In-situ Anaerobic Bio-remediation of Oily-Sludge at Large-Scale using EM Technology

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Executive Summary

In order to properly dispose of the oily-sludge being produced in oil sector/refineries, UNIDO-NCPC in collaboration with the EM Research Organization of Japan, prepare project(s) for bioremediation of oily-sludge. A project has recently been successfully completed and bio-fertilizer produced has been applied to agricultural crops and is being tested for toxicity, yield, & commercial viability of by-product.

The EM Technology project of the oily-sludge bio remediation was carried out at Attock Refinery Limited Morgah Rawalpindi Pakistan (ARL). The pure, odorous, greasy and black oily-sludge was transformed, with the help of microorganism, into dispersed and brownish diminished shapes with fermentation smell. It was observed that not only the harmful target chemicals in the pure oily sludge were eliminated by this technique but the bio by product obtained was rich in nutrients, like nitrogen, phosphorous, potassium and organic matter, and can be used as bio-fertilizer instead of the farm-yard manure (FMY) and as a soil amendment to improve the salt affected lands. As far as the reduction in heavy metals is concerned, the Ba reduced by 85% of the original concentration in the oily-sludge and Pb, Zn, Fe, Ni reduced by more than 50% with EM technology.

The bio-sludge is mixed with dry soil in the same proportion to make it easy to handle, transport, and store. This mixing further dilutes the concentration of the heavy metals in the by-product available for agriculture application.

The proposed bioremediation of petroleum sludge is not only cost-effective but resource productive as well. The bio by product obtained at the end of bioremediation is highly rich in essential macro, nutrients, nitrogen, phosphorous, potassium and organic matter. This bio by product can provide a good alternative to FYM and the use of this bio by product in agriculture will reduce the quantity of chemical fertilizer to be applied and hence the cost in agriculture sector. The application of this bio by product /bio fertilizer to the land will improve the physical properties of the soil and hence the yield with increased uptake of nutrients.

The application of EM technology is the most economically feasible method for the safe disposal of the oily-sludge as compared to the other options like incineration and an engineered landfill site. The cost of engineered landfill site includes a lot of initial investment even for the preliminary site assessment. UNIDO-NCPC/EM as a joint venture partnership is offering in-situ treatment of the entire sludge (in sludge farms etc. industrial locations) at the consolidated **lump-sum rate of Rs. 5/kg for bio remediation treatment of sludge for safe disposal**. The bio-remediation may be applied to various industrial process sludges. The cost of the EM Technique will further decrease, as the saleable bio-fertilizer is obtained as an end-product of the bioremediation of the sludge but the arrangements and efforts are to be made for its sale by the respective oil refinery through its marketing section or through an agency already dealing with such bio by products or supplying it to big land lords directly or through local agriculture department (extension

wing) to start with on free of cost and later on cost bases or through advertisement published in the daily news papers and inviting tenders .

For all those world reputed oil related companies, which are also seeking ISO-14000 certification and interested in the safe disposal of their solid /liquid wastes, EM treatment is one of the most feasible options for the oily-sludge disposal and ARL has already observed and witnessed the anaerobic bio-remediation of ARL oily sludge using EM Technology. This proposed in-situ bio-remediation project will take about 3 months for completion (regardless of quantity of waste to be treated). The first month is needed to transport all types of material needed, preparation of EM solution and arrangement of other equipments at site. In the next 1¾ months bio-remediation of oily sludge will be completed. After which the premises can be vacated in the 12th week.

ANAEROBIC BIO REMEDIATION OF OILY SLUDGE

AT LARGE SCALE
USING EM TECHNOLOGY

1.0 BACKGROUND

Safe disposal of oily-sludge is a difficult problem in the overall waste treatment management program of oil sector operators. Even the most advanced methods give residues that are no longer amenable to cost-effective treatment. Oil sector industries and other industries as well are troubled by the problem of handling substantial quantity of sludge in one form or the other depending upon the nature of the crude/raw materials, 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 mess. The Oil-sector needs 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.

For this purpose UNIDO-NCPC continued searching environment-friendly advanced and preferred options, other processes, and technologies for oily-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. It was an honor for UNIDO-NCPC, the leaders in the field of cleaner production techniques in Pakistan, that Prof. Dr. Teruo Higa, University of the Ryukyus, Okinawa, Japan, founder of EM Technology visited NCPC on 14th December, 2002 and delivered lectures in the symposium on bio-remediation of sludges arranged by UNIDO-NCPC.

Subsequently UNIDO-NCPC in a joint venture with EMRO of Japan undertook a project for Attock Refinery Limited Rawalpindi for the disposal of oily-sludge and is looking forward to provide similar support to all other refineries/oil-sector operators of Pakistan. The oily-sludge was treated with different EM products. The oily-sludge was changed into nicely fermented sludge (may be called bio sludge) in a period of 6 weeks only. The bio-sludge was mixed with equal quantity of dried soil in order to change its present physical form. It became a powdery material, which looked like a dried-soil as the sludge lost its blackish and bluish colour. This powdery by-product was easy to handle, transport, and store.

For all those world reputed oil related companies, which are also seeking ISO-14000 certification and interested in the safe disposal, EM treatment is one of the most feasible options for the oily sludge disposal and ARL has already observed and witnessed the anaerobic bio-remediation of ARL oily sludge using EM Technology.

A technical proposal is, therefore, being submitted for safe disposal of oily-slurry/sludge. The oily sludge will be treated in-situ, with EM technique. The project takes about 3 months in completion. The first month is needed to transport all types of material needed, preparation of EM solution and arrangement of other equipments at site. In the next 1¾ months bio-remediation of oily sludge will be completed. After which the premises can be vacated in the 12th week.

It is guaranteed that all the treatments will be environment-friendly and free of any kind of danger. The handling, transportation of final by product (bio-fertilizer) will be easy. This is actually the environment friendly safe disposal for all times to come. The technical proposal components like processes, equipments, materials, methodology and financial aspects are given in respective sections of this proposal.

2.0 INTRODUCTION

2.1 EM Research Organization

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.

2.1.1 Effective Microorganisms (EM)

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 not a synthetic chemical nor a medicine. The following is the brief introduction on various EM products:

2.1.2 EM Extended Solution

EM Activated, EM Secondary, etc. are different names for the same product. It consists of 1~3% EM and 1~5% molasses in 92~98% water held in an airtight container. It is then left to ferment for one to two weeks. A sweet-sour smell and a pH rating of 3.5 or below indicate that the process is

complete.

2.1.3 EM Bokashi (Anaerobic)

EM Bokashi consists of 1% EM-1, 1% molasses, and the rest water. This mixture is then added to organic matter, like rice bran, and mixed thoroughly until it becomes approximately 30% moist. It is then left to ferment for one to two weeks. A pleasant sweet-sour smell indicates that the process is complete. Different types of EM Bokashi can be made from different organic materials and used for different purposes. The most often used ingredients are rice/wheat bran, rice/wheat husks, oil cake, fishmeal, etc.

2.1.4 EM Compost

EM Extended is sprinkled/injected and mixed thoroughly with the material until it becomes approximately 30% moist. It is then covered over with a large sheet to maintain an anaerobic state and left to ferment. A white mold (fungi) appearing on the material indicates that the EM compost process is in progress.

3.0 PROCESSES

The combined team of UNIDO-NCPC and EMRO will visit the present dumping site, the waste will be estimated for the quantity. Anaerobic bioremediation of oily-slurry/sludge will involve following steps:

i) Sampling before treatment

A representative sample of oily slurry and sludge will have to be taken to know the concentration of pollutants. Many samples of oily slurry and sludge will be taken from all over the lagoon to form a composite sample for further analysis.

ii) Analyses of the sample before treatment

The samples collected before start of the bio-mediation at large-scale will be analyzed from a reputable organization to have correct analysis results (payment by waste generator).

iii) Cleaning of oily sludge

The oily-sludge will have to be cleared from all the admixtures. It will have to be done mechanically as well as manually.

iv) Mixing of dried soil with oily slurry

The dried soil material free from all stones will be mixed mechanically in order to change the nature of the slurry to sludge (dried soil to be provided by waste generator according to the moisture content required).

v) Quantity of EM and Bokashi needed

For example about 180m^3 EM solution and about 12 M Tons Bokashi are needed for anaerobic bio remediation of over 600 M Tons oily sludge. EM and necessary material for Bokashi will have to be transported from Lahore to the proposed site.

vi) Preparation of EM solution and Bokashi

A solution of different EM products inclusive of molasses will have to be prepared in water. The preparation of EM solution and Bokashi will be taken in installments. For this purpose containers, tanks, drums, buckets etc. are required.

vii) Mixing of EM products and Bokashi

Huge quantity of EM products and Bokashi given under section (v) are to be mixed thoroughly mechanically with the help of tractor attached with various equipments (tractor/driver to be provided by the waste generator).

viii) Anaerobic bio-remediation

The oily-sludge mixed well with EM solution and Bokashi will be covered with suitable size of plastic sheets for anaerobic remediation.

ix) Monitoring

Monitoring of moisture contents, temperature, and status of bio-remediation of oily-sludge is needed to achieve desired results. Accordingly deficiency of moisture will be removed with EM solution. At times mixing will also be needed. This will be achieved mechanically.

x) Completion of anaerobic bio remediation

The oily-sludge will be converted into a bio-sludge after the completion of anaerobic bio remediation. It is hoped that the bio-remediation process will be completed within 8 weeks.

xi) Sampling of bio-sludge and its analysis

A composite sample of bio-sludge will be taken for analysis to know the final level of pollutants. The expenditure on analysis at cost will have to be paid separately. This will help to determine the fertility status of bio-sludge for further planning and use in agriculture.

xii) Transportation of bio sludge to field area

As soon as bio-sludge is ready the whole quantity will be shifted to field area immediately for the preparation of bio fertilizer.

xiii) Preparation of bio fertilizer

The bio-sludge (xii) will be mixed with reasonable quantity of dried soil (may be ½ to ¾ of that of sludge) to change the still existing oily nature of bio-sludge and its physical form. In this way a dried powdery material looking like a dry soil will be obtained. This may be called bio-fertilizer. It can be used as and when required within 6th months in agriculture. It is easy to handle, transport and store.

xiv) Analysis of bio fertilizer

A representative sample will be taken and analyzed to know the present status of macro and micronutrients (payment for analysis by waste generator).

xv) Use of bio fertilizer

It can be applied as a substitute to farmyard manure (FYM). The quantity of bio-fertilizer needed will be about $1/4^{th}$ of that of FYM depending upon the level of nutrients in the bio fertilizer. The bio fertilizer contains macro-nutrients NPKS and micro nutrients Mn, Fe, Zn, Cu. Its application will enhance not only fertility of the soil but also increase soil microbial activity. This will result in improved physical properties and better uptake of nutrients by the crops. Bio-fertilizer can also be used as 'soil amendment' to improve/reclaim salt affected lands, a major problem in Punjab and Sindh provinces.

By completing above steps the environment friendly safe disposal of oily sludge in the form of bio fertilizer is achieved physically for all purposes of environments and ISO certifications.

4.0 EQUIPMENT

Huge quantity of EM solution and Bokashi is to be applied to the oily sludge and mixed mechanically but thoroughly into it. For this purpose large containers, drums, buckets, scoops, mixtures, injectors, plastic sheets and plastic rubber pipes are needed. Tankers, trucks, tractors and cranes have to be hired. Further details are given in the financial section.

5.0 METHODOLOGY

The required quantity of various type of EM-Envs and the material needed for Bokashi will be transported from Lahore to the sludge site. At sludge site the arrangement for the containers, tanks, drums, buckets and plastic rubber pipes etc. will be made as EM solution is to be prepared in these equipments. The preparation of EM extended in large quantity will be continued simultaneously in installments to the processes being undertaken on sludge site.

At sludge site the arrangements for the dried soil free from all stones will be made. The quantity of oily sludge will be estimated. The soil will be mixed in the slurry with the help of a tractor having suitable attachments. The whole sludge will be mixed thoroughly.

As soon as EM extended solution, Bokashi and sludge are ready a thorough mixing with the help of a tractor having suitable attachments will be undertaken. Having completed thorough homogenized mixing the EM treated sludge will be covered with a suitable plastic sheet to create anaerobic conditions.

Monitoring will be continued to adjust moisture contents and record of temperature in order to achieve bio-remediation fully. As soon as the oily sludge is converted into a bio-sludge it will be transported to the field area, where it will be mixed thoroughly with the dried soil already arranged at site. The final by-product is bio-fertilizer. It can be stored in a suitable shed in loose form.

The bio-fertilizer can be made use of in agriculture as a substitute to the farmyard manure and as soil amendment on salt affected lands. With this environment friendly safe disposal is achieved.

6.0 JUSTIFICATION FOR BIOREMEDIATION

The results obtained after the completion of the trial project were extraordinarily optimistic and encouraging. The salient features of the results proving validity of the bioremediation are hereby concluded for the justification in favor of the project

i. Bioremediation is ecologically sound, natural process that destroys organic contaminants the residues obtained are no more harmful

ii. Instead of merely transferring contaminants from one environment medium to another bioremediation completely eliminates the target chemicals

iii. Disposal of oily sludge by using EM technology helps in the fulfillment of the ISO 14000 compliance

iv. Regarding the reduction in the heavy metals, the Ba was reduced by the 85% of the original concentration in the oily sludge and Pb, Zn, Fe, Ni reduced by more than 50% with EM technology

v. Cr, Cu though showed no change but they were reduced by 50% in another EM research (6th International Conference on Kyusei Nature Farming held at University of Pretoria, South Africa October 1999). As only one sample was taken for the metal analysis it may be that the sample was not fully representative/statistically valid.

vi. Cr was even reduced from 50,000 ppm to 450 ppm in leather industry sludge in Pakistan (PTA trial 2002) in an other study

vii. EM treated sludge can be used as a bio fertilizer in agriculture as a substitute to farm yard manure and as a soil amendment to improve or reclaim salt effected lands (particularly that of Punjab and Sindh).

viii. It is the most economically feasible method for the safe disposal of the oily sludge as compared to the other options including incineration and an engineered landfill site. The cost for the incineration of oily sludge is about US $ 182 / ton and that of engineered landfill site includes a lot of initial investment even for the preliminary site assessment. But on the other hand NCPC- EM offers the services of the safe disposal along with the saleable byproducts at the cost of US $ 88 / ton only. So the comparison of the costs for the two applicable methods proves the effectiveness of the EM technique, justifying the application.

ix. This technique is not only cost-effective but resource-productive as well; by producing saleable manure as an end product

x. The technique of bioremediation also helps in avoiding the harmful emissions of the dioxins from the incinerator.

xi. As for as the effectiveness of the by-products is concerned, the treated sludge is found enriched in organic matter along with sufficient amount of Nitrogen, phosphorous and potassium as required by the crops of their growth.

xii. If the concentration of NPK of treated sludge mixed with original soil in 1:1 ratio is compared with that of original soil, the former is found enriched in Nitrogen, phosphorous, potassium and organic matter as clear from the table below.

Further the bio-fertilizer produced can prove to be an excellent bio-fertilizer and with small additional change of NPK concentrations it can be used as an alternate to chemical fertilizer as well.

7.0 ECONOMIC EVALUATION

Treatment Based Evaluation: Internationally the charges for the treatment of Oily Sludge are:

Method	Range of cost of remediation (US$ per ton Oily Sludge)
Incineration	400-1200
Washing	200-300
Bioremediation	20-200

Which comes to approximately:

1. Incineration Rs. 23 – 69 per Kg
2. Washing Rs. 12 – 17 per Kg
3. Bioremediation Rs. 02 – 12 per Kg

While NCPC is offering:

1. Incineration Rs. 10.00 per Kg
2. Bioremediation Rs. 5.0 per Kg

Bioremediation has the potential to treat the contaminants on-site (*in situ*) thus ensuring that the contaminant is not merely moved from one place to another. Apart from the various factors like the type and characteristics of the soil, nutrient and oxygen availability, various sampling and analytical techniques, a successful approach towards bioremediation involves the indigenous microorganisms, their survivability, and their response to toxic contaminants as well as nutrient enrichment. The reintroduction of indigenous microorganisms isolated from the contaminated sites after culturing seems to be a highly effective bioremediation approach, especially when oxygen and fertilizers supplement the growth of the microorganisms.

Some advantages of bioremediation are:

i. A natural process that destroys organic contaminants
ii. By-products are generally innocuous
iii. Represents a closure solution
iv. Cost-effective when compared to other treatment technologies
v. Can be performed on-site, low profile.

Based on the enrichment of the treated bio-fertilizer produced from the industrial sludge, and also with metal reduction, pay-back may be considered

8.0 FINANCIAL PROPOSAL

The cost estimate of all the components can be been worked out for this project. The details are given in the tables below. The summary of the activities break up for which the costws will be requiired, are as under:

8.1 Overall Proposal

Sr. #	Description	Cost Rs.
1.	**Material*** EM	 As required
2.	Dried soil material	As required
3.	**Equipments**** Plastic containers etc. purchase	 As required
4.	Transportation hired***	As required
5.	**Lab analysis** Charges for analysis	 As required
6.	**Technical Supervision******	As required
7.	**Miscellaneous *****	As required
8.	**Application as Bio-fertilizer********	As required
Total is based on the requirement		

*Breakup of elements for which the cost is required for EM material and soil based on the requirement

Sr. #	Description
1.	Dried soil
2.	**EM-Envs.** Envs. A Envs. B Envs. C Envs. P
3.	Bokashi

**Equipments to be purchased

Sr. #	Description
1.	Mechanical mixter, 1hp
2.	Mechanical injector, 1hp
3.	Plastic container, $5m^3$
4.	Plastic container, 1-.$5m^3$
5.	Scoop
6.	Steel bucket
7.	Plastic sheet
8.	Plastic rubber pipe

***Transportation on rent

Sr. #	Description
1.	Tanker of 10-12 tons
2.	Trucks
3.	Tractor
4.	Crane

****Technical Supervision

Team Leader
Team Member

Sr #	Description	Amount (Rs.)
Startup		
1.	**No of days each for (Team Leader + Member)** • Arrangements of Pre-requisites, • Equipment arrangements, inspection and installation • sludge preparation & • Start of trial at site	As required
2.	**Operations, Monitoring & Reporting** • Team Leader • Member	As required
3.	**Removal of treated sludge / site clearance** • Team Leader • Member	As required
4.	**Traveling**	As required
5.	**Miscellaneous**	As required
6.	**Reporting** • Including weekly update, monthly draft reports and final report. • Material Cost, other expenses	As required
Total		

*****Miscellaneous

Sr. #	Description	Cost
1.	**Local staff** laborers	As required
2.	**Board & lodging**	As required
3.	**Traveling**	As required

******Application as Bio-fertilizer

Sr. #	Description	Cost
1.	**Mixing & application, evaluation of crop growth and toxicity** • Team Leader • Member • Evaluation charges (sampling & testing) • Liason & travel	As required
Total		