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Rehabilitation of the Historically Polluted Site – Oil Residue Lagoons. Techniques for Remediation

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Abstract

The contaminated site of 8,200 m^2 comprises of four oil sludge (tar) lagoons and adjacent area. The over 100 years of crude oil processing activities carried out by the refinery had a significant impact in this area. With the review of the Site use history, field observations, soil and water samples test results there was a very clear pollutant linkage between the open tar lagoons and any member of the local community. To break these pollutant linkages and to address the associated human health and environmental risks, some form of remedial action will be warranted. The objective of the remedial work was to reduce the mobility of contaminants present on site to groundwater and to protect the land use to a standard suitable for usage as green area.

Introduction

The contaminated site of approximately 8200 m^2 comprises of four oil sludge (tar) lagoons and adjacent area. The contaminated site is located in Romania in the region where the oil industry started to develop since 1895, when the first refinery in Romania was erected. Over 100 years of crude oil processing activities carried out by the refinery had a significant impact in this area to the society and environment, as well.

Description of the current conditions, site history and historical activities developed on the site were based on the PHASE I [1] and PHASE II [2] Environmental Site Assessment (ESA) by ASTM and a preliminary Conceptual Site Model (CSM,) prepared to illustrate the principal risk drivers at the contaminated site· With reference to the analytical data and the CSM, there was very likely a confirmed pollutant linkage between the tar lagoons and the groundwater evidenced by the impact on groundwater quality.

Tier 1 risk assessment

The Tier 1 risk assessment and development of the options for remediation has come about through a natural evolution and understanding of the Conceptual Site Model [5] and - where applicable - iterative risk estimation and evaluation. All stages have been used to evaluate the relevant pollutant linkages for the site and whether or not remedial action is likely to be required.

The Tier 1 risk assessment approach for the contaminated site has where possible been implemented using Romanian screening criteria available. The metals analysis conducted targeted the top 0.5 m of soil cover across the western limit of the site. Data screening against the most sensitive land use criteria under Romanian guidelines (future use as a playground / public open space), identified widespread exceedances of zinc, cadmium lead, copper and arsenic. Organic contamination within site soils around the lagoon structure is relatively sporadic, but observed to reasonable depth below the site. The hydrocarbons present typically fall into the heavier end of the TPH range (C_{20} – C_{36}), but some of the lighter fraction hydrocarbons were also noted within site soils (e.g. the C_{12} – C_{14} range). Minor detections of the PAH compounds were recorded but all were at concentrations of no concern.

The metals data screen has shown there to be minimal impact on groundwater in the immediate vicinity of the tar lagoons. There are minor detections of zinc and nickel but overall dissolved metal concentrations are low.

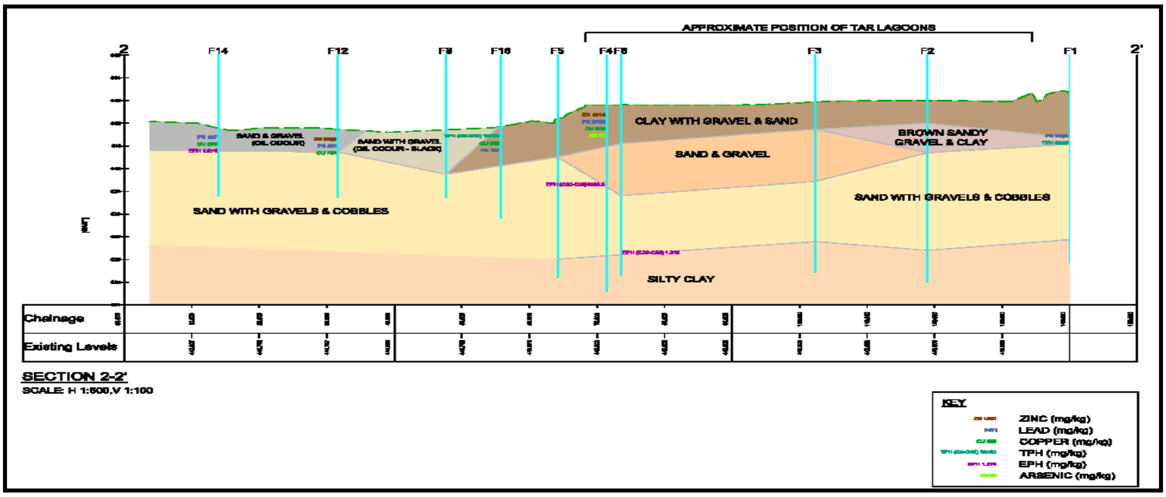

Fig.1. Contaminants Exceedences in Soil

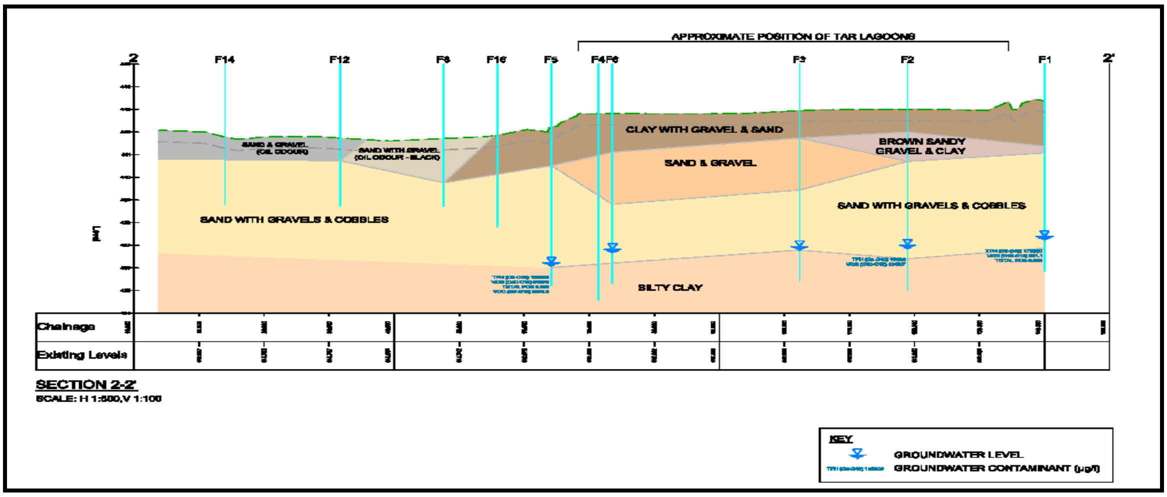

Fig.2. Contaminants Exceedences in Groundwater

The groundwater data screen of samples recovered from around the tar lagoon structures demonstrates a clear impact by former site use – most probably by the leaching of hydrocarbons from the lagoon structures over time. The observed impact on groundwater above is corroborated by the observations during the soil investigations and by the magnitude and extent of the organic contamination detected in the soils analysis. Of note, chlorinated solvents were not detected in any of the groundwater samples.

Conceptual site model

A preliminary Conceptual Site Model (CSM) has been prepared to illustrate the principal risk drivers [5] at the Campina site. The following contaminant sources have been assumed in the preliminary CSM.

- Tars and sludges residing within the lagoon structures (S1);
- Volatile organic compounds derived from sludge materials (S2), and
- Potentially deleterious materials within fly-tipped deposits (S3).

The principal pathways considered applicable in the initial conceptual model are as follows:

- Dermal contact and/or ingestion of tars and sludges (P1);
- Direct inhalation of volatile organic compounds fraction (P2), and
- Leaching of light and heavy-end hydrocarbons through the unsaturated zone below the base of the sludge lagoons and migration of the dissolved contaminant phase into shallow groundwater beneath the site (P3).

Receptors considered in line with the most contemporary knowledge of the site and in accordance with best practice have been assessed to be as follows:

- Local residents, trespassers (R1), and
- The controlled water environment (ground and any surface water in the vicinity) (R2).

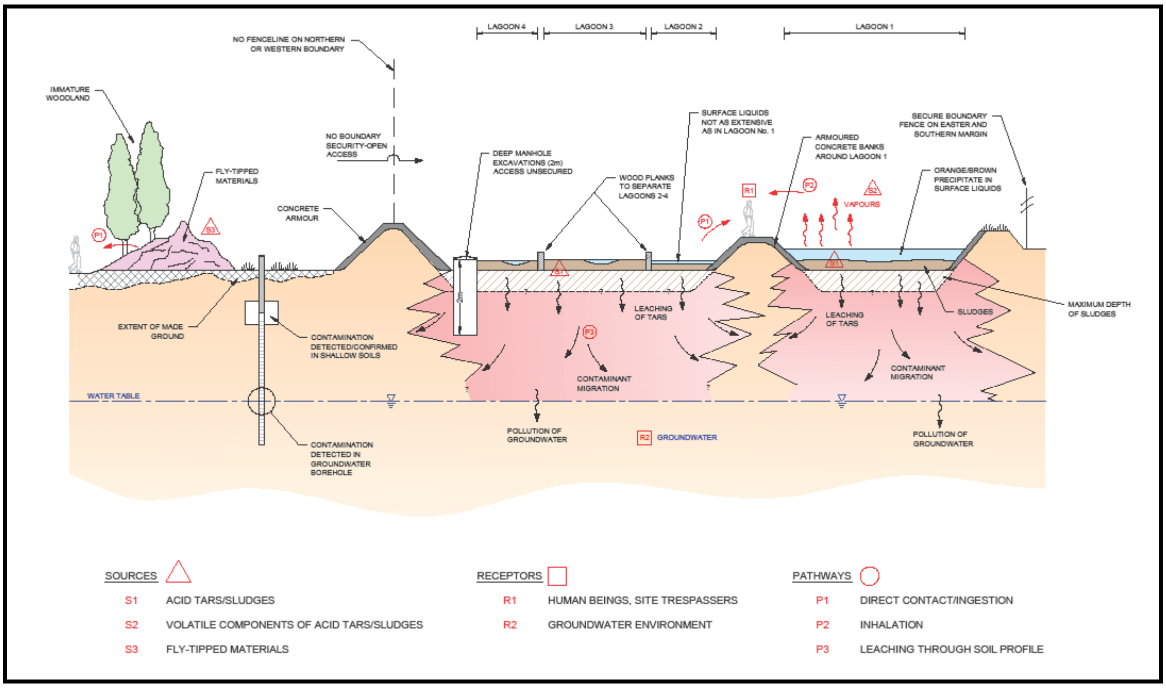

Fig.3. Conceptual Site Model

Phase I and II esa conclusions

With the review of the Site use history, field observations, soil and water samples test results [4]; the likelihood of contamination is not due to the present activities of the actual site owner. Furthermore, the site was impacted with hydrocarbons from historical activities conducted by the local refinery since 1895.

There was a very clear pollutant linkage between the open tar lagoons and any member of the local community, either via direct (dermal) contact or ingestion of tarry product. To break these pollutant linkages and to address the associated human health and environmental risks, some form of remedial action will be warranted. Risks associated with all relevant pollutant linkages were to be appropriately reduced by the most expedient remedial option given the sites' constraints.

Identification of the feasible remedial options

Contamination extend

The main source of soil and groundwater contamination on the site is the oil sludge from the four lagoons. The estimated volume of oil sludge is approximately 5,000 m^3 by considering 3300 m^2 total surface of lagoons at an average depth of 1.5 m. Shallow and deep contamination on soil mainly with TPH at depths up to 6 -7 mbgs on the area around lagoons on the site. Furthermore, soils with metal contamination were identified on the outside area of the lagoons at depth of 0.5 mbgs, estimated at approximately 4,900 m^2.

Groundwater contaminated mainly with TPH and total VOCs is present around lagoons and outside area on the site. Furthermore, free phase of oil was identified into one well. The estimated area where the free phase is present of 100 m^2 partially includes some area from and outside lagoons 4 and 3 and the volume of oil free phase was estimated to a volume of 10 m^3.

General recognised methods of remediation

Following identification of relevant pollutant linkages, feasible remediation options have been considered. 'Best Practice' considers three main ways to reduce or control unacceptable risks [5]. These are to:

- Remove or treat the source of pollutants;
- Remove or modify the pathway(s);
- Remove or modify the behaviour of the receptor(s).

Remedial action objectives (RAO)

The principal objective of the remedial work is to reduce the mass/mobilization of contaminants present on the site to protect the land use to a standard suitable for use as green area for the public, to include areas of landscaping (planting) and recreational access for the general public, as well addressing any impact to the local environment from previous site activity.

Based on field investigations and laboratory results from the completed wells on the site more likely the plume of contamination with hydrocarbons extends outside the four lagoons area. Furthermore, the risk to groundwater is not relevant for the lagoons from the site to the fact that the site is surrounded by several much larger oil sludge lagoons: to the southwest 3 lagoons of 36,300 m^2 total area and to the northeast a lagoon of approximately 84,712 m^2.

Therefore, the water treatment on the site will not improve the quality for the groundwater until surrounding sources are not removed and free oil phase that may be present outside the site is not eliminated. However, considering presence of other bigger contamination sources in the vicinity of the site and the limited period of funding and implementation dictated by SOPE PA2 MIF2, this project will not address any active action addressed to the groundwater. Moreover, a passive action more likely as Monitored Natural Attenuation (MNA) for at least 10 years is considered to be more suitable.

Therefore the main RAOs for this pilot project application are following:

1. Remove the oil sludge from the four lagoons and treat it on-site/off site;
2. Remove the free oil phase; and
3. Eliminate the contact risk of the land users to oil/metal contaminated soil.

Feasibility rehabilitation options

The soil contaminants observed and the characteristics to date of the tar residues residing within the lagoon features focus the remedial approach towards sets of methods capable of dealing primarily with organic/inorganic contaminants. A range of techniques [3] may be applicable in addressing in the first instance the contaminant source of sludge from the four lagoons.

The array of potentially feasible remedial techniques to remove or treat the contaminant source in this case is as follows:

- Civil engineering methods (source removal and/or containment solutions);
- A Chemical approach involving chemical stabilization;
- Biological method with Biosparging
- Physical methods such as soil washing (lends itself to a soil re-use potential);
- Incineration and Ex situ thermal desorption.

General response actions (GRA)

Not known a precise delineation of contaminated groundwater and volume as well as surrounding other much larger sources may lead to a failure for an active treatment method of contaminated groundwater. Therefore the remedial objective for groundwater will be Monitoring Natural Attenuation accompanied by combined methods to reduce the contaminants and contaminants mobilization from soil to groundwater as active action.

Furthermore, the project funding and implementation are limited by SOPE PA2 MIF2 (end of 2015). Considering these constrains was concluded that long term treatment methods are not suitable.

Options of technology evaluation

The remedial options considered and to be evaluated are presented below:

Option 1: Chemical oil stabilization ex-situ and capping (required meeting the objectives)

- Oil sludge excavation and on-site chemical stabilization of approximately 5,000 m^3 using additives mixing method in stabilization plant (requires mobile treatment authorization). The liquid phase above the oil sludge is pumped, is made the pH correction then is filtered on layer with active carbon. The contaminated active carbon and the precipitate will be transferred into the storage tank then disposed to a regulated facility.

Option 2: Oil sludge disposal off site and capping (required meeting the objectives)
- Oil sludge excavation and off site disposal of approximately 5,000 m^3 to a certified facility.
- Make up volume deficit of approximately 5,000 m^3.

Option 3: Oil sludge thermal desorption and capping (required to meet the objectives)
- Remove and thermal desorption treatment of 5,000 m^3 oil sludge on site. The liquid phase above the oil sludge is pumped, is made the pH correction then is filtered on layer with active carbon. The contaminated active carbon and the precipitate will be transferred into the storage tank then disposed to a regulated facility.
- Fill the lagoons with thermally treated sludge.
- Geo net layer installation on 8,200 m^2.

All remedial options considered include:
- Remove and dispose of above ground waste materials.
- Removal and dispose of approximately 10 m^3 free oil phase with three phase separator from thermal desorption unit.
- Leveling the site and clean soil import (0.35 m layer) of approximately 2,870 m^3.
- Leveling the site and clean soil import (0.15 m layer) of approximately 1,230 m^3.
- Total of 7 post remediation monitoring wells around the perimeter of the site and in vicinities to a depth up to 7 mbgs.

Notes and explanation on the above Remedial Options Analysis Scoring

Protective of Human Health and the Environment

Health and Safety

Impacts to the health of both construction operatives and the local population have been considered when evaluating the three remediation options. The effects have been considered over the short (1 – 3 years); medium (4 – 10 years) and longer term (10 years plus). The likely severity of health impacts was also considered. Health impacts associated with Options 1 and 2 may potentially occur to both the local population and construction operatives, however it is considered that impacts would only occur over the short term i.e. only until remediation works have been or are substantially completed associated to potential mobilization of contaminants or chemical substances manipulated during execution works.

Health impacts associated with Options 3 even at low risk may potentially occur to both the local population and construction operatives, would only occur over the short term i.e. only until remediation works have been or are substantially completed associated to potential mobilization of contaminants in air during execution works.

Option 1 and 2 was considered to have a medium risk to safety, as risks to the local population would be removed immediately when remediation commenced and the site was secured. Risks to site operatives would occur throughout the remediation process however given the proposed methods, the risks are likely to be over the short to medium term only. More likely the risk will be addressed to chemicals handling and mixing process for Option 2.

Remedial Options Analysis

Evaluation Criteria		Option 1		Option 2		Option 3		KEY RISK VALUES
		Evaluation	**Rating**	**Evaluation**	**Rating**	**Evaluation**	**Rating**	
0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	
1	Protective of Human Health and the Environment	Risks associated during and post remedial project works	6	Risks associated during and post remedial project works	8	Risks associated during and post remedial project works	4	**2 - very low** **4 - low** **6– moderate** **8 - high** **10- very high**
2	Complies with regulatory requirements	Risks to not comply with regulatory requirements	6	Risks to not comply with regulatory requirements	4	Risks to not comply with regulatory requirements	2	
3	Long-Term Effectiveness and Permanence	Risks to not meet RAOs	8	Risks to not meet RAOs	4	Risks to not meet RAOs	4	
4	Reduction in Toxicity, Mobility and Volume	Risks associated to residual contamination	8	Risks associated to residual contamination	4	Risks associated to contaminants mobility	4	
5	Short-Term Effectiveness	Risks to not meet RAOs	8	Risks to not meet RAOs	4	Risks to not meet RAOs	4	
6	Implementability	Risk to not apply to similar contaminated sites in the area	8	Risk to not apply to similar contaminated sites in the area	6	Risk to not apply to similar contaminated sites in the area	4	
7	Cost of remedial works (mil euro)	1,238.2	4	1,017.8	4	1,638.2	6	
8	Estimated Remedy Duration	Risks not complete the works	6	Risks not complete the works	4	Risks not complete the works	4	
9	Addresses regulatory concerns	Risks to not achieve the contaminants mass reduction	10	Risks to not achieve the contaminants mass reduction	4	Risks to not achieve the contaminants mass reduction	4	
10	Addresses community concerns	Risks to not meet the expected benefit	10	Risks to not meet the expected benefit	8	Risks to not meet the expected benefit	4	
Least Score Preferred – Low Risk for the project to be successful and meet the RAOs.								
11	**Total Score**		**74**		**50**		**40**	

Option 3 was considered to have a low risk to the safety as risks to the local population would be removed immediately that remediation commenced and the site was secured. Risks to site operatives would occur throughout the remediation process; given the methods proposed it is likely that the program and technology for Option 3 would be better handled during project duration than that of Option 1 and 2.

Environment

The effects of each option were considered in the longer term as this would allow sufficient time for each of the remediation options to mature and give the most benefit.

Options 1 and 2 were considered likely to give rise to an acceptable quality environment in the long term, as a result of a reduction in contamination mobilization leading to an improvement in soil condition and air quality. However, some hazardous residuals as secondary products from remedial technology of options 1 and accidentally spill during transportation may be a threat for the environment.

Options 3 was considered likely to give rise to a high quality environment in the short and long term, as a result of a mass reduction in contamination leading to an improvement in soil condition and air quality. Furthermore, options 3 do not involve any hazardous chemical as secondary product of technology. However, during pre-treatment stage (three phase separation) before thermal desorption phase small quantities of water and oil will result and is necessary to be disposed accordingly and, is considered to present a low risk for the environment. Following improvements in these environmental factors, the potential for improvements to flora and fauna also exists.

Complies with regulatory requirements

Remediation Objectives for a contaminated land are not based on norms, standards or procedures, only GD 1403/2007 establishing remedial targets based on contaminants screening criteria for soil considering actual/future land use from Order 756/1997 by MoE. Option 1 will not reduce the mass of contaminants but at some level off site migration. Furthermore, chemical stabilization is not regulated yet and the estimated volume to approximately 5,000 cm oil sludge with high hydrocarbons content to encapsulate it with additives/chemicals will involve a large scale of treatment works with questionable efficiency in stability of the sludge and immobilization of the contaminants. Therefore, Options 2 will present high risks to not comply with authorities expectations. Remedial works for Option 2 and 3 are better regulated and do not present a high risk to not comply with further regulations if is the case.

Long-Term Effectiveness and Permanence

Options 2 require more data of oil sludge content to establish mixing rate with additives/chemicals and perform tests of stability for long term effectiveness. The existing data presents high risks in applying a technology which may not be enough effective in achieving the targets for this project. Oil sludge disposal for Option 3 will partially solve the issues with contamination on this site.

Thermal desorption for Option 3 is well known method to reduce the mass of contaminants in oil sludge demonstrated and various projects in Romania and international and present low risk in not accomplish the RAOs for long term period. Then, capping works for the entire site will be addressing both concerns existing on the site: metals (outside area of the lagoons) and treated sludge restored into lagoons.

Reduction in Toxicity, Mobility and Volume

Options 1 present high risks in accomplishing reduction volumes and values of contaminants concentrations based on screening criteria since tests were not carried out to demonstrate the outputs for treated oil sludge.

Option 2 is well known as effective in reducing the mobility and volumes of contaminants existing in oil sludge by reducing the hydrocarbons content through disposal off site. However, the method presents a low risk more likely caused by a potential mobilization of contaminants during excavation and loading operations.

Option 3 is well known as effective in reducing the mobility and volumes of contaminants existing in oil sludge by reducing the hydrocarbons content. However, the method presents a low risk more likely caused by non-adequate execution of works than efficiency of technologies.

Short-Term Effectiveness and implementability

The need for technological tests of resulted mix and therefore certain data of Options 1 effectiveness present a high risk to not meet projected reduction of toxicity, mobility and volume of contaminants in soil and groundwater.

Groundwater level unpredictability during rainfall season may mobilize the free phase from soil that lead to a moderate risk for Options 1, 2 and 3 to not meet the expected effectiveness in free phase removal.

The technicality of each of the options was considered on the basis of whether the option required low / high technical inputs, whether proven technologies were to be used or whether new or emerging technologies in Romania were proposed.

Option 1 include the use of sludge chemical stabilization method which is partially proven technology used previously in similar environments, internationally but not at a large scale of remedial applications in Romania. Option 2 includes oil sludge off site disposal, free phase removal well known and implemented abroad but still at a moderate scale in Romania and capping method as well with large applicability for domestic landfills. Furthermore, hazardous regulated facilities are in operations for few years in Romania and not dealing for long period of time with contaminated soils to handle properly the storage/cleaning operations. However, by implementing even a low level technology still with some operational issues and not applicable to a larger similar contaminated site, presents a moderate risk. Option 3 includes thermal desorption, free phase removal well known and implemented at a large scale used oil industry in Romania and capping method as well with large applicability for domestic landfills.

Cost of remedial works and estimated remedy duration

The costs of each of the options were considered only for the works identified in this Feasibility Study in achieving the RAOs for land as public open space end use. No consideration was given to any costs associated with creating any beneficial future use of the site i.e. landscaping, construction of buildings etc.

Option 3 is slightly less expensive method than 1 and 2 but considered moderate for this type of contaminated land.

Option 2 was considered to have a high duration of remedial works because of test period and uncertainties of adjusting the technologies to operate within effective parameters with associated risks to overdue the implementation projected timescale.

Addresses regulatory and community concerns

Option 2 was considered to have a very high concern from regulatory environmental authorities since the technology is new implemented in Romania and its effectiveness may be questionable without tests performing before remedial solution to be decided.

In the context of this evaluation social benefits are considered to be the possibility of the site being put to use by the local municipality to the residents, however that be a recreational or other public end use. Social impacts were considered in the short to long term for each of the options.

Options 1 was considered to have potential for a very high risk in not accomplishing the benefit in the short to long term as the effectiveness of methods and completion of works on time arise from some uncertainties caused by the need of more soil and groundwater data parameters. Option 3 was considered to have potential for a low risk in not accomplishing the benefit in the short term more likely because of contamination still present in groundwater for long period of time.

Conclusions

Finally the main methods considered for this remediation project by ensuring land use regarding both metal and contaminated soil and, spreading contamination in the groundwater lead to the approach where it is necessary to modify the pathways through the contaminants are mobilized from soil matrix to groundwater and to modify the behaviour of the most affected receptor by applying a cost effective solution in regards with the main RAOs proposed.

Options 1 and 2 have some uncertainty related to effectiveness of remediation and data available which may lead to a potential failure of meeting RAOs, for costs and questionable positive benefit on social and economical impact.

Option 3 is less expensive than Option 1 and 2 and, answers to the present and future concerns in regards of land use for the contaminated site at Campina. Furthermore, provides a solid and achievable technology that may be handled for this type of contamination mainly with hydrocarbons and heavy metals by the beneficiary, contractor and environmental authorities.

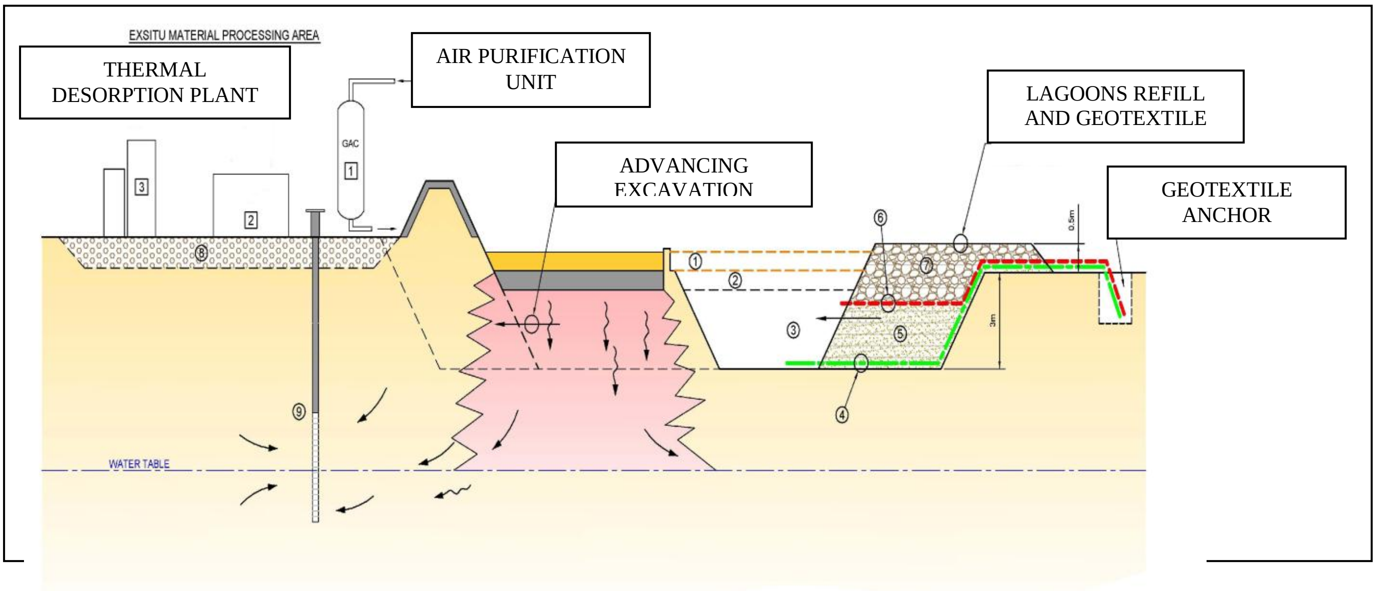

Fig.4. Remedial Sequence

References

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Reabilitarea sitului poluat istoric – Batal reziduuri petroliere. Tehnici de remediere

Rezumat

Situl contaminat cu suprafata de 8,200 m^2 *consta in 4 bazine (batal) cu slam petrolier (gudroane) si zona adiacenta. Peste 100 de ani de activitati de procesare a titeiului desfasurate de catre rafinarie au avut un impact semnificativ in aceasta regiune.*

Pe baza istoricului sitului, a observatiilor de teren, rezultatelor probelor de apa si sol, a rezultat foarte clar o legatura de poluare intre batalul cu gudroane si orice membru al comunitatii locale.

Pentru ruperea acestor legaturi de poluare si reducerea riscului asociat cu sanatatea umana si mediul, anumite tipuri de actiuni de remediere au fost necesare. Obiectivul lucrarilor de remediere a fost de a reduce mobilitatea contaminantilor prezenti in apa subterana si a proteja utilizarea terenului la un standard acceptabil de utilizare ca zona verde.