDURE AND ANALYTICAL TESTING

2.6.1. 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.

2.6.2. 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 and soil filtered and soil is dried at its atmospheric temperature.

Fig 6 Filtered water from the soil

3 RESULTS AND DISCUSSION

3.1 ANALYSIS OF LEACHATE SAMPLE

The parameters of leachate samples are as follows:

Table no. 3.1. 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 are high. A heavy metal concentration of Copper and Chromium in leachate was very high. Therefore it was concluded that, these two heavy metal concentrations were decided.

3.2 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 3.2 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

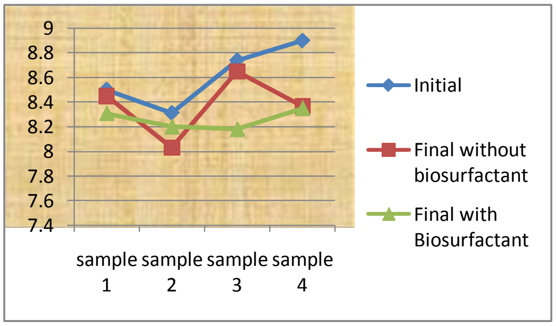

Fig.7 1st pH variation in soil

Table 3.3 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

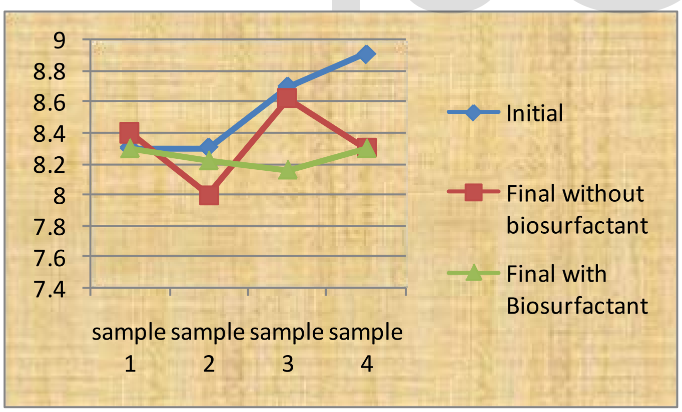

Fig.8 2nd pH variation in soil

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.

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 3.4 1st Electrical conductance variation in soil (mhsos/cm)

Sr. No.	InitialElectrical 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

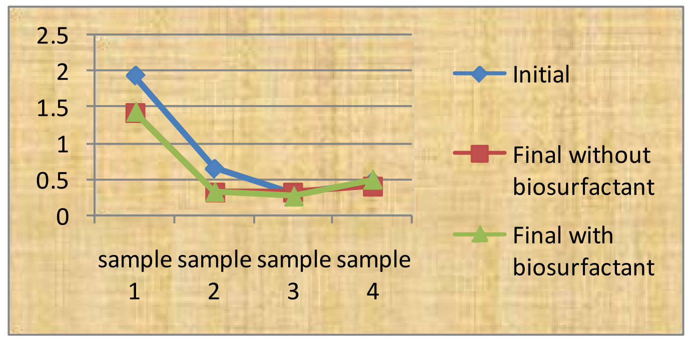

Fig.9 1st Electrical conductance variation in soil (mhsos/cm)

Table 3.5 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

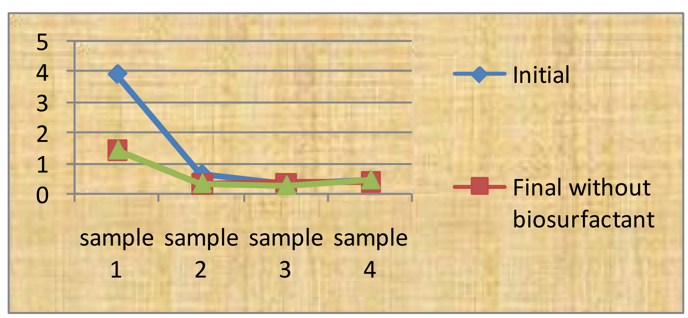

Fig.10 2nd Electrical conductance variation in soil (mhsos/cm)

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 is 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 3.6 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	0.47
Sample 4	0.42	0.50	0.42

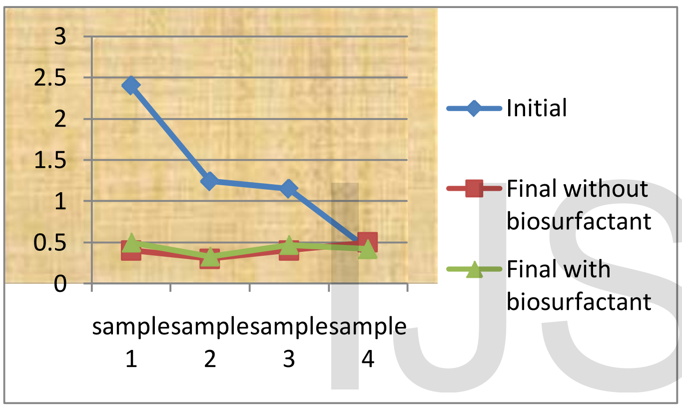

Fig.11. Organic matter content variation in soil (%)

Table 3.7 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

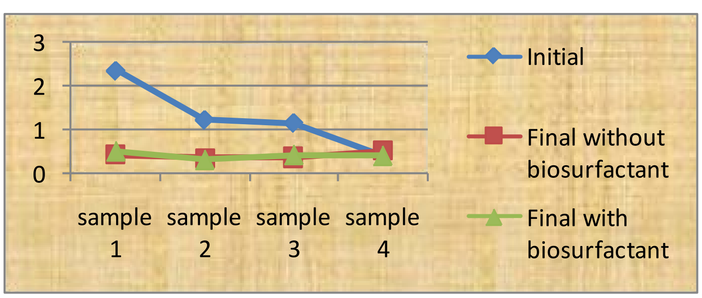

Fig.12. 2nd Organic matter content variation in soil (%)

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 weight 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:

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

Where: W_1 = weight of tin (g)

W_2 = weight of moist soil + tin (g)

W_3 = weight of dried soil + tin (g)

Table 3.8 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

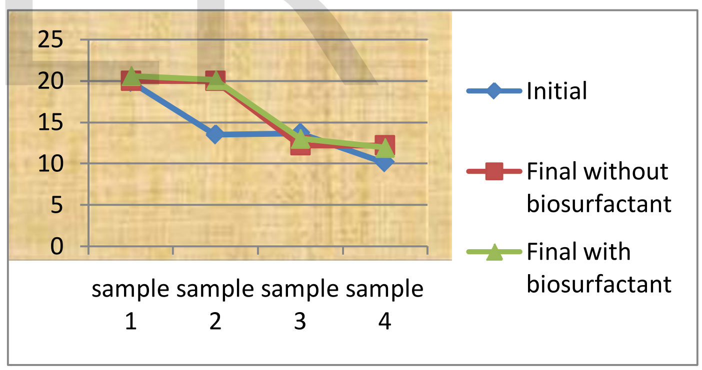

Fig.13.1st Moisture content variation in soil (%)

Table 3.9 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

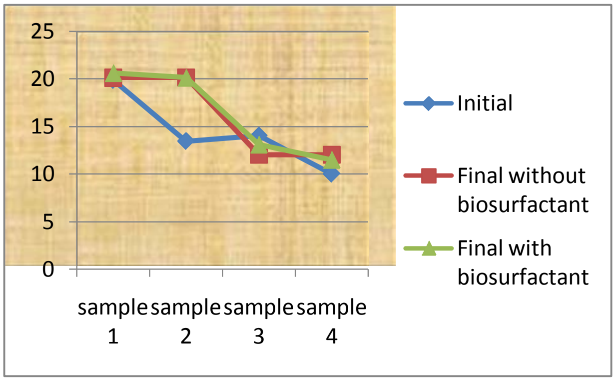

Fig.14. 2nd Moisture content variation in soil (%)

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:

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

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 3.10.1st 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

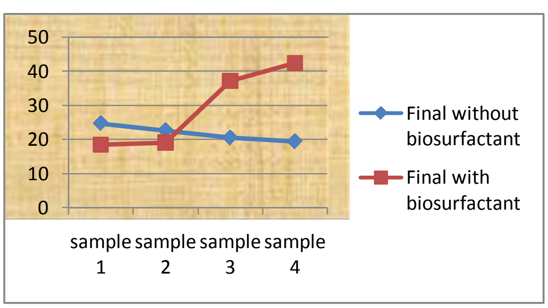

Fig.15 1st Removal efficiency of copper (%)

Table 3.11 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

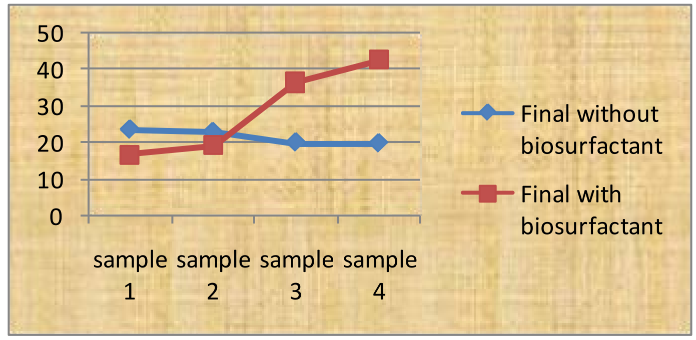

Fig.16 2nd Removal efficiency of copper (%)

F. Removal efficiency of chromium

A removal efficiency of heavy metal is determined as follows:

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

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 3.12 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

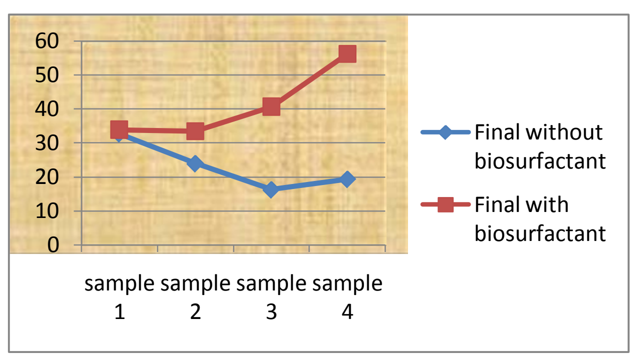

Fig.17 1st Removal efficiency of Chromium (%)

Table 3.13 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

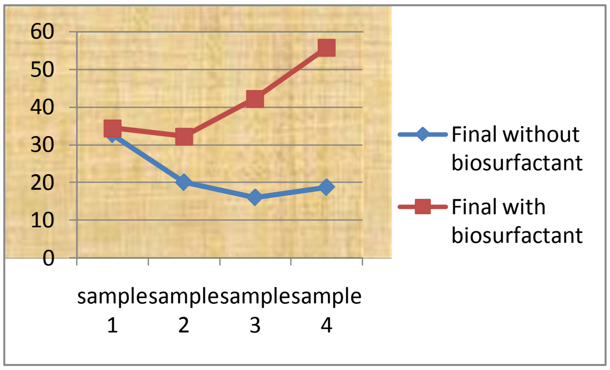

Fig.18 2nd Removal efficiency of Chromium (%)

From the results, a maximum removal efficiency removal is carried out at Hadapsar stretch and Urali devachi and minimum removal efficiency was 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.

4 Conclusion

In present study, the technique of soil washing with the addistion 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 choosen to analyze the level of contamination due to MSW disposal. The soil samples where procured from the location at adepth 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 considearable 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 effecrtiveness of soil washing.

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