FINAL REPORT

of

ATTOCK REFIENRY LIMITED
OILY SLUDGE BIOREMEDIATION
USING EM TECHNOLOGY

Phase –I: Treatment of Sludge with EM products
Phase –II: Application of Bioremediated Sludge to Onion Crop

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Preface

The participation of EM Research Organization Inc., Lahore (EMRO) and National Cleaner Production Centre (NCPC) in CPP workshop held at Islamabad, resulted to join hands in providing cost effective and simple solution for the safe disposal of refinery sludge, which is a difficult problem in overall waste treatment program of refineries. It was decided by both the organizations to undertake a research trial in the premises of Attock Refinery Limited (ARL), Rawalpindi using EM Technology to treat the pure oily sludge with EM products in order to remedy biologically the sludge. For this purpose it was decided to conduct the trial in two phases i.e. phase –I: treatment of oily sludge with EM products and phase –II: application of EM treated sludge to onion crop. The phase –I experiment was completed on 10th December, 2002 (Oct 29th to 10th Dec) after 43 days. The biosludge was mixed with equal quantity of soil to change its oily nature (biofertilizer) and a calculated quantity was applied to onion crop. The trial in detail is given in this report.

Phase – I

Treatment of Petroleum Sludge

Using

EM Technology

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EXECUTIVE SUMMARY

Disposal of refinery sludge is a difficult problem in the overall waste treatment management program of refineries. Even the most advanced methods give residues that are no longer amenable to cost effective treatment. Petroleum refining industries are troubled by the problem of handling substantial quantity of sludge in one form or the other depending upon the nature of the crude, processing capacity, downstream capacities, design of effluent treatment plant, pollution abatement measures and the efficiency-cum-effectiveness of these plants.

Due to regulatory or legislative requirements, public pressure, side effects on humans, and enlightened corporate behavior; there is a growing realization and movement to clean-up such environmental messes. Oil refineries need a well-planned oily sludge management strategy to manage oily sludge and there is a need to have a more cost-effective alternative to traditional physical and chemical methods of remediation.

UNIDO NCPC has been asked for the disposal of oily sludge from almost all refineries of Pakistan. Different options were proposed by NCPC for the disposal of oily sludge from the refineries. The option of treatment of oily sludge through clean microbes (bioremediation) was mutually agreed and implemented in a southern refinery. Aerobic bioremediation was utilized which is a slow process and the total time period for full bioremediation is 40-50 weeks. However it takes 8-12 weeks for 60~70% treatment, depending upon TPH value, and the process is totally environment friendly and after the treatment through clean microbes the soil can be used for agriculture purpose. This project was initiated in collaboration with National Institute for Biotechnology and Genetic Engineering (NIBGE) Faisalabad.

Before progressing with a preferred option NCPC is searching other processes and technologies for sludge treatment to provide an effective solution that may be applied to various process sludges, and also for the restoration of polluted sites, treatment of hydrocarbon pollution caused by accidental spills during production, transportation or storage.

In this regard, NCPC participated in CPP workshop held at Serena Hotel recently, where EM Research Organization also took part. EM Research Organization has vast experience of providing bio-solutions in various fields. EM Research Organization was approached by NCPC to join hands in providing cost-effective and simple solution for the bio-degradation of oily sludge at refineries.

The Principal Officer from EM Research Organization visited NCPC on October, 2002. In the meeting it was agreed to perform the trial treatment in collaboration with NCPC at ARL. EMRO team then visited NCPC on October 22, 2002 and the pre-requisites to undertake the trial were discussed

The activities indicated to undertake the trial included sampling and analysis of the sludge, technicians to be trained, space, materials such as plastic sheets to maintain anaerobic conditions, drums and buckets etc. Effective microorganisms were supplied by EMRO Regional Office for Central & Eastern Asia based Lahore.

ARL, which is also ISO-14000 certified, is interested in the treatment of its Oily sludge. Accordingly a trial was designed to effectively address ARL requirements and objectives. The trial project was designed to treat and convert 1.7 M ton of oily sludge into environmental friendly residue (compost) *under anaerobic conditions*. The residue can be used as a bio-fertilizer for agricultural purpose.

A room near old bulkasar gantry was selected to carry out the trial. The sludge was shifted from site (near tank 1) to the room and mixed with the EM solution in proper ratio. EM Experts visited the site every week. NCPC carried out activities in sludge mixing, solution making and sludge condition monitoring, and coordination of testing. NCPC monitored the room temperature and logged it for the six weeks on daily basis. Laboratory test samples were taken for the priority parameters i.e. pH, C, N, H, S, TPH and metals analysis from QCL, PINSTECH, HDIP, NIBGE and NARC, before and after treatment of the sludge to find out the response of the EM technology to sludge treatment. (The metals analysis for the ARL sludge before treatment was completed; while after treatment is awaited).

After six weeks the sludge which was odorous greasy and black, transformed into dispersed & brownish shape and the pungent odor diminished and changed into sweet fermentation smell. During the process of sludge bioremediation it was observed that houseflies and mice/rats were attracted by the sludge and found there alive which shows that the sludge has lost its hazardous ingredients or nature.

With EM application Ba was reduced up to 85%, Pb, Fe, Zn, Ni up to 50% in the bio-sludge while As, Cr, Cu and Mn showed no significant change in concentration.

The treated sludge (bio-fertilizer) was then applied in phase II to agriculture land as bio fertilizer, after mixing with dry soil in proper ratio. Here the effectiveness of sludge treatment would be proved through physical growth and chemical analysis of the crop. N, P, K, and Organic Matter of the treated sludge mixed in 1:1 ratio with soil after treatment was compared to same analysis for field soil, where an agricultural experiment is being undertaken as part of phase II of this program. The entire N, P, K, and Organic Matter of the treated sludge have the properties of bio-fertilizer, and indicates it is rich in macro-nutrients. In fact the doses of the treated sludge will have to be determined on the basis of farmyard manure for agricultural purposes for various crops inclusive of vegetables and gardens.

Conclusion:
The trial on bio-remediation (anaerobic) of pure oily sludge of ARL, Rawalpindi within its premises using EM Technology was successfully completed with the collaboration of EMRO/NCPC/ARL within a period of 6 weeks (29th October to 10th December, 2002). The effective microorganisms transformed the undiluted oily sludge from ARL into bio-active-sludge; which may be called bio-sludge.

For heavy metal breakdown the trial data shows that Ba has been reduced by 85% in the EM treated oily sludge as compared to original ARL sludge, and Pb, Fe, Zn and Ni have been reduced by about 50% in the treated bio-sludge. The contents of As, Cr, Cu and Mn showed no change.

With this the first phase of the experiment ended showing:

i Effective Refinery Sludge Treatment providing environmentally friendly/safe disposal; has been demonstrated;
ii ISO-14000 compliance; ensured;
iii Cost-effectiveness; being evaluated in phase II i.e. application as bio-fertilizer
iv By-product (saleable); oily sludge has been converted which is easy to handle, transport, store, and applicable in agriculture. To start with may be distributed free of cost and later on commercial basis.
v Reduction in concentration of heavy metals; reduction in concentration of heavy metals has occurred up to 50 to 85%.

Recommendations:
The EM treated sludge being a bio-fertilizer can be used in agriculture and a substitute to farm-yard manure and as a soil amendment to improve/reclaim salt affected lands (a major problem in Punjab and Sindh). While applying in agriculture the doses are to be determined by experiments carried out under given climate conditions.

- Test application of the ARL treated sludge as bio-fertilizer and test toxicity of chosen crop and also treated sludge/bio-fertilizer dose optimization.
- Compare treated sludge/bio-fertilizer yield and cost with farmyard manure and chemical fertilizer.
- After successful completion of the trial, this technology can be applied to the estimated 400 – 600 M tons / year of ARL sludge on large-scale and also expanded to other Refineries.
- Using the experience of this trial and the methodology used, proposal may be developed for other petroleum sector sludges upstream and downstream.

A. INTRODUCTION

A.1 EM Technology

EM stands for Effective Microorganisms. EM is a combination of various beneficial, naturally occurring microorganisms mostly used for or found in foods. It contains beneficial organisms from three main genera: phototrophic bacteria, lactic acid bacteria and yeast. These effective microorganisms secrete beneficial substances such as vitamins, organic acids, chelated minerals and antioxidants when in contact with organic matter. At first, EM was considered an alternative for agricultural chemicals, but its use has now spread to applications in environmental, industrial, and health fields. However, it must be stressed that EM is neither a synthetic chemical nor a medicine.

EM technology can bio-treat wastes that are impossible to be treated chemically. The EM tech. de-ionizes all elements present in the sludge.

EM Research organization was founded in 1994 in Okinawa, Japan. EM Research Organization promotes and disseminates EM Technology all over the world through its regional branch/liaison offices, Joint venture companies, NGO, NPO affiliates and local governments. EM Research Organization has a team of more than 100 researchers around the globe conducting EM research in different fields to uncover viable solutions for existing environmental and health problems. EM bacteria environmentally friendly and does not pose problem of contamination.

A.2 EM/NCPC Collaboration

EM Research Organization (EMRO) and National Cleaner Production Center (NCPC) took part in a workshop on cleaner production program (CPP) held at Islamabad during August 2002. There after through mutual discussions and meetings it was decided by NCPC that EMRO possesses vast experience in bio-remediation (anaerobic) in various fields (industrial solid wastes, sewage effluent and solid wastes) using EM Technology, a technology, without using chemicals but involving the active working and effectiveness of effective microorganisms (EM). NCPC/UNIDO is already working on different options inclusive of aerobic bio-remediation for the disposal of petroleum oily sludge. Aerobic bioremediation of oily sludge was utilized, which was a slow process completed in 40–50 weeks period.

A.3 Sludge Disposal Problem

Petroleum refining industries are troubled by the problem of handling substantial quantity of sludge in one form or the other depending upon the nature of the crude, processing capacity, downstream capacities, design of effluent treatment plant, pollution abatement measures and the efficiency-cum-effectiveness of these plants. To fulfill all the legislative and environmental requirements oil refineries need a well-planned oily sludge management strategy to manage the oily sludge with more cost-effective alternative to traditional physical and chemical methods of disposal.

B. TRIAL FOR ARL SLUDGE DISPOSAL

B.1 Objectives of the trial

The oily sludge poses various kinds of environmental hazards such as:

- Fire, as oil being lighter floats on water and is liable to catch fire;
- Ground-water pollution due to gradual percolation;
- Threat to marine life;
- Air pollution due to evaporation.

The objective of the trial project is to provide ARL:

i. Effective Refinery Sludge Treatment providing environmentally friendly/safe disposal
ii. ISO-14000 compliance
iii. Cost-effectiveness
iv. By-product (saleable)

B.2 Advantages of Bioremediation

- An ecologically sound, natural process that destroys organic contaminants; residues are usually harmless products and byproducts are generally innocuous;

- Instead of merely transferring contaminants from one environment medium to another (e.g. from water to the air or to land) bioremediation completely eliminates the target chemicals, represents a closed solution;

- Bioremediation is far less expensive than other technologies that are often used to clean up hazardous waste cost-effective when compared to other treatment technologies;

- Can be performed on-site, low profile.

B.3 Trial Room

The initial plan was to treat 5 Tons of ARL sludge in a closed-door environment. In this regard, the old control room of BB STILLS was selected. The main task was to shift the sludge from sludge pit to room. While shifting, it was decided to reduce the sludge quantity, as it would be easy to transport and handle during the trial, especially while mixing of EM products in the sludge.

B.4 Trial Requirements

As the trial was conducted in collaboration with four Organizations, ARL/NCPC/ UNIDO/EMRO; it was, therefore, imperative to summarize the pre requisites and responsibilities to complete the designed trial as per schedule:

i. **Provision of required material**: Few buckets of 50litre capacity for mixing EM ingredients, few drums (steel or plastic) 250 or 500 lit capacity to prepare homogeneous solution of EM extended as well as for

storage purposes, and big plastic sheets to spread on the floor of the room and to cover the sludge heap for anaerobic bio-remediation.
These were arranged by ARL .AM (TS).

ii. **Apparatus and equipment**: beakers for liquid measurements and thermometer for temperature measurement.
Arranged by ARL Principal Chemist.

iii. **Provision of Transport, room and labor**:
Transport required shifting oily sludge from the storage lagoon to the trial site, a room and few laborers for mixing EM products with the oily sludge.
ARL made the arrangements.

iv. **Gloves:** These were provided by NCPC**.**
Sampling and analysis of sludge samples:
Samples of oily sludge were taken before the start of the trial and after completing the trial.
NCPC took responsibility to get these samples analyzed for NPK, C: N ratio, organic matter and metals, etc. from external agencies/organizations.

v. **Room temperature**: NCPC Engineers took readings of room temperature.

vi. **Training of Workers/Technicians**: EMRO provided necessary training to workers.

vii. **Monitoring of Sludge temperature and moisture**: EM team visited the trial at ARL on weekly basis, took inside sludge temperature measurement and maintained moisture up to 30%

viii. **EM products**: **EMRO** provided all EM Products and transported them from Lahore to ARL (Rawalpindi Islamabad).

B.5 Trial Design

EM Research Organization headed by the Principal Officer initially proposed to treat 10 tons of oily sludge. EMRO Team visited NCPC on 22nd October 2002 to finalize the arrangements, requirements and design of the trial. At last it was agreed to conduct trial using 5 tons of sludge in a closed-door environment within the ARL premises. For this purpose the old control room of BB STILLS was selected and necessary equipments and material was shifted to this room.

On October 29, 2002 EMRO Team, NCPC & ARL dignitaries arrived at the trial site. A trolley was employed to shift the sludge from the lagoon to the room. Having shifted two trolleys it was observed that the capacity of the room did not allow shifting more sludge. At this conjuncture the shifted sludge was thought to be enough for the trial. The weight was calculated and it was 1.72 tons of sludge. EM Team/NCPC/ARL officers considered this quantity reasonable to handle and mix with EM products. EM Team brought already prepared EM products e.g. Bokashi, EM-1, EM-3. Molasses and EMRO powder from Lahore.

The oily sludge was spread over the plastic sheet in a 10cm thick layer. Half of the Bokashi was used to cover the whole surface of the sludge uniformly. Then half of the EM solution prepared by mixing 6litre each of EM-1, EM-3, and 18 lit molasses and EMRO powder in 100litre of water was sprinkled carefully. The sludge was mixed with spade thoroughly and a heap was formed. About 60kg Bokashi and 25litre EM solution was sprinkled all over the heap. Then again it was evenly spread while mixing on the plastic sheet. During this process of spreading wherever very dark sludge clod was seen a little bit Bokalshi was spread at once.

Having spread/sprinkled the remaining quantity of 65 kg Bokashi and 15 liter EM solution, the sludge was mixed thoroughly and a heap was prepared. Thirty grams of EMRO powder was very carefully spread over the whole heap. The extra part of the underlying plastic sheet was wrapped around the heap circular base. Thereafter, with two plastic sheets the whole heap was tightly covered and bricks were placed on and around plastic sheet at almost all defined points.


Fig. B.1: Mixing and sampling of petroleum sludge during bioremediation.

Fig. B.2: Sludge placed on plastic sheet and covered by plastic sheet

The room had few small openings near the roof for ventilation and besides this two windows were also kept partly opened to cause air to circulate freely in the room because of evaporation of hydrocarbons and bad odor.

B.6 EM Products utilized

The mixing process of EM products is shown in Figure B.3. The sludge was manually mixed with the following ingredients:

- EM solution [2 kinds of solution of different types of bacteria (6 lit + 6 lit)
- EM Bokashi (200kg)
- EM Powder (90g)
- Molasses (8lit)
- Water (100lit).

The sludge to be treated was supposed to be dry, however, on site it was of 80% above TPH, which made to change the formula of EM products accordingly.

Figure B.3: EMRO team getting ready to conduct mixing

C. FIRST WEEK ACTIVITY

C.1 Monitoring during first week

Actual data on maximum and minimum room temperature was recorded daily once (table-1). Activity of EM was observed; it was seen that after two days a white coloring of the surface sludge was observed showing the presence of fungus on the surface of heap. Moreover, the hydrocarbon (HC) odor started to diminish significantly.

ARL Safety department also undertook the HC measurement and the reading on the explosive meter was zero, showing no HC vapors inside the room, while at the start it was not bearable to breathe (no actual measurement).

The weather pattern observed over the first week was, with clear and dry sunny days and a bit colder nights. It was observed that after a couple of days brownish discharge probably molasses started to leak towards the external slope of the room. This was due to some loose packing of the sides of the heap. However the flow was trivial and stopped itself it was not dangerous from the safety point of view and the leakage was washed with clean water.

C.2 Analysis of Sludge Samples

The sludge samples (before treatment) were sent to PINSTECH and HDIP for the analysis. NCPC coordinated the activity. The description is summarized in table 1.4

C.3 Observations During EMRO Team 1st visit

EM team visited to monitor the microbial activity, moisture content and temperature of the heap. The heap was uncovered and the mix was physically checked/examined for the moisture content.

i. According to EM team, the action of the EM process was found speedy as compared to the other sludge's treated by EM before (e.g. Leather industry sludge).
ii. The moisture content was found to be a little bit less therefore EM solution already prepared on 29 October 2002 was spread over the whole heap in order to bring the moisture content up to 30 %.
iii. The temp of heap was also observed by inserting a thermometer at various places into the heap. The temperature ranged between 30~32 C. The temperature range of the heap was quite satisfactory to stimulate the growth and action of the bacteria.
iv. The sludge was examined from all over the heap and at places from the depth. The smell of the sludge revealed that the activity of the microorganisms is encouraging as there was no bad smell of the sludge.

D. SECOND WEEK ACTIVITY

D.1 Monitoring during second week

Actual data on maximum and minimum room temperature was continued to be recorded daily once during the second week (table-1). There was a decrease in ambient room temperature with the start of winter season. Subsequently, when the temperature of heap was monitored, a decrease in temperature was also detected. **Moreover, the HC odor was totally diminished.**
The sludge temperature measured since the start of the trial is given in table-1

The weather was cloudy during the second week with a cool breeze during the day and night. It was observed that the brownish discharge from the heap has stopped and everything was ok.

D.2 Observations During EMRO Team 2nd visit

EMRO team visited NCPC/ARL on November 12, 2002 to monitor the microbial activity, moisture content and temperature of the heap.

- The heap was uncovered and the mixture was physically checked/examined for the moisture content. Temperature of the heap was immediately measured after uncovering the heap.
- Additional activity for the second week was to shuffle and mix the upper one-foot of half of the heap. This was done to evenly mix the colonies developed on the surface of the heap, as the penetration through the depth is difficult for microbes.
- Moreover, approx. 2 Sq Ft area of the heap was thoroughly mixed to the depth. This was done to see the difference between the totally mixed portion with the portion, which was mixed till one foot only.
- According to EMRO team, activity was found a bit slower during the second week. The main reason behind this slow rate of microbial activity could be due to lowering of the temperature by 6°C as compared to the first week inside the heap.
- The moisture content was found enough, as the activity is low during the second week with the decrease in temperature. Therefore, EM Solution was not added.
- The temperature of heap was also observed by inserting a thermometer at various places into the heap. During first week the temperature of the heap was in the range of 30-32°C and the current temperature was in the range of 24-26°C. From EMRO team point of view temperature range of the heap was still satisfactory to stimulate the growth and action of the bacteria.
- The sludge was examined from all over the heap and at places from the depth. The smell of the sludge revealed that the activity of the microorganisms is encouraging, as there was no bad smell of the sludge. Additionally, houseflies were seen attracted towards the heap after uncovering, which is not the case with the oily sludge in its original condition.
- By mixing it was observed that the original physical condition of the sludge has totally changed. The lump of sludge, which was greasy and cohesive in nature, has transformed in to a brittle and dispersed condition.

E. THIRD WEEK ACTIVITY

E.1 Monitoring During Third Week

Actual data on maximum and minimum room temperature was also recorded daily once during the third week. There was a decrease in ambient room temperature with the start of winter season but the constant room temperature range of 19~21°C was observed during the whole week. Subsequently, when the temperature of heap was monitored, the temperature range was same as that of second week.

- The weather was partly sunny during the third week with colder nights and sunny days.

E.2 Observations During EMRO Team 3rd Visit

EMRO team visited NCPC/ARL on November 19, 2002 to monitor the microbial activity, moisture content and temperature of the heap.

The heap was uncovered and the mixture was physically checked/examined for the moisture content. The moisture content was found enough for microbes to remain active. Temperature of the heap was immediately measured after uncovering the heap.

During last week EMRO visit, half of the heap was mixed. This week, the other side of the sludge heap was also mixed/shuffled till upper one-foot of the heap in order to accelerate the microbial activity. This was done to evenly mix the colonies developed on the surface of the heap, as the penetration through the depth is difficult for microbes.

i. According to EMRO team, activity was found faster on the side, which was mixed during last visit.
ii. The moisture content was found enough; therefore EM Solution was not added.
iii. The temperature of heap was also observed by inserting a thermometer at various places into the heap. The temperature in the mixed side (during last week) was 1~2 C higher than the undisturbed side. This is due to the higher rate of microbial activity in the mixed side. The temperature was in the range of 24-26°C.
iv. The sludge was examined from all over the heap and at places from the depth. The smell of the sludge revealed that the activity of the microorganisms is encouraging, as there was no bad smell of the sludge but the smell of fermentation has increased.

F. FOURTH WEEK ACTIVITY

F.1 Monitoring During Fourth Week

Actual data on maximum and minimum room temperature was recorded daily once during the fourth week . Further decrease in ambient room temperature was observed as we reached the fourth week of the trial. Subsequently, when the temperature of heap was monitored, the temperature range was same as that of last week, i.e. it was dropped.

The weather was partly sunny during the fourth week and a bit colder than the third week.

F.2 Observations During EMRO Team 4th Visit

EMRO team visited NCPC/ARL on November 26, 2002 to monitor the microbial activity, moisture content and temperature of the heap.

The heap was uncovered and the mixture was physically checked/examined for the moisture content. The moisture content was found enough for microbes to remain active. Temperature of the heap was immediately measured after uncovering the heap.

This week no mixing was conducted.

i. According to EMRO team, activity is slower on the side, which was mixed during last visit.
ii. The moisture content was found enough; therefore EM Solution was not added.
iii. The temperature of heap was also observed by inserting a thermometer at various places into the heap. The temperature was in the range of 23-25°C. The current temperature range is lower than before, which could be due to the lower rate of microbial activity.
iv. The sludge was examined from all over the heap and at places from the depth. The smell of the sludge revealed that the activity of the microorganisms is still encouraging but slow.

G. FIFTH WEEK ACTIVITY

G.1 Monitoring During Fifth Week

Actual data on maximum and minimum room temperature was recorded daily once during the fifth week (table-1) .

The weather was sunny during the whole fifth week.

G.2 Observations During EMRO Team 5th Visit

EMRO team visited NCPC/ARL on December 3, 2002 to monitor the microbial activity, moisture content and temperature of the heap.

The heap was uncovered and the mixture was physically checked/examined for the moisture content. The moisture content was found enough for microbes to remain active. Temperature of the heap was immediately measured after uncovering the heap.

This week mixing was also conducted.

i. The moisture content was found enough; therefore EM Solution was not added.
ii. The temperature of heap was also observed by inserting a thermometer at various places into the heap. The temperature was around 22°C. The temperature range was lower than before and low ambient room temperature could be the dominant factor.
iii. The sludge was examined from all over the heap and at places from the depth. The smell of the sludge revealed that the activity of the microorganisms is encouraging but slow. Areas of activity (brown colored spots in sludge) have been observed within the heap. Two

samples (brownish & blackish) from the heap have been taken for TPH analysis from QCL, ARL. The results are stated in table-4. (NCPC:ARL analysis results)

iv. Two persons were employed from contractor to mix the sludge. About 100kg of EM Bokashi was added to the heap.
v. Over all bioremediation process was encouraging and was slow expectedly due to winter season.

H. SIXTH WEEK ACTIVITY

H.1 Monitoring During Sixth Week

Actual data on maximum and minimum room temperature was recorded daily once during the sixth week.

H.2 Observations During EMRO Team 6th Visit

EMRO team visited NCPC/ARL on December 10, 2002 to monitor the microbial activity, moisture content and temperature of the heap.

- The heap was uncovered and the mixture was physically checked/examined for the moisture content.
- The moisture content was found enough for microbes to remain active.
- Temperature of the heap was immediately measured after uncovering the heap.
- This week mixing was also conducted.
- The moisture content was found enough; therefore EM Solution was not added.
- The temperature of heap was also observed by inserting a thermometer at various places into the heap. The temperature was around 23°C.
- The sludge was examined from all over the heap and at places from the depth. It was observed that the sludge is fully fermented, the color is changed into light brown and black mix, the smell is fermenting smell and the sludge is decomposed well so that the brittleness is formed. Two samples (brownish & blackish) from the heap have been taken for TPH analysis from QCL, ARL.
- After observing the completion of bioremediation/composting process, it was concluded that the oily sludge has been converted to a bio-fertilizer. The first phase of the trial was considered accomplished. This sludge can be used as by-product for horticulture and agro purposes. Once the compost is ready it must be used as by-product with in 10-15 days of its preparation.
- First phase of 100% (undiluted) oily sludge bioremediation trial has been successfully completed.
- This week, about 20kg of composted sludge was brought to NCPC for pot experiment. Treated sludge was mixed with soil 1:1. Two pots of treated sludge and 2 pots of control ? were designed for a preliminary test.

I. RESULTS AND DISCUSSION

During the first week (29th October to 5th November) it was observed that the action of EM was found speedy and huge number of fungus colonies was visible. The temperature of the heap by inserting a thermometer into the heap at 4-6 places was noted. On an average it was 32ºC. The moisture content was maintained up to 30% with EM solution already prepared on 29th October. The temperature of the heap fell to 25ºC in the 2nd week (12.11.2002) and it was 24ºC on 03.12.2002(5th visit). This means that the temperature remained at 32ºC for 7 days after that at 24ºC for 28 days (05.11.2002 to 03.12.2002) and at 23ºC for 7 days (table-2). With even this low temperature range, the 100% pure undiluted oily sludge of ARL was completely changed to a bio-sludge within a period of 6 weeks.

If the temperature remained a little higher in the range of optimum (30 to 40C), one could expect even earlier anaerobic bio-remediation. The heap temperature dropped to 23 ^{o}C after 6 weeks, simply due to the beginning of winter season. In spite of this, the EM-micro-organisms remained active and a lot of fungus, white in color, appeared on the surface of the sludge, even the activity in deeper layers was medium to high. The typical odor of the sludge disappeared, it was perceptible to smell the fermented odor. The original sludge was more cohesive in structure. With this trial it has become brittle and breaks into small aggregates.

It is worth mentioning here that the increased activity of microorganisms not only enhanced the number of microorganisms manifold (10^5 to 10^7) but also produced heat and energy during the phase of increasing their population while consuming organic matter and certain heavy metals. The is the reason that the inside heap temperature remained on reasonably higher side (table-2) as compared to average minimum and maximum room temperature (table-3).

I.1 Reduction in concentration of Heavy Metals

I.1.1 ARL Sludge Treatment Trial

The perusal of data of oily sludge given in table-4 and its graphical presentation in Fig-1 indicate that Ba has been reduced by 85% in the EM treated oily sludge as compared to original oily sludge, and Pb, Fe, Zn and Ni have been reduced by about 50% in the bio-sludge. The contents of As, Cr, Cu and Mn showed no change.

I.1.2 Other Successful EM Experiences

i. The EM does reduce the contents of heavy metals in EM-treated sludge. EM reduced Cr from 50,000ppm to 450ppm in Leather industry sludge in Pakistan (PTA trial 2002).
ii. The research carried out by Eric Nielsen in Denmark on wastewater sludge indicated a reduction in Cd, Cr, Cu, Hg, Ni, Pb, and Zn by more than 50% with EM application (6th International Conference on Kyusei Nature Farming held at University of Pretoria, South Africa October 1999).

iii. EM application reduced Dioxin generation in the garbage incinerator in the fly ash as well as in the residual ash by 99.9% and 74% respectively (Masato Miyajima et al 6th International Conference, Pretoria, South Africa 1999).
iv. The research carried out by Syed Ali in Egypt on sewage/industrial wastewater indicated a reduction in Cd 40%, Pb 90%, Cu 20%, Zn 99.9%, Ni 80% and Cr 98% with EM application (EM Treatment on Sadat City Sewage/Industrial Waste Water report of Dec. 1997, Egypt).

I.2 Preparation of by-product

The EM treated sludge being a bio-fertilizer can be used in agriculture and a substitute to farm yard manure and as a soil amendment to improve/reclaim salt affected lands (a major problem in Punjab and Sindh). The bio-sludge is to mixed with dry soil in 1:1 ratio before use elsewhere. With this it will become a by-product which is easy to handle, transport, store and applicable in agriculture, horticulture, floriculture and house gardening etc. as and when needed if the by-product is well- dried and packed in bags. While applying in agriculture the dozes are to be determined by experiments carried out under given climate conditions. The application of known quantity of by-product will help to further dilute the concentration of heavy metals as it will be mixed with one acre of ploughed layer (0-9 inches) weighing 1176120kg soil (Annexure-1).

I.3 Fate of Heavy Metal Cr

Cr in its hexavalent form is dangerous for health. It is 26ppm in the bio-sludge (table-4). It will become 13ppm in the by-product (bio-sludge+soil 1:1 ratio), in simple words one kg by-product contain 13mg Cr. Normally, one M.ton of farm yard manure is added to one acre to have good physical conditions and microbial activity. By-product being very rich or high in microbial activity and other NPK nutrients (table-5) the quantity can be reduced to 500kg/acre. This means 6.5kg Cr will be added to one acre (1176120kg soil); this means 181kg soil (6.60ft^2) will receive 1mg Cr. In other words 0.149mg Cr will be in one ft^2 of land. Now the question arises that how much Cr will be taken up by Wheat, Rice or Vegetables when many plants of wheat/rice per ft^2 are growing, again with a number of grains in ear/spike.

For reference purposes WHO (Environmental Degradation by Engineer Col. Rtd. Mumtaz Hussain page 73) has allowed 0.05mg/lit of Cr in drinking water for human consumption. At least 5-10 liters/day of drinking water is the requirement. It will add 0.25 to 0.5mg of Cr daily to the human body. While in our case it is 0.149mg Cr per ft^2 of land. It means WHO has kept in view the daily absorption of Cr into the blood. On the basis of this simple mathematical calculation the ARL-by-product (ARL oily sludge treated with EM and mixed with soil 1:1 ratio) may safely be declared useful for application in agriculture but in known quantity. It will have to be determined by agricultural experiment with all prevailing practices of soil and water in different areas with heterogene soil.

Table I: Temperature Monitoring of The Sludge Under Treatment

S.#	Days	Date	*Max °C	*Min °C
1.	Tuesday	29-10-02		
2.	Wednesday	30-10-02		
3.	Thursday	31-10-02	26	22
4.	Friday	01-11-02	29	23
5.	Monday	04-11-02	26	22
6.	Tuesday	05-11-02	24	22
7.	Wednesday	06-11-02	24	19
8.	Thursday	07-11-02	24	19
9.	Friday	08-11-02	24	19
10.	Monday	11-11-02	23	19
11.	Tuesday	12-11-02	21	18
12.	Wednesday	13-11-02	21	19
13.	Thursday	14-11-02	21	18
14.	Friday	15-11-02	20	19
15.	Monday	18-11-02	21	19
16.	Tuesday	19-11-02	21	19
17.	Wednesday	20-11-02	21	18
18.	Thursday	21-11-02	20	16
19.	Friday	22-11-02	20	16
20.	Monday	25-11-02	21	18
21.	Tuesday	26-11-02	20	17
22.	Wednesday	27-11-02	20	18
23.	Thursday	28-11-02	20	19
24.	Friday	29-11-02	20	17
25.	Monday	02-12-02	21	17
26.	Tuesday	10-12-02	22	16

***Note:** *Temperature was monitored at 1200 hrs daily.*

Table 2: Average Weekly Temperature of Sludge Treatment Heap

Week	Heap Temp (Celsius)
First	30~32
Second	24~26
Third	24~26
Fourth	23~25
Fifth	22
Sixth	23

Table 3: Average room temperature during 6-weeks of sludge treatment heap (Celsius)

Max Reading	Max (Avg.)	Min Reading	Min (Avg.)
29	20.4	16	17.2

The special odor of Hydrocarbons vanished within a week and at the end of 2nd week, it was observed by all that houseflies were attracted by the treated sludge. The concentration of Hydrocarbons was tested and it was found nil.

While mixing Bokashi on 3rd December (after 35 days) with the sludge, it was quite distinct and clearly perceivable that the sludge after treatment with EM has changed its physical properties. sludge became brittle instead of cohesive mass and breaks into small aggregates with pleasant fermenting smell. This made the mixing of Bokashi with EM sludge easy. Beside these, colonies of effective microorganisms were clearly visible with human eye everywhere.

After six weeks the sludge which was odorous greasy and black, transformed into dispersed & brownish shape and the pungent odor diminished and changed into sweet fermentation smell. During the process of sludge bioremediation it was observed that houseflies and mice/rats were attracted by the sludge and found there alive which shows that the sludge has lost its hazardous ingredients or nature.

On 10th December 2002 (after 43 days) the trial was declared successful by EMRO team. This means oily sludge was completely converted to a bio-sludge (bio-fertilizer). This was authenticated by Prof. Dr. Teruo Higa, the founder/inventor of EM Technology, in the presence of NCPC and ARL dignitaries during his visit to this very trial on 14th December 2002 after the symposium at NCPC. This is being tested through application as fertilizer in the field where seasonal crop onions are to be planted.

Original Sludge (before treatment)

Mixing of Bokashi in Sludge

Microbial Activity (Fungus)

Sludge during bioremediation **process**

Sludge after Fermentation

Fig I.1 Living rat found eating sludge

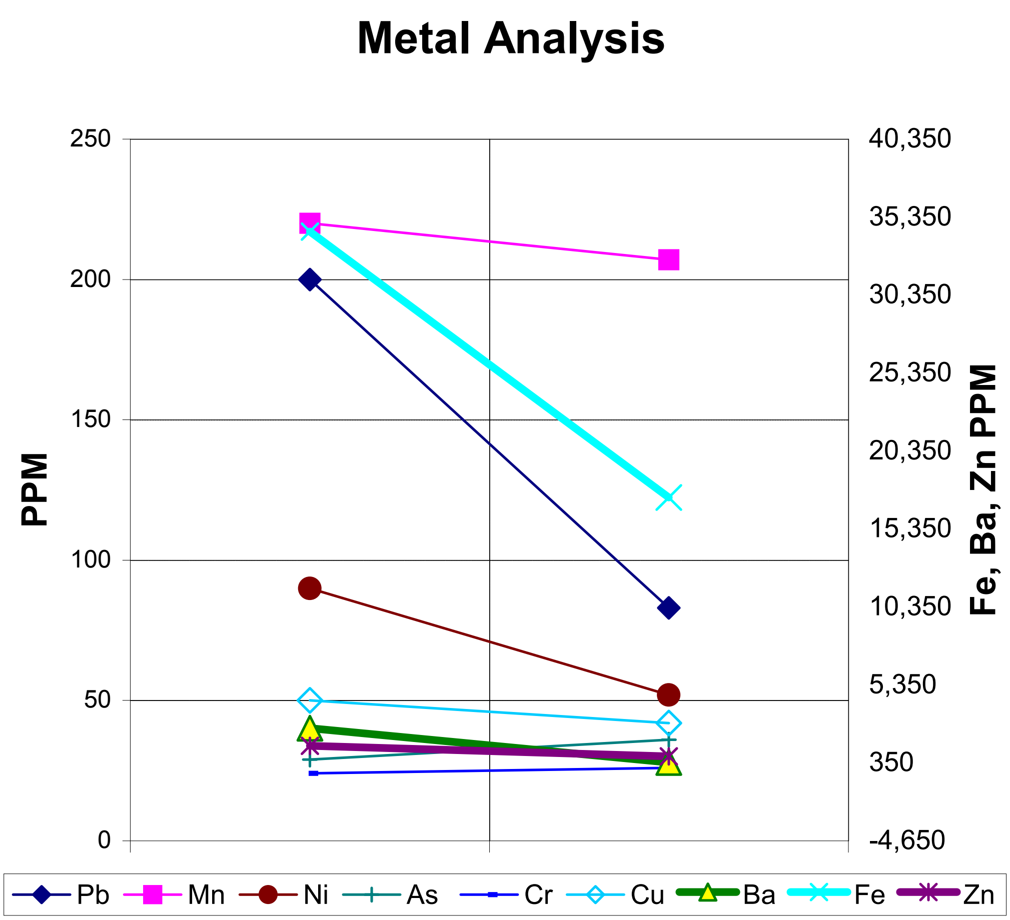
Fig I.2 Rat hiding

The trial results are listed below:

Table 4 Analysis of pure oily sludge and after treatment with EM

S. #	Test	Before Treatment		After Treatment
1.		**HDIP**		**HDIP**
	pH	6.7		7.0
2.		**NIBGE**		**NARC**
	Nitrogen	0.83		
	Carbon	81.5		
	Hydrogen	9.25		
	Sulphur	3.61		
3.		**PINSTECH**		**PINSTECH**
	Metals	%	ppm	ppm
	Pb	0.020	200	83
	Mn	0.022	220	207
	Ba	0.257	2570	382
	Fe	3.443	34430	17373
	Zn	0.144	1440	765
	Ni	0.009	90	52
	As	0.0029	29	36
	Cr	0.0024	24	26
	Cu	0.005	50	42
4.	**QCL**			
	TPH	65.10		76.2

Fig.1: Metal Analysis of oily sludge before and after treatment with EM



The above results show that the metals level has generally decreased across the board.

I.4 Mechanism

The mechanism of bioremediation involves EM-microorganisms (non-GM) which belong to 3 main genera:

- Phototropic bacteria;
- Lactic acid bacteria; and
- Yeast.

EM secretes beneficial substances:

- vitamins;
- organic acids;
- chelated minerals; and
- antioxidants

Phototrohpic bacteria have the characteristics to accept alkaline substances and produce protein. Yeast contains Apo-protein-A&B which also converts such elements into protein and chelates. EM Microorganisms produce NH3, CH4, CO2, etc. during fermentation to enhance the nutrient value of organic matter. Thus EM regenerates the organic matter by eliminating the harmful microorganisms. The acidic nature of EM reduces pH of the alkaline substances. The anti-oxidation nature of EM stops from chemical reactions and bonding.

A compound aluminum ammonium dibutylamine and bacteria like:

- Rhodobacter;
- Pseudomonas;
- Lactobacillus;
- Furabacterum;
- Gluconobacter; etc.

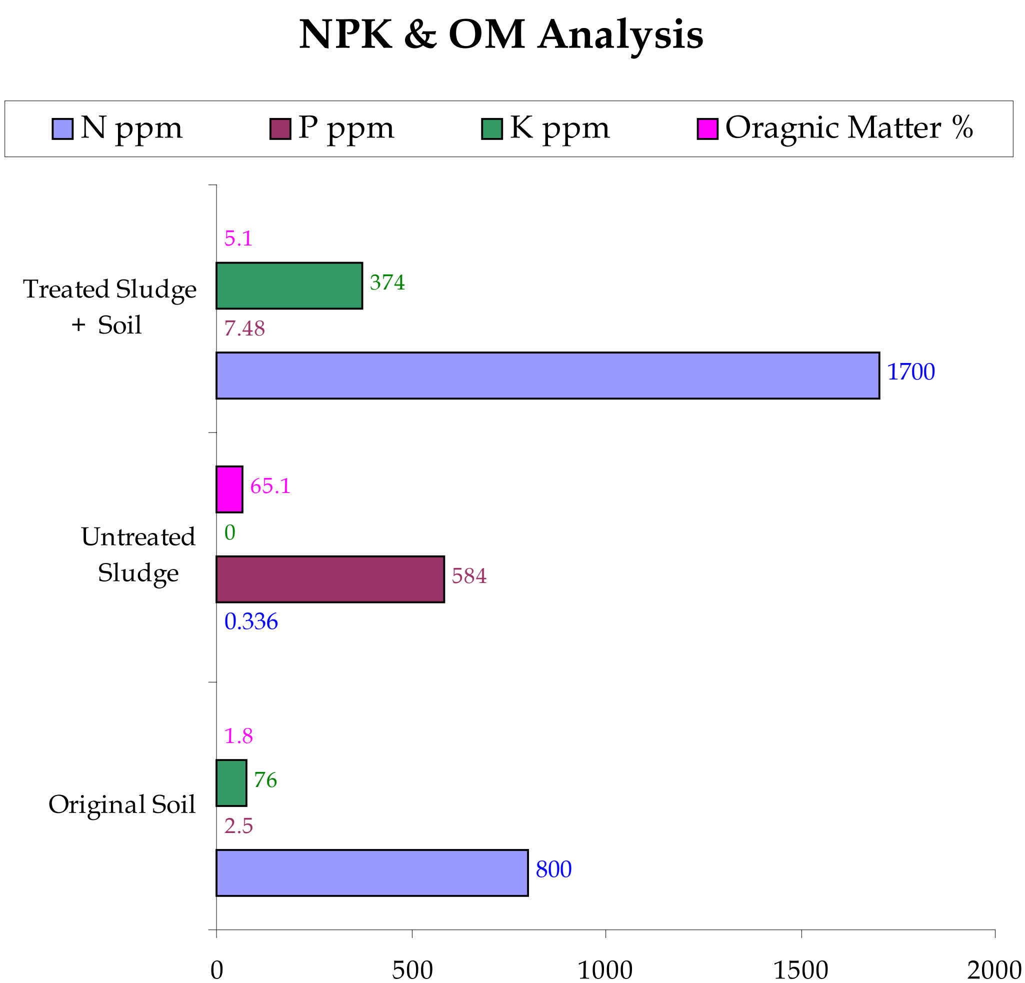
have the characteristics to de-ionize the harmful elements and de-toxify them.

I.5 Application (Phase II)

The treated sludge (bio-fertilizer) was then applied in phase II to agriculture land as bio- fertilizer, after mixing with dry soil in proper ratio. Here the effectiveness of sludge treatment would be proved through physical growth and chemical analysis of the crop. N, P, K, and Organic Matter of the treated sludge mixed in 1:1 ratio with soil after treatment was compared to same analysis for field soil, where an agricultural experimentation is being undertaken as part of phase II of this program. The entire N, P, K, and Organic Matter of the treated sludge have the properties of bio-fertilizer, and indicates it is rich in macro-nutrients. In fact the doses of the treated sludge will have to be determined on the basis of farm-yard manure for agricultural purposes for various crops inclusive of vegetables and gardens.

Provided below are the results of the soil samples and pictures of the preliminary experiments, which show plants, growing in the EM treated sludge.

Fig-2: NPK & OM Analysis before and after treatment



	Original Soil	Untreated Sludge	Treated Sludge + Soil
Oragnic Matter %	1.8	65.1	5.1
K ppm	76	0	374
P ppm	2.5	584	7.48
N ppm	800	0.336	1700

Preliminary Pot Experiment

J. CONCLUSION

It can safely be concluded that the pure oily sludge after treatment with EM Technology has transformed into odorless disposable bio-by product having pleasant fermenting smell, easy to handle, not dangerous to workers and safe to transport else where for use. With this the first phase of the trial is completed successfully. Phase II is being planned. As per advice of Prof. Dr. Teruo Higa, the bio-sludge can be mixed well with the soil (1:1 ratio) for its comfortable transport and practical application in agriculture, orchards, household gardening, pot flowering and for reclamation of salt affected lands, a burning problem in Punjab and Sindh.

The main conclusions are:

1. **Effective Refinery Sludge Treatment providing environmentally friendly/safe disposal;** this has been demonstrated;
2. **ISO-14000 compliance;** ensured;
3. **Cost-effectiveness;** being evaluated in phase II i.e. application as bio-fertilizer
4. **By-products (saleable);** oily sludge has been converted which is easy to handle, transport, store, and applicable in agriculture. To start with may be distributed free of cost and later on commercial basis.

K. RECOMMENDATIONS:

K.1 Application as an Organic Fertilizer:

The treated sludge of two tons after full fermentation is to be treated with equal amount of dry soil and after mixing the treated sludge would be ready to apply and use for agricultural purpose as an organic fertilizer.

In order to reduce the cost of the sludge treatment, it is planned to have two application trials: (i) comparison of yields and cost with farmyard manure, (ii) comparison of yield/cost with synthetic fertilizer.

K.1.1 Comparison with Farm Yard Manure (Original Cost and Dose)

The cost of treating sludge here is considered as $44/Mtons. It is planned to use half kanal plot divided into two portions, each of 1 / 4 kanal area. The first plot would be cultivated with EM treated sludge fertilizer and second with the conventional fertilizer of farmyard manure. *(In both the trial and control plots onions have already been planted).*

K.1.2 Comparison with Synthetic Fertilizer (Optimizing Cost and dose)

It is practicable to add 0.5 ton/acre to achieve the same results. To arrive at a reasonable correct decision the trial, on newly created plot by spreading soil material on existing ground, be conducted with at least 4 or more replications. On the formulation, the doses of bio-fertilizer will be 12g, 25g, 50g, and 100g/ft^2 area for vegetables.

Similarly, the doses can be formulated for cash crops e.g. wheat, rice, cotton, etc. or we would use one kanal plot divide into two portions each of half kanal area and similarly one plot would be cultivated with the EM treated sludge of 151. 50 Kg quantity and the other with synthetic fertilizer @ Rs. 3000/acre so that the process of sludge treatment with EM technology can be justified and shown with the break-even concept.

In both the cases the comparison would be carried out by Observing / Checking

i. The physical growth of the crop
ii. Chemical analysis of the crop
iii. Chemical analysis of the soil before and after cultivation for the following parameters
iv. Nitrogen (N), Phosphorus (P), Potassium (K) Carbon Nitrogen ratio(C: N), Organic Matter.

K.2 Full Scale Sludge treatment at ARL

It is recommended that based on the success of this trial, this technology may be applied to the estimated 400 – 600 M Tons/year of ARL sludge on large-scale. Immediate feasibility should be prepared.

K.3 Expansion to other Refineries

As the trial is the first of its kind in Pakistan so it can be applied on full-scale to other Refineries as well i.e NRL, PRL, and PARCO.

K.4 Proposal for other Upstream and Downstream Petroleum Sector

Using the experience of this trial and the methodology used, proposal may be developed for other petroleum sector sludge upstream and downstream.

ANNEXURE-I: Calculation Methodology

The soil possesses a definite weight depending upon its texture, structure and bulk density (gm/cm^3). The weight of a ploughed layer (1ft x 1ft x 3/4ft) or (30.48cm x 30.48cm x 22.86cm) with bulk density of $1.2gm/cm^3$ varies from 25kg to 30kg.

For practical purposes especially for bio-by-product trial let us take 27 kg weight of one square foot soil up to a depth of 9 inches.
Calculated further for one acre (220ft x 198ft = $43560ft^2$) the weight of ploughed layer comes to 1176120kg.

Normally, **one-ton (1000kg) farmyard manure is added to one acre** to keep organic matter content within satisfactory limits. The weight of farmyard manure per ft^2 (1000 divided by 43560) comes to about 23g but it is 0.85g/kg of soil or it is about $23g/ft^2$ up to a depth of 9 inches.

Now our bio-by-product is rich in effective microorganisms and other elements, it is practicable to add 0.5 ton/acre to achieve the same results. To arrive at a reasonable correct decision the trial, on newly created plot by spreading soil material on existing ground, be conducted with at least 4 or more replications. On the formulation, the doses of bio-fertilizer will be 12g, 25g, 50g, and $100g/ft^2$ area for vegetables.

Similarly, the doses can be formulated for cash crops e.g. wheat, rice, cotton, etc. At least 2 years trial period results will be reasonably decisive.

ANNEXURE-II: Symposium on bio-remediation of industrial sludge

A half-day symposium on Bio-remediation (anaerobic) of industrial sludges using EM Technology was arranged by National Cleaner Production Center (NCPC/UNIDO) in honor of Prof. Dr. Teruo Higa, founder and inventor of EM at NCPC, Rawalpindi inviting dignitaries of ARL, Federal Government, and Ministry of Petroleum.

Environmental Protection Department, and UNIDO representative Dr. Carlos E. Chanduvi-Suarez were briefed about the NCPC role to introduce and promote Cleaner Production Techniques and processes and pollution control at source along with integrated waste management by the Advisor, NCPC, and opening remarks about the industrial waste especially sludge being a menace and threat to environment, Prof. Dr. Teruo Higa was invited to deliver his lecture and experience on industrial solid waste management. Prof. Dr. Teruo Higa presented application of EM Technology to not only the waste management but also for agriculture with proven benefits and success stories all over the world with pictures and slides. The trial study on treatment of EM Technology on ARL oily sludge was completed successfully within 6 weeks by EMRO (presented by Mr. Syed Ali) in collaboration with ARL and NCPC/UNIDO.

In the end the UNIDO Representative Dr. Carlos thanked Dr. Teruo Higa and while concluding the symposium informed thus UNIDO will promote EM Technology in Pakistan, and UNIDO network worldwide will consider its application internationally as well.

Dr. Syed Ali's Lecture
at the Symposium.

Prof. Dr. Teruo Higa's Lecture
at the Symposium.

Phase – II

Application

of

Bioremediated Sludge

as

Biofertilizer to Onion Crop

TABLE OF CONTENTS

1. EXECUTIVE SUMMARY

Oil and gas industry is considered to be one of the most important industries in a country. Apart from its contribution to the economic of the country, it has many side impacts. Oily sludge containing different contaminants pollutes the environment. Some oil industries are using various physical treatments to reduce oil contents. Bioremediation is an effective technique for the biodegradation of oil by using Microbial diversity. Disposal of refinery sludge is a difficult problem in the overall waste treatment management program of refineries. Even the most advanced methods give residues that are no longer amenable to cost effective treatment. In order to provide an effective solution that should be cost-effective, environment friendly and on site use, NCPC in collaboration with EM organization Japan, offered ARL a trail for bioremediation of refinery sludge through its consultants (EHSC) in Pakistan. Accordingly a trail project was designed to treat and convert 1.7 M tons of sludge into environment friendly residue (bio-fertilizer) under anaerobic condition. The trail was completed in a period of 6 week (29^{th} Oct. to 10^{th} Dec. 2002). The oily sludge was tested for various parameters like TPH value, pH, heavy metals concentration before and after the treatment with EM. During bioremediation the sludge was monitored on weekly basis and heap temperature was measured routinely. The data so obtained was tabulated and was compared with sludge before treatment. Results so obtained showed that Ba has been reduced by 85% in EM treated oily sludge as compared to original ARL oily sludge, and Pb, Fe,Zn and Ni have been reduced by about 50% in treated bio-sludge. The contents of As, Cr, Cu and Mn showed no change in their conc.

Following the above-mentioned phase I, the resultant treated sludge (biofertilizer) was then applied in phase II to agriculture land as bio fertilizer, after mixing with dry soil. Here the effectiveness of sludge treatment proved through physical growth and chemical analysis of the crop. N, P, K, and Organic Matter of the treated sludge mixed in 1:1 ratio with soil after treatment was compared to same analysis for field soil, where an agricultural experimentation was undertaken as part of phase II of this program.

The entire N, P, K, and Organic Matter of the treated sludge have the properties of bio-fertilizer, and indicate it is rich in macronutrients. Onions were grown using bio-fertilizer and FYM for yield comparison and also for comparison of their toxic metals levels. Sampling was undertaken on random basis after harvesting the crop and samples were sent for heavy metals analysis and also for analysis of micronutrients; both by University of Arid Agriculture Rawalpindi. The data so obtained showed that levels of heavy metals meet the FAO and NEQS standards and almost similar concentration found in FYM grown onions, which shows that the product is not harmful and the biofertilizer, is safe to use instead of FYM and hence is also saleable.

It may also be mentioned that the oily-sludge which was bioremediated and as mentioned above showed 50-85% reduction in heavy metals, was further tested after its application as a bio-fertilizer in the field and it showed further reduction in its toxic metal content to such an extent that its not harmful for agricultural applications. In fact the soil analysis showed that the heavy metals in the soil after application were all well below the internationally recognized permissible limits.

It is further concluded that the metal breakdown tested 9 months earlier after initial bioremediation/at time of application does not undergo any reversal back to elemental state.

Further, the data shows that the non-ionization process/breakdown of metals continues after the formal bioremediation of the oily sludge during the field application phase as well, which shows that microbial activity continues after the completion of the first phase (oily sludge bioremediation). It seems EM treatment of sludge reduces the content of heavy metals due to its ability to change the ionization of heavy metals. As a result the plants do not take up non-ionized heavy metals.

This work has demonstrated environment-friendly and safe disposal of petroleum sludge, and it indicates ISO 14000 compliance can be ensured.

Large-scale agricultural experimentation is recommended to further test the positive outcomes of this work. In addition to environment-friendly disposal of industrial sludges, it is recommended that special emphasis is laid on developing safe (meeting NEQS) and socially acceptable biofertilizer from bio-remediated sludges; to make the whole process sustainable and commercially viable.

2. INTRODUCTION

Natural gas and oil are natural resources, which contribute to almost all energy needs for domestic as well as industrial activities. Thus the exploration of this type of resources worldwide has been very extensive. Along with the production activities, environmental problems such as the accumulation of oily sludge and heavy metals as well as the generation of the any kind of wastewater containing petroleum hydrocarbons, phenol, ammonia, sulfur and other unwanted parameters became inevitable. These pollutants threat soil, ground water and also surface water. In addition, air pollution should also be considered as problem associated with the activities of oil and gas industry. Nowadays, where people awareness on environmental health is increasing, effort to minimize the impact caused by the release of wastes from natural oil and gas should also be maximized.

Some oil and gas industries are currently applying various physical treatments to reduce oil contents of their wastewater. Biological treatment, if any, is merely aimed to reduce phenol as well as ammonia but not for oil. In addition, oily sludge has become the major problem since no treatment can be introduced at the possibly tolerable cost. Bioremediation, though essentially is not to be applied for wastes continuously released such as oily sludge, nevertheless this term has been quite popular and is also applied in some industry to treat oily sludge.

This sludge cannot be just open-dumped since it has great potential to leach and become persistent sources for soil and water environment. The sludge needs either treatment to reduce its potential or to be isolated. Isolation of sludge by storing in small storage tanks nevertheless can cause another difficulty since that tank may occupy spaces.

Bio-Treatment

Sludge and liquid waste from oil and gas industry contains mainly petroleum hydrocarbon. Petroleum hydrocarbon is mixture of aliphatic, aromatic, polycyclic hydrocarbon ranging from short C_3 to much longer carbon chains.

The most important role of microbes in the degradation of oily liquid waste or even sludge is to transform complex and may be toxic compounds to simple and harmless ones and more over to convert oily sludge to bio-sludge.

Industry needs a well-planned sludge management system as the Sludge poses various kinds of environmental hazards such as Fire Hazard (in case of oily sludge), Groundwater contamination, Soil Contamination, Threat to Marine life and Air pollution/Odor. EM with all its advancements made since its invention has the potential of biodegradation (anaerobic) of most type of sludges. In this regard NCPC in collaboration with EM organization offered a trial to ARL for the bioremediation of 1.7M tons of Oily sludge. This would provide the basis for further research and development. The trial was designed into two phases:

3. OBJECTIVE

The 1st phase was the bioremediation of sludge that was completed successfully and bioremediated product was obtained. In 2nd phase, application of bioremediated product as biofertilizer was carried out, the **main objective** of which is to provide ARL an effective environment-friendly waste disposal system for oily sludge treatment and the cost effectiveness through development of saleable by-product, after checking the toxicity.

4. METHODOLOGY

The effectiveness of the biofertilizer was checked through:

v. The physical growth of the crop.
vi. Chemical analysis of the crop.
vii. Nitrogen (N), Phosphorus (P), Potassium (K) Carbon Nitrogen ratio(C: N), Organic Matter.

4.1 Physical growth of Onion Crop

Having completed the **Phase I** trial at ARL on "oily sludge bio remediation (anaerobic) using EM Technology" within a period of 6 weeks (29th Oct to 10th Dec 02) in collaboration with UN/NCPC Rawalpindi, it was decided to apply the byproduct named EM-Bio-Sludge in agriculture for the safe disposal of oily sludge. ARL has its own field area within its boundary and is presently being used for growing vegetables for his staff. A Horticulturist (MSc. Agri) is supervising all the agricultural operations for growing vegetables. A ten Marlas plot (126 ft x 18 ft) was earmarked in the vegetables area of New Abadi. The area was already being used for growing vegetables meaning thereby that the soil was in good tilth. Chillies was the previous crop. After its harvest the land was ploughed well. It was divided into two equal parts. One part was kept for control in which farmyard manure (FYM) was added and in the other plot EM-Bio-Sludge, after mixing with equal quantity of soil to finish its oily nature, of about 1.2 tons was spread over 5 marlas of land (63 ft x 18 ft) and mixed well with the upper layer of the soil. EM irrigations were given to accelerate the decomposition of biofertilizer. Each plot was sub-divided in ten small plots in order to irrigate with groundwater pumped out with a hand-pump fixed with an electric motor. The Onion nursery was transplanted in both the plots during the end of second week of February 2003.

The biofertilizer plot received groundwater irrigation augmented with EM extended solution whereas the control plot got normal groundwater irrigations. On 4th March, 2003 the experiment was visited and it was not possible to observe any difference in the growth between the two plots as the crop was too young. Later on the crop was visited on 7th May, 2003 along with the honourable guest from U.A.E., Mr. Jabber Al-Mazroui, Chief Executive Officer, Emirates Science and Environmental Safety (ESES) and NCPC and EMRO experts. At this stage it was observed that EM plot was showing better growth both in the bulb and aerial part (photo).

Experimental Plot

EM biofertilizer plot

Control

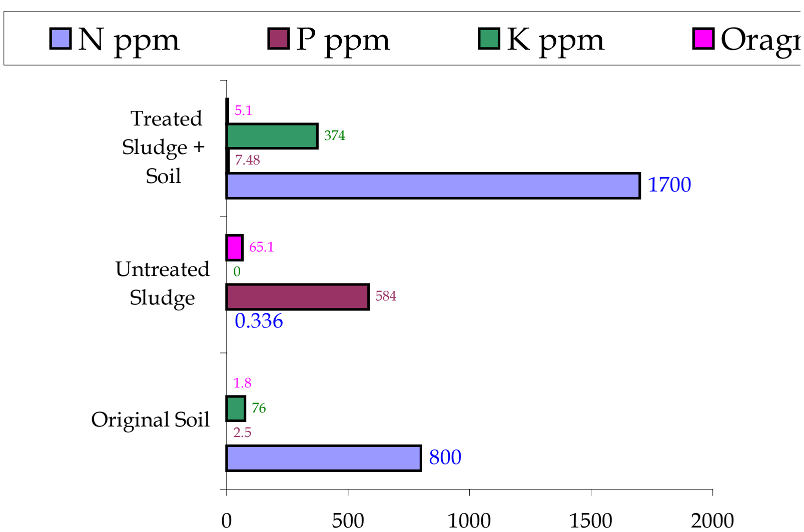
Honourable guest Mr. Jabber Al Mazroui,
UAE, in conversation with UN/NCPC expert

APPLICATION OF EM BIOFERTILIZER IN AGRICULTURE.

4.2 NPK & OM Analysis.

The EM treated sludge was applied in phase-II to agriculture land after mixing with dry soil in proper ratio 1:1 (bio-fertilizer) for easy handling, application, and transportation.. Here the effectiveness of the biofertilizer was proved through physical growth and chemical analysis of the crop. N, P, K, and organic matter (OM) of the biofertilizer (EM treated sludge mixed in 1:1 ratio with dried soil material) was compared to same analysis for field soil (control), where agricultural experiment was carried out as phase II of this program. The entire N, P, K, and OM of the EM treated sludge have the properties of bio-fertilizer, and indicate it is rich in macronutrients and organic matter. Figure 1 shows the NPK & OM Analysis.

NPK & OM Analysis



	Original Soil	Untreated Sludge	Treated Sludge + Soil
Oragnic Matter %	1.8	65.1	5.1
K ppm	76	0	374
P ppm	2.5	584	7.48
N ppm	800	0.336	1700

After the analysis of NPK and assuring that treated sludge contains enough nutrients and organic matters for vegetation, onions were grown in two fields having a plotted area of 64X20 feet using farm yard manure in one field and treated sludge, mixed with soil (1:1), in other field. The agronomical factors were kept in view such as number of plants (nursery plantation).

4.3 Field Parameters

Table 1

Field parameters

Parameters	**EM treated area**	**FYM treated area**
Plotted Area	64X20 feet	64X20 feet
Yield enhancer added	EM 23mond(1:1) added	FYM 23mond added
Paneeri added	2,673 plants	2,673 plants

Once the onions were harvested, sampling was carried out on random basis and following samples were taken for evaluation of Toxicity.

4.4 Sampling Criteria

Table 2: Sampling Criteria

Yield enhancer	**Samples required to check the toxicity**
Biofertilizer	Onion, Soil, biofertilizer
Menure	Onion, Soil, manure

NOTE:
Naturally occuring Soil wasl also tested for its toxicity as control

In order to analyze the samples, 24 onions from different locations of the field were taken and their core was used as a samples. After taking the samples were crushed and grounded for uniform mixing of sample. The same procedure was carried out for the samples of onions from both bio-fertilizer from oily sludge, and FYM.

4.5 Dry Ashing For Micro Nutrients Cations Of Plants

Plant analysis by Dry ashing is simple, non-hazardous and less expensive compare with HNO3, HCLO4 wet digestion. Dry ashing is appropriate for analyzing all macro and micronutrients in plant tissues.

Procedure:

1. Place 0.5 to 1.0 gram portion of plant material (onion) in a glass beaker.
2. Place the beaker in cool muffle furnace and increase the temperature gradually to 550^0 C.
3. Continue ashing for 5 hours after attaining 550^0 C.
4. Shut off the muffle furnace and open the door cautiously for rapid cooling.
5. When cool, take out the beaker carefully.

6. Dissolve the cool ash in 5 ml portion of 2 N HCl and mix with the plastic rod
7. After 15 to 20 minutes, make up the volume (usually 50 ml) using 0.1 N HCl.
8. Mix thoroughly, allow standing for about 30 minutes, and filtering it.
9. Analyze the aliquots by using Atomic absorption spectroscopy.

Subsequently otesting was conducted using atomic absorption spectrophotometery.

4.6 Analysis For Micronutrients And Heavy Metals

For soil, the samples were prepared by the following method:

Apparatus required:

i. Reciprocal shaker
ii. Atomic absorption spectrophotometer.

Reagents:

i. Diethylenetriaminepenta acetic acid (DTPA).
ii. Standard Solutions.

Procedure:

i. Take 10 g soil sample.
ii. Add 20 ml of DTPA (Diethylenetriaminepenta Acetic Acid).
iii. Shake this solution for 15 min.
iv. Filter the solution and analyse using Atomic Absorption Spectrophotometry

5. RESULTS

5.1 Yield Comparison

The yield of the crop is summarized as in the following Table 3 below:

Table 3:

Treatments	*Yield (Kg)*	*Remarks*
FYM treated area	275 Kg	Plant growth was ok and their leaves were greenish at the time of cultivation as compared to those grown in EM treated plot.
EM treated area	230 Kg	Plant growth was good and the onions harvested were larger in size as compared to those grown in FYM treated plot.

The green colouration of leaves in FYM plot was due to the presence of more chlorophyll in these plants as compared to those plants that were grown in EM treated plot showing that using *biofertilizer the cultivation can be achieved earlier as compared to FYM.*

Similarly the large volume of onions grown in bio-fertilizer shows that *the bio fertilizer is richer in nutrients and organic matters as compared to FYM.*

5.2 Heavy Metal Contents in Soil Samples

Soil samples from both treatments were taken at the time of harvesting and were analyzed.

Table 4: Heavy metals content in Soil taken from EM treated area and FYM treated area:

Heavy metals	***FYM soil ppm***	***treated sludge (1:1) ppm***	***Permissible limit (ppm)****
Chromium (Cr)	0. 04	0. 07	1. 0ppm
Cadmium (Cd)	0. 17	0. 14	>1. 0 ppm
Copper (Cu)	0. 03	1. 05	3. 0 - 5. 0 ppm
Nickle (Ni)	0. 45	0. 32	1. 0 ppm
Lead (Pb)	2. 0	1. 57	15 – 20 ppm

Source for Permissible limits: NEQS and Department of Plant & Soil Sciences Laboratory

It may be seen that the oily-sludge which was bio-remediated and showed 50-85% reduction in heavy metals initially through the bioremediation, was further tested after its application as a bio-fertilizer in the field (Table 4 above) and it showed that the bioremediated sludge after mixing with soil resulted in dilution of its toxic metal content to such an extent that it is not harmful to the environment and agricultural applications.

The soil analysis showed that the heavy metals in the soil after application were all well below the internationally recognized permissible limits which provides us the evidence that the metal breakdown tested 9 months earlier after initial bioremediation/at time of application does not undergo any reversal back to elemental state.

From these findings it appears that the non-ionization process/breakdown of metals continues after the formal bioremediation of the oily sludge during the application phase as well.

5.3 Heavy Metal Contents in onion samples

Onion samples from both treatments were taken at the time of harvesting and were analyzed.

Table 5: Conc. of Heavy metals in onions grown using Biofertilizer and FYM.

Heavy metals	*FYM onions*	*treated sludge (1:1) oni\ons*	*Permissible limit (ppm)*
Chromium (Cr) ppm	0. 15	0. 21	1.0
Cadmium (Cd) ppm	0. 05	0. 04	0.24
Copper (Cu) ppm	4. 11	8. 14	05-20
Nickel (Ni) ppm	0. 14	0. 10	1.0
Lead (Pb) ppm	1. 87	3. 30	>1.0

Source: Pakistan Book Foundation, and FAO Standards

The results above show that the Chromium concentration in EM treated soil and in onions was far below than the NEQS (permissible level 1.0 ppm). This is the same for copper. Other standards were so far not available.

It seems EM treatment of sludge reduces the content of heavy metals due to its ability to change the ionization of heavy metals. The plants do not take up non-ionized heavy metals.

5.4 Micronutrients in Soil Samples

Table 6: Micronutrient conc. In originl soil, EM treted soil and in FYM treated soil

Micronutrients (ppm)	original soil	EM treated soil	FYM treated soil	Permissive level
Iron (Fe)	2. 8	4. 4	7. 13	2.0 – 8.0 ppm
Zinc (Zn)	ND	1. 43	2. 1	5.0 ppm
Maganese (Mn)	24. 7	10. 2	8. 1	>1.0 ppm

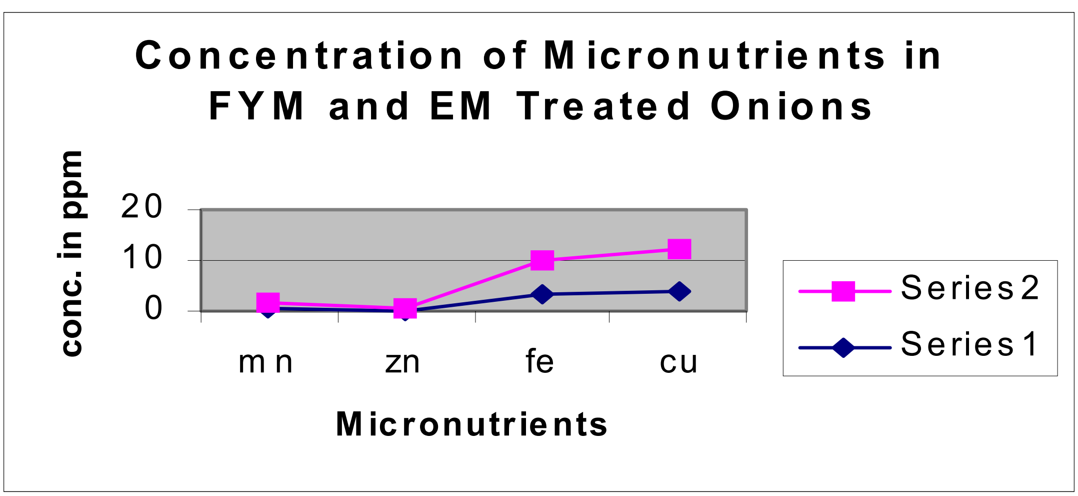
Source NEQS and Soil Science Book National Book Foundation 1996

It is clear from the above data that all the values for the micronutrients are with the NEQS and FAO standards and the soil is enriched with th e micronutrients essential for its growth.

Graphical Presentation of the results is also shown with respective headings below.

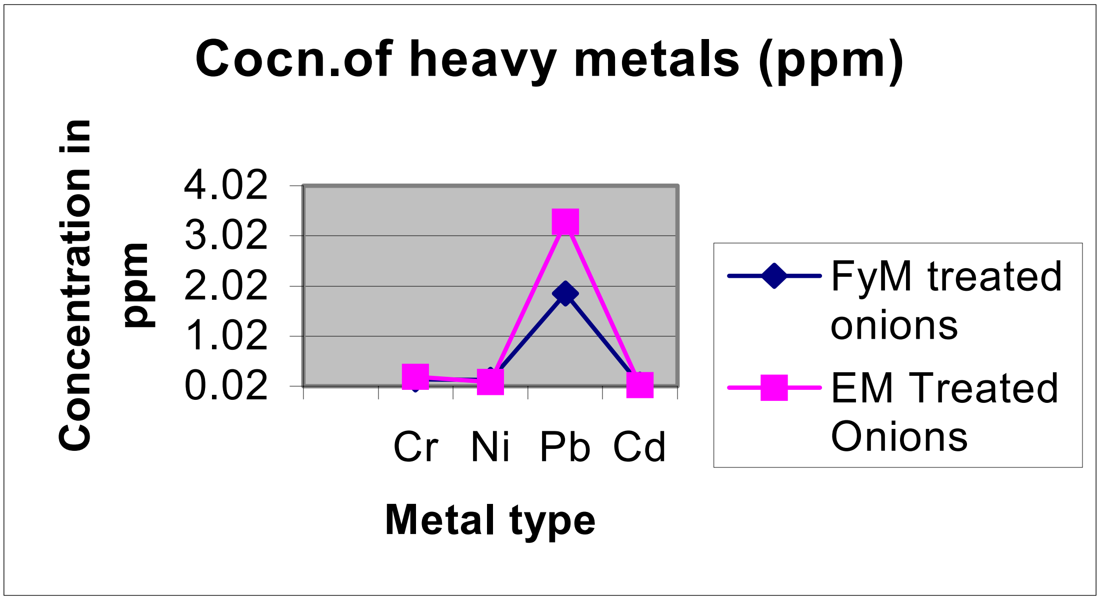
5.5 Concentration of Micronutrients in Onion Samples

The Comparison of Micronutrients is shown in graphical presentatin below:

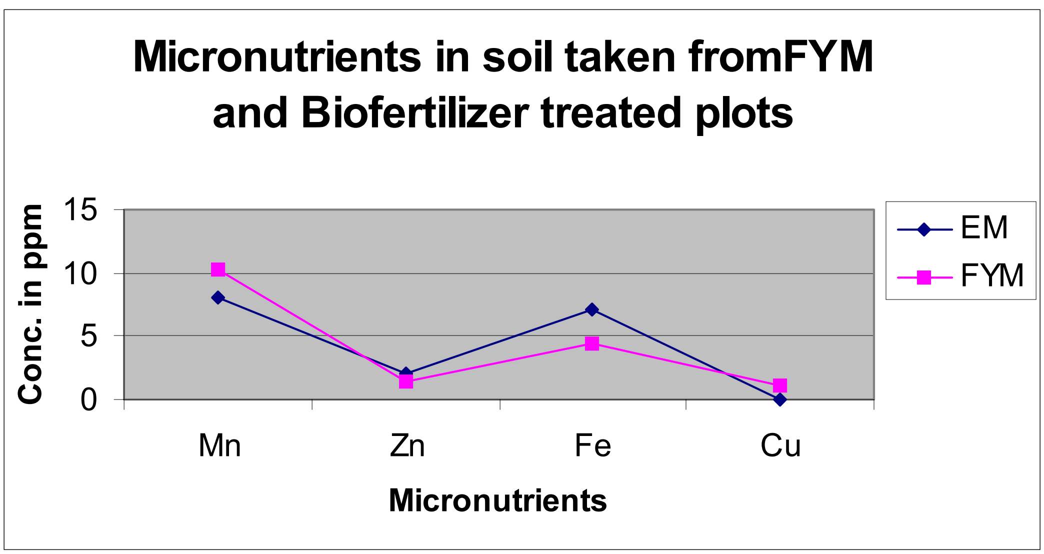


Series 2= micronutrients in EM treated onions
Series 1= micronutrients in FYM treated onions

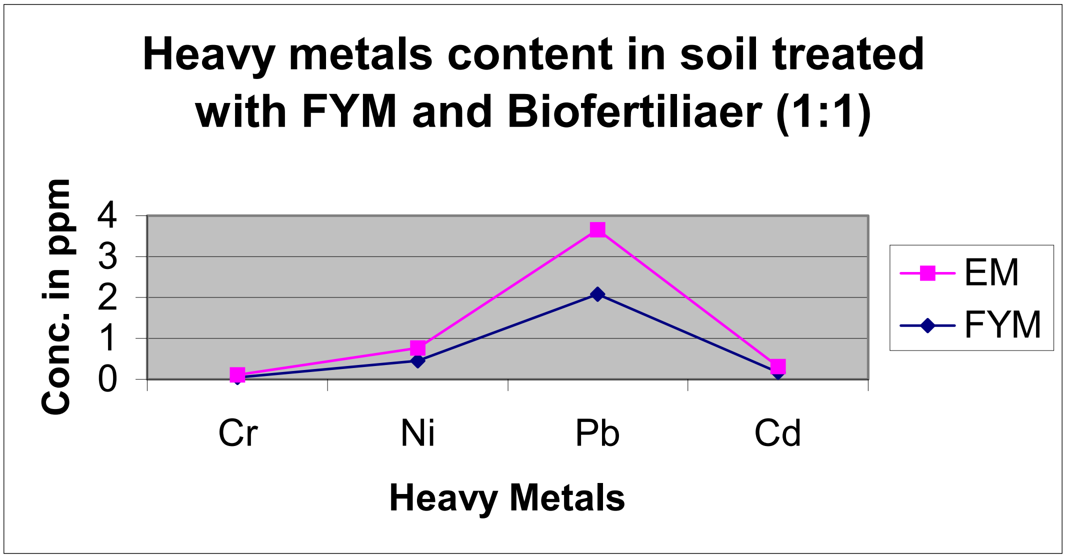
5.6 Concentration of heavy metals in onion samples



5.7 Micronutrients content in soil samples



5.8 Heavy Metals content in Soil Samples



6. CONCLUSIONS

From the above results it can be safely concluded that:

1. Through bio-fertilizer the same yield can be achieved as through FYM.
2. The bio-fertilizer is richer in all the essential nutrients and organic matters to support the plant growth, similar to FYM.
3. Bioremediation waste has increased the nutrient content as well as soil organic matter which resulted in enhanced plant growth. The bio-fertilizer may be used as a substitute to Farm-Yard Manure.
4. The bioremediated sludge after mixing with soil undergoes further reduction in its toxic metal content to such an extent that it is not harmful to the environment and agricultural applications.
5. In fact the soil analysis showed that the heavy metals in the soil after application were all well below the internationally recognized permissible limits.
6. It is further concluded that the metal breakdown tested 9 months earlier after initial bioremediation, does not undergo any reversal back to ionized state.
7. Further, the data shows that the non-ionization process/breakdown of metals continues after the formal bioremediation of the oily sludge during the field application phase as well, which shows that microbial activity continues after the completion of the first phase (oily sludge bioremediation).
8. The results show that the Cr concentration in onions from EM treated soil was far below than the NEQS (permissible level 1.0 ppm). The same is the situation for other metals.
9. It seems EM treatment of sludge reduces the content of heavy metals due to its ability to change the ionization of heavy metals. As a result the plants do not take up non-ionized heavy metals.
10. It is clear from the above data that all the values for the micronutrients conc. are also within the NEQS and FAO standards.
11. This work has demonstrated environment-friendly and safe disposal of petroleum sludge, and it indicates ISO 14000 compliance can be ensured.

7. RECOMMENDATIONS

1. Large-scale agricultural experimentation is recommended to further test the positive outcomes of this work.
2. In addition to environment-friendly disposal of industrial sludges, it is recommended that special emphasis is laid on developing safe (meeting NEQS) and socially acceptable biofertilizer from bio-remediated sludges; to make the whole process sustainable and commercially viable.
3. Motivate farmers to use biofertilizer through farmer's schools cooperation and also taking the help from agricultural institutes.

ANNEXURE 1: ANALYSIS RESULTS

Test	Original soil	FYM treated Soil	EM treated soil	Onions from FYM	Onions from EM
Cr	0.86	0.04	0.07	0.15	0.21
Ni		0.45	0.32	0.14	0.10
Pb	ND	2.08	1.57	1.87	3.30
Cd	1.56	0.17	0.14	0.05	0.04
Mn	24.7	8.1	10.2	0.80	0.89
Zn	ND	2.1	1.43	ND	0.45
Fe	2.8	7.13	4.44	3.33	6.85
cu	0.93	0.03	1.05	4.11	8.14