STUDY ON PIT CLOSURE GUIDELINES FOR OIL AND GAS PRODUCTION ACTIVITIES

by

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ABSTRACT

Study on pit closure guidelines for the oil and gas industries has been conducted by Lemigas Team to observe the existing guidelines and the implementation of the guidelines in the closure program of the temporary use of pits. Goals of the study are to review the manual guideline or standard operating procedure (SOP) of pit closure applied to the petroleum fields, and compare it to the relevant government regulation.

So far, governnental regulation concerning pit construction and closure has not been established yet. Nevertheless, management approach of pit construction and closure can be established by referring to the available regulation, namely PP. 18/1999 - hazardous waste regulation, and the related Ministerial Decree. This approach is based on the reason that such solid wastes are also categorized as hazardous wastes. Looking at from regulation point of view, it can be said that pit management guideline established by the industry has fulfilled and matched with the available regulation such as Kep.-04/Bapedal/09/1995. Nevertheless, some criteria have to be re-evaluated and post-closure plan seems not to be included in the guidelines yet.

This paper presents the results of the study describing the existing guidelines used by the oil and gas industry and its implementation as well as reviewing the government regulation related to the pit closure program.

I. INTRODUCTION

Exploration, development, and production activities associated with oil and gas production projects can have a variety of impacts on the environment. A variety of wastes is produced by such activities. Apart from the wastewater that is in the form of produced water, many kinds of solid wastes are produced during exploration and production of oil and gas. These solid wastes, among others, are drilling mud and cuttings, and tank bottom oily sludge. These solid wastes are dumped temporarily in a certain place called a pit before they can be treated further.

In order to minimize and possibly eliminate the environmental impacts of those solid wastes, pit construction has to be developed in such a way that release of pit contents to the environment could be prevented. In addition, pollutant loading of ground water from waste leaks, releases of hydrocarbons and hydrogen sulphide to the atmosphere are some of the factors that have also to be considered. As dumping such solid wastes in a pit is a temporary storage, pit closure management has also to be developed.

So far, governmental regulation concerning pit construction and closure has not been established yet. Nevertheless, management approach of pit construction and closure can be established by referring to the available regulation, namely PP. 18/1999 - hazardous waste regulation, and the related Ministerial Decree. This approach is based on the reason that such solid wastes are also categorized as hazardous wastes.

In regard to pit construction, study on pit location should include the hydrogeology pattern of the site. Furthermore, pit wall materials are parameters that also have to be considered in minimizing impacts to the surrounding. Upon closing the pit, a pit closure plans that call for the dewatering of mud and reserve pit contents before burial have to be developed to reduce the chance of the downward transport of contaminants to shallow aquifers. The grading of soils covering the pits may reduce the chances of infiltration of rainwater, which may mi

grate to ground water. Other consideration, for example revegetation, has also to be included.

All of the above factors should be considered in pit closure and assessment guideline. In addition to the available references, such as PP. 18/1999 and related Ministerial Decree, other references such as those of US-EPA guidelines are deserved to be included.

The authors have conducted a short study concerning with pit closure management that has been implemented by the oil and gas producer. Goals of the study are to review the manual guideline or standard operating procedure (SOP) of pit closure applied to the petroleum fields. The scope of works of the study includes interact with the industry regarding current practice in pit closure procedure, custom made guideline and assessment of pit closure program, closure strategy selection guideline, and review manual guideline or standard operating procedure for pit construction and closure

II. PROBLEMS WITH OIL FIELD PIT

A so-called pit is a leftover from oil exploration and oil production on land. Typically the oil companies in earlier years left drilling mud and crude oil, discharged in connection with drilling and testing of the new well, in ponds or pits next to the drilling hole. Over the years the lighter fractions of the oil have evaporated and in many cases additional contamination has taken place due to the dumping of chemicals, refinery waste, and debris. Consequently the pits may contain extremely viscous and debris laden asphalt-like oil, which is very difficult to recover. The soil in the bottoms and sides, as well as the surrounding land may suffer from serious oil pollution. Contaminated water from the pits may be in connection with rain overflow into rivers and lakes

A. *Types of Pits*

The use of pits, earthen or lined, is an integral part of E&P waste management operations. Historically, on-site pits have been used for the management of drilling solids, evaporation and storage of produced water, management of workover/completion fluids and for emergency containment of produced fluids.

Drilling Pits

The primary wastes from exploratory drilling operations include drilling muds and cuttings, cementing wastes, well completion, workover and stimulation fluids, and production testing wastes. All of these wastes are normally dumped in the pits. Other wastes include excess drilling chemicals and containers, construction materials (pallets, wood, etc.), process water, fuel storage containers, power unit and transport maintenance wastes, scrap metal and domestic and sewage wastes. These wastes are not normally dumped in the pits, instead they are transported to other storage facilities for further treatment.

Skimming Pits

Oil pumped from deep within the earth is almost always combined with brine water. In general, oil producers and pit operators separate the oil and water with a series of surface pits. These pits are often centrally located near several oil production wells, which are often located in relatively undeveloped areas. The skim pit is used to separate the lighter, less dense oil and allow the water to drain from the bottom of the pit into a second pit - the evaporation pond - for evaporation.

B. *Pit Construction*

In general, pits should be as small as possible and be strategically located to prevent spillage of waste materials onto the drilling or production site. Pits should be lined unless site characteristics ensure that there will be no significant threat to water resources. In areas where it may be necessary to construct pits adjacent to water bodies or on sloping terrain, special engineering precautions should be taken to ensure the integrity of the pit. Free hydrocarbons should be removed from pits and returned to the production process for recovery as soon as possible, and precautions should be taken to prevent pit disposal of chemicals, refuse, debris or any other materials which were originally not intended to be placed in pits. These materials can alter the nature of the bulk fluids in the pit and make disposal more difficult.

Several efforts of pit construction are meant to protect the environment, such as:

- Construction of a slurry wall around the pit to isolate the wastes can prevent groundwater contamination.
- Installation of a clay cap on top of the pit to keep water from seeping through the pit and contaminating groundwater.
- For additional protection, traffic barriers were placed around the perimeter of the cap to prevent damage.
- Installation of several groundwater wells to monitor the on-going effectiveness of the slurry wall.

C. *Pit Cleaning and Closure*

Although pits are an accepted component of exploration and production (E&P) operations, they could represent an environmental liability if managed improperly.

Pits should be for temporary use, and should not be used for disposal of oil. Pits should be closed as soon as practicable and their closure follow the required or generally accepted practices of the region.

Pit Cleaning

Pit cleaning, is intended to cope with the very old, extremely viscous and debris laden pits. It has to be considered whether the cleaning will be done *in-situ* or *ex-situ*. It gives a lot of meaning to do in-situ cleaning, as this minimizes further environmental damage caused by transportation and double handling of the oil, soil, water, debris, etc. If, however, the pit is located close to a refinery or a municipal waste incineration plant with electric power generation, it may in some special cases be feasible to bring the whole problem to such a facility for treatment.

Dependent on climate, geography/geology, and lifestyle of local inhabitants, the cleaning should be more or less complete. For example, in the Amazon Rain Forest, where the locals drink the water from the rivers and have their children and animals close to the contaminated sites, the cleaning requirement will be high, and pit closures using concrete or quicklime stabilization should be ruled out, due to the rain and groundwater's ability to continue washing out oil and heavy metals. But in the deserts, with sparse population, and if there is no groundwater, it may be safe to recover whatever the oil can be pumped and dug out, and then stabilized the remaining oil. Biodegradation may be an option to stabilization if the required amount of humidity can be obtained.

In the rain forest, where the pits contain extremely viscous oil, water, and debris there are a couple of complete and environmentally friendly processes for the in-situ cleaning of difficult waste oil pits. This could be done through an inverse emulsification of the asphalt-like crude in the old pits.

Inverse emulsification is a process where a biodegradable dispersant is mixed with water and thereafter sprayed on the pit. By using compressed air (large bubbles) and pressure water from fire pumps, the dispersant is mixed with the oil, which gradually becomes more and more liquid. Sand and stones sink to the bottom and debris is relatively easy recovered for final cleaning. As the compressed air nozzles are pointing downwards, this process treats the bottom and the water in the pit at the same time as treating the oil. Heavy oil products in the bottom sediments will be washed out, and air bubbles from the agitation process enable the oil to float to the surface.

The oil water mixture is then easily recovered, using overflow weir skimmers. Once the water meets the regulation requirements, it will, upon approval by the authorities, be discharged to the surroundings. With a little remaining water left in the pit, the bottom and sides are now pressure washed with water and dispersant to a depth of 0.5 m, by high pressure cleaners. In this way the remaining oil from bottom and sides will be washed out. The oil is skimmed off the surface and when it is clean enough the last bit of water is then discharged.

The recovered oil may after filtration be re-injected into production, or it may be used for the production of asphalt and/or fuel for thermoelectrically power plants.

Pit closure through landfill and burial

Landfills are generally specially constructed and monitored facilities designed to accommodate burial of large volumes of wastes. However, some landfills may be little more than open dumps. A landfill may be constructed in a manner that makes it an appropriate disposal site for certain toxic wastes. A key consideration in the operation of a landfill site is the need to ensure long-term containment. Design considerations for a landfill include:

- An impermeable lining to contain the landfill contents. Liners may be constructed of clay, plastic sheeting and/or multi-layer linings with integrated drainage systems.
- Monitoring boreholes or leachate collection systems to provide a means for regular inspection of the effectiveness of the containment.
- Special provisions for disposal of liquid wastes, or prohibition of liquids disposal. If disposal of liquids is permitted, the conditions should be controlled to prevent leaching. The landfill design should include arrangements for the collection and treatment of leachate.

It should be kept in mind that all landfills may not be constructed to the same standards, and that industrial wastes should only be disposed of in sites with the proper design criteria and proper monitoring and maintenance programmes. Landfilled materials should not be capable of reacting to generate excess heat or noxious gases. Special systems may need to be installed to collect generated methane. The operator should remember that landfilled wastes are not destroyed, but are actually in longterm storage. Disposal sites should be operated either by the waste generator who will maintain responsibility for its own wastes or by a properly managed disposal facility.

Due to its simplicity, burial of wastes in small pits at drilling and production sites has been a popular means of waste disposal in the past. However, with current awareness of pollutant migration pathways, the risks associated with burial of wastes should be carefully considered. In general, wastes with high oil, salt, or biologically available metal content, industrial chemicals, and other materials with harmful components that could migrate from the pit to contaminate usable water resources should not be buried. Burial may be the best method of disposal for inert unrecyclable materials. If a pit's contents contain concentrations of constituents only slightly elevated above levels regulated for disposal, then burial provides a simple mechanism to reduce concentrations in the waste, via dilution with soil, as it is being disposed. This may often be the case for water based muds and cuttings. In dilution burial, the pit contents are mixed with soils from the pit and surrounding areas until the pit contents meet specifications for burial, then the pit is covered and the surface graded.

III. PIT CLOSURE REGULATION

Explicitly, oil field pit closure regulation has not been established yet by the government of Republic of Indonesia. Nevertheless, appropriate document or regulation can be referred to for managing pit closure. Residual oil in the pit may contain toxic substances, such as aromatic hydrocarbons and heavy metals, contaminats in the waste that can be categorized as hazardous. It is appropriate, therefore, to refer to the Bapedal regulation No. Kep.-04/BAPEDAL/09/19995 decsribing methods of landfilling or land disposal for hazardous wastes.

A principle part of land disposal program in the hazardous waste management regulatory program is designed to protect groundwater. Hazardous waste can pollute groundwater through the process known as leaching, in which precipitation percolating through the ground draws contaminants out of buried waste and carries them into groundwater. Placing barriers between wastes and underground water sources is one way to prevent migration of hazardous contaminants into groundwater. This can be done for example by installation of impermeable liners beneath hazardous waste landfills. Such barriers separate vulnerable groundwater from hazardous constituents likely to leach from the buried wastes.

Hazardous waste could be made less dangerous to ground water in two main ways: (i) by reducing waste's toxicity through destruction or removal of harmful contaminants, or (ii) by reducing a waste's leachability by immobilizing hazardous contaminants. Land disposal program requires waste handler to fundamentally change the threat posed by hazardous waste before it is land disposed. Waste specific restrictions are manifested as thresholds for adequate treatment, known as treatment standards. The regulation expresses these treatment standards as either numeric concentration levels for hazardous constituents, which is tabulated in the Table 2 column A and column B of the Kep.-04/Bapedal/09/1995, or as a required technology, which is stated in the Bapedal regulation of Kep.-03/Bapedal/09/1995. Wastes that meet appropriate treatment standard may be land disposed. Figure 1 shows a simplified diagram for selecting landfill category according to the concentration levels of hazardous constituents.

A. *Landfill Category*

As pits have to be closed, the owner/operator must maintain the facility in a way that ensures it does not pose a future threat to human health and the environment. Closure is the period following active management during which hazardous wastes are no longer accepted. Oil field pit operators normally remove all of the pit liquids, sludge and oily soil prior to close the pit. The collected wastes are then managed accordingly, such as discharging the water to a disposal well, recovering the oil, and treating the oily material by slurry injection , bioremediation, or reuse for road construction. These actions of reducing contaminant concentration in the pit can be considered as treating the waste in order that the residual wastes meet the standard treatment in which the contaminant concentration levels of the wastes comply with the regulation before it can be land disposed.

Kep.-04/Bapedal/09/1995 states that there are three categories for landfill of untreated hazardous waste according to the contaminant concentration level (cf. Figure 1). Category I is intended to the specific wastes that are included in the regulation (cf. Table 1). If the wastes are not included in the list of the regulation of Kep.-04/Bapedal/09/1995 then landfill category follows the contaminant concentration level as stated in the Table 2 of the regulation (cf. Table 2).

B. *Landfill Design for Each Category*

Landfill design for each landfill category is depicted in Figure 2. All three categories of landfill have the same layers, from bottom to top, as follows (cf. Figure 2): (i) sub-base layer, which is made of compacted soil of 1 m thickness, (ii) leak detection system layer, (iii) barrier soil layer, which is made of compacted clay of 30 cm

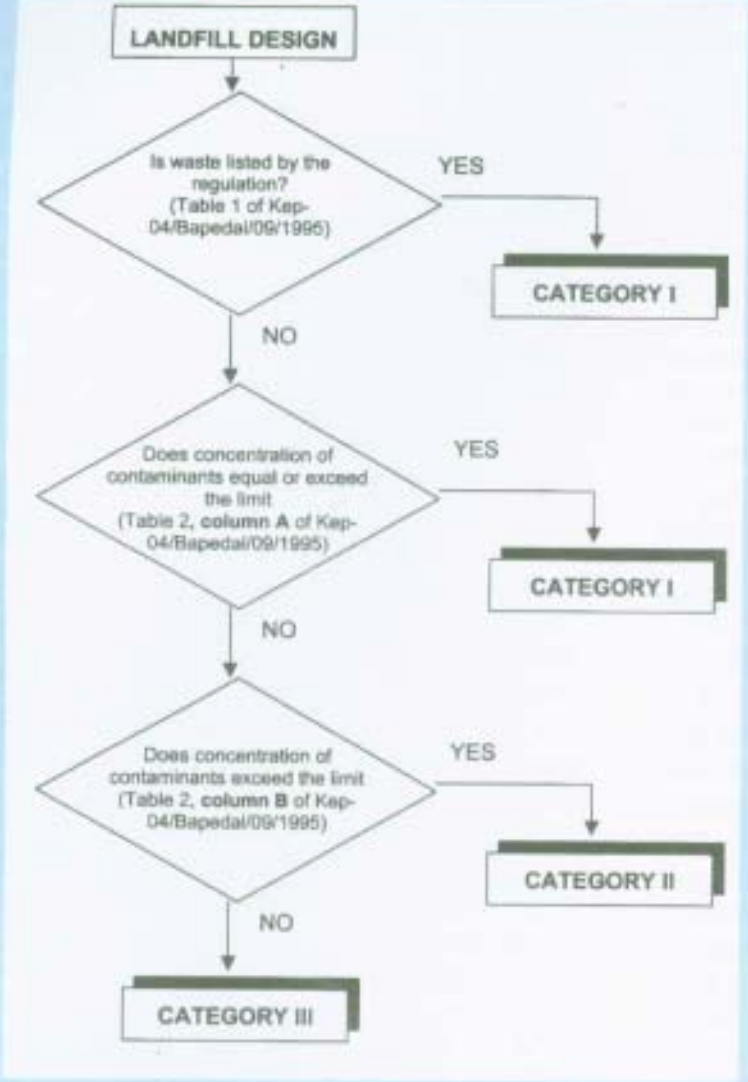

Figure 1
Simplified diagram of category of landfill design according to Kep.-04/Bapedal/09/1995

thickness, (iv) leachate collection system, and (v) operation cover layer. Basic different between landfill design of category I (Secure Landfill Double Liner), category II (Secure Landfill Single Liner), and category III (Landfill Clay Liner) is the use of geomembrane layer made of high density polyethylene (HDPE) with a minimum thickness of 1.5 – 2.0 mm. Category I landfill uses two layers of geomembrane, one layer (primary geomembrane) is placed beneath the leachate collection system layer and another one (secondary geomembrane) is placed beneath the layer of leakage detection system. Category II landfill uses only one geomambrane layer which is placed beneath the barrier soil liner, while category III landfill does not use any geomembrane layer.

Finally, the buried waste has to be covered by a final cover, which consists of six layers (from bottom to top): (i) intermediate soil cover of 15 cm, (ii) cap soil barrier of 60 cm of compacted clay, (iii) cap geomembrane made of HDPE of 1 mm minimum thickness, (iv) vegetative layer of 60 cm (v), and vegetation (cf. Figure 3).

C. *Post Closure*

Post-closure, which applies only to land disposal facilities and facilities that cannot decontaminate all equipment, structures, and soils, is normally a 30-year period after closure during which owners/operators conduct monitoring and maintenance activities to preserve the integrity of the disposal system and continue to prevent or control releases of contaminants from the disposal units.

Leachate collected from the leachate collection system should be analized once in a month during the first year of post closure and once in three month period during the next 10 years, and once in six month period during the next 20 years.

IV. PIT CLOSURE GUIDELINES ESTABLISHED BY THE PETROLEUM INDUSTRY

The petroluem industry has established "Pit Management Guideline", which is provided to the field personnel with advice on the responsible operation and closure of various types of pits. The guidelines describe the actvities that should be conducted before, during, and after a pit is closed. Guidance on the collection of samples and risk based cleanup levels based on total petroleum hydrocarbon (TPH) and metal content are included. However, detailed descriptions, evaluation, or recommendations of treatment technologies for pit content are beyond the scope of the guidelines.

Philosophical background of pit management is based on the fact that pits could represent an environmental liability if managed improperly. Pits should be for tempo

Table 1
Type of industries/activities that the hazardous waste landfill should follow Catagory I

Waste Code	Type of Industry	Waste
D202	Pesticides	Sludge from waste water treatment containers used for pesticide formulation
D203	Alkaline chloro process	Sludge from waste water treatment
D204	Adhesives	Spent product off-specification catalysts
D205	Polymeric industries	Monomers that not undergo reaction catalysts
D207	Timber	Sludge
D210	Used lead smelting	Sludge, ash, slag
D212	Ink industries	Sludge, sludge containing heavy metals
D214	Automobile	Sludge
D215	Electroplating	Sludge
D216	Paint	Sludge
D217	Dry batteries	Sludge, mix paste, off-spec products
D218	Batteries	Sludge, ash
D219	Electronics	Sludge
D224	Leather tanning	Sludge
D225	Dyes	Sludge
D228	Research and commercial laboratory	Sludge

rary use, and should not be used for disposal of oil. Pits should be closed as soon as practicable and their closure follow the required or generally accepted practices of the region.

Accordingly, the industry has established a general philosophy for the management of pits, which states that pits for oil and gas operations will only be used if critically necessary, pits must be constructed, operated, and monitored to assure that there is no leakage and threat to wildlife or people, and non critical pits will be closed and restored to a condition that poses no potential harm to surrounding communities and the environment.

In implementing these phylosophy of pit management when a pit is necessary for oil and gas operations, the industry has also established condition guidelines that have to be followed such as leakage prevention, overflow and accumulation of floating hydrocarbons prevention, measures that limit access by animals and the public, and regular maintenance and monitoring. It is stated in the manual that the need for monitoring wells may be reevaluated only if site characteristics or engineering controls ensure that there will be no threat to water resources and humans, as determined by a qualitative or quantitative risk evaluation. Use of pitless alternatives, such as tanks, separators, cooling tower, and other technologies are suggested in the guideline for produced water processing. The industry has also established pit closure procedures consisting seven items of conditions that should

Table 2
Maximum concentration of hazardous waste and its landfill category

Contaminants	Maximum Concentration (mg/kg of dry weight)	Maximum Concentration (mg/kg of dry weight)
	Column A	Column B
Remarks:	• Greater than or equal to: Category I Landfill • Less than: Category II Landfill	• Less than or equal to: Category III Landfill
Arsenic	300	30
Barium	-	-
Cadmium	50	5
Chromium	2,500	250
Copper	1,000	100
Cobalt	500	50
Lead	3,000	300
Mercury	20	2
Molybdenum	400	40
Nickel	1,000	100
Tin	500	50
Selenium	100	10
Silver	-	-
Zinc	5,000	500
Cyanide	500	50
Fluoride	4,500	450
Phenols Pentachlorophenol (PCP) 2,4,5-trichlorophenol 2,4,6-trichlorophenol	10	1
Monocyclic aromatic Hydrocarbons Benzene Nitrobenzene	70	7
Monocyclic aromatic compounds 0-Cresol m-Cresol p-Cresol Cresol Total 2,4-dinitrotoluene methyl ethyl ketone pyridine	200	20
Total petroleum hydrocarbons (TPH) C6 to C9 TPH, all Cn	1,000	100
TPH, greater than C9	10,000	1,000
Organochlorine compounds: Carbon tetrachloride Chlorobenzene Chloroform Tetrachloroethylene (TCE) Trichloroethylene 1,4-dichlorobenzene 1,2-dichloroethane 1,1-dichloroethylene hexachlorobenzene hexachlorobutadiene hexachloroethene vinyl chloride	10	1

Table 3
Acceptable pit closure concentration

Parameter	Acceptable concentration, mg/kg		
	Oil and Gas	A*	B*
Total Petroleum Hydrocarbons		10,000	1,000
Restricted access	18,000		
Non-restricted access	1,500		
Total Metals			
Antimony	16	400	40
Arsenic	2	300	30
Barium	2,800	-	-
Beryllium	80	-	-
Boron	NA	-	-
Cadmium	3,600	50	5
Chromium	20	2,500	250
Cobalt	2,400	500	50
Copper	1,480	1,000	100
Lead	400	3,000	300
Mercury	12	20	2
Molybdenum	200	400	40
Nickel	800	1,000	100
Selenium	200	100	10
Silver	200	-	-
Thallium	3	-	-
Tin	24,000	500	50
Vanadium	280	-	-
Zinc	12,000	5,000	500

* A and B denote Coloumn A and Coloumn B of Table 2 of Kep.-04/Bapedal/09/1995 (cf. also Table 2)

be followed: pit closure goals, closure shedule, documentation, sampling, analyses, acceptable soil concentration for closure, and pit closure sequence.

Analyses of the pit contents, clean bottom soil, or bakground samples are necessary to ensure whether the residual materials in the pit has a concentration of the contaminants meet the acceptable concentrations that are based on human health risks. Table 3 shows a copy of the acceptable pit closure concentrations established by the industry. For comparison purposes, it is also included in Table 3 the maximum concentration limit of the contaminants that are suggested by Kep.-04/Bapedal/09/1995.

Pit closure sequence procedure that has been

Figure 2
Landfill layer design for waste land-disposal

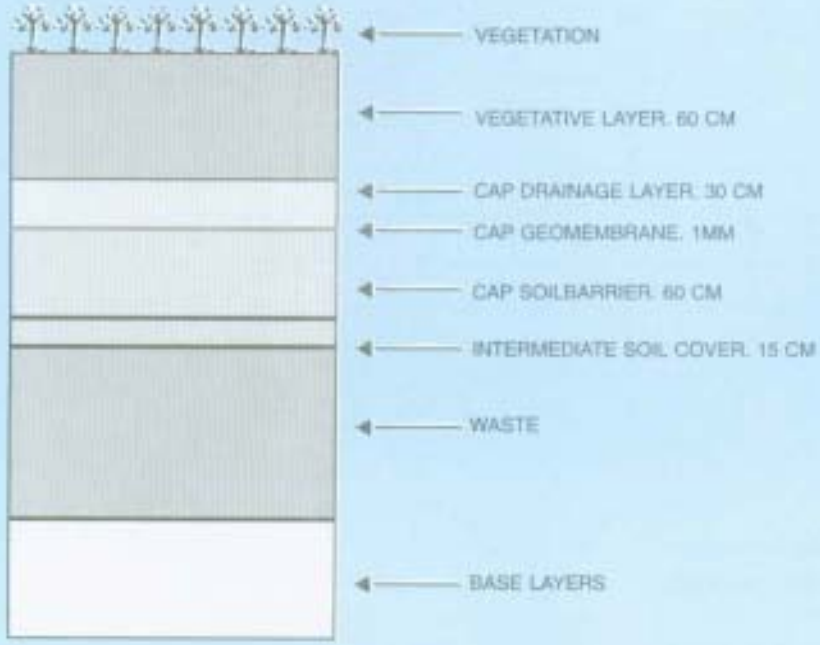

Figure 3
Final cover for all category of landfill

established by the industry consists of the following steps: selection of pit to be closed based on established SBU priorities, recording site information, collecting samples of liquid in pit, removal pit liquids, collecting pit bottom samples, determining appropriate treatment or disposal procedure for pit bottoms, removing all of the pit liquids, sludge, and oily soil, sampling and analysing the "clean" pit, bacfilling the pit, and recording appropriate information, including copies of all drawings, analyses, and photographs. One of the closed pit that was visited during the study is presented in Figure 4.

V. DISCUSSIONS

Generally, salts and hydrocarbons have been identified as

Figure 4
One of closed pit at the field

the principal limiting constituents of concern relative to onshore exploration and production operations because they may induce a phytotoxicity or, in the case of sodium salts, may deteriorate soil structure interrupting normal soil-plant-water relationships and cause excessive erosion. Salts and hydrocarbons associated with exploration and production wastes may also pose a significant threat to surface and groundwater resources if not properly managed.

Another source contaminants of concern is if significant levels of toxic metals are believed to exist or there is concern due to type of sources of wastes. In this case mobility of these metals may be evaluated utilizing the Toxicity Characteristic Leaching Procedure (TCLP). It is important, therefore, to consider these factors when a pit has to be cleaned prior to closing the pit.

A pit is considered cleaned up when it meets the recommended levels. Such levels could be referred to the Bapedal regulation of Kep.04/Bapedal/09/1995. Beside the recommended levels, before closing the pit, the pit content should contain no liquid. Liquid can be allowed to dry by evaporation or be removed and treated in such a way that meets the standard operating procedure, such as injection in the well. Occasionally, solidification using cementitious/pozzolanic process that envelops the waste solids in a material matrix could be applied before burrying the pit content.

Looking at from regulation point of view, it can be said that pit management guidelines established by the industry complies with the available regulation such as Kep.-04/Bapedal/09/1995. The waste in the pit has undergone such treatment that the residual materials in the pit have a concentration of the contaminants that meets the acceptable concentrations that are based on human health risks. Wastes that meet appropriate treatment standard then may be land disposed.

The guideline established by the industry seems to conform to the Bapedal regulation. Kep.-04/Bapedal/09/1995 states that there are three categories for landfill of untreated hazardous waste according to the contaminant concentration level. Category I is intended to the specific wastes that are included in the regulation. If the wastes are not included in the list of the regulation of Kep.-04/Bapedal/09/1995 then landfill category follows the contaminant concentration level, and the landfill category will follow category II or III.

One thing that should be studied in more detailed is that there are differences in the contaminant concentration levels between the one that is followed by the industry gudeline and the other that is stated in the Bapedal regulation (cf. Table 3). Moreover, other parameters that are included in the regulation and not mentioned in the guideline have also to be considered.

The working area of the industry is located in a relatively remote area, in which the area is relatively far from the public settlements. Future land use has been used by the industry for considering the risk determination. Hence, the industry has devided land use for the operation into two general categories: unrestricted access and restricted access. Dependent on climate, geograp geology, and distances of public settlements, the cleaning may be more or less complete. It would be more accurate, if the categories were made after having summation of several factors such as distance to ground water, native soil type, annual precipitation, distance to nearest public water well, distance to surface water, and potentially affected populations. These factors would be subject to be considered and studied in the near future.

When burial and/or pit closure is complete, the area should be graded to prevent water accumulation, and revegetated with native species to reduce potential for erosion and promote full recovery of the area's ecosystem. It is obsereved that vegetation at the closed pit that has been studied (cf. Figure 4) seems not to grow normally. The soil that covers the pit is obviously dry. This would need further study to investigate whether the top soil covering the pit has changed due to chemical tranformations that might occurs in the closed pit. Revegetation study would be a subject for the future. Moreover, post-closure care has also to be included in the pit closure program to ensure it does not pose future threat to the environment. The post-closure program will con-

sist groundwater monitoring and maintaining waste containment system.

VI. CONCLUSIONS AND RECOMMENDATIONS

A. *Conclusions*

The use of pits, earthen or lined, is an integral part of oil exploration and production (E&P) waste management operations. Nevertheless, they could represent an environmental liability if managed improperly. Accordingly, every establishment that responsible in E&P operations should provide a pit management guidelines that has to be followed by the responsible personnel to ensure that the pit and its content does not pose future threat to the environment. Pit management guideline, is also provided to the field personnel with advice on the responsible operation and closure of various types of pits.

Looking at from regulation point of view, and from the references that have been cited in this report, it can be said that pit management guideline established by the industry has fulfilled and matched with the available regulation such as Kep.-04/Bapedal/09/1995. Nevertheless, some criteria have to be re-evaluated and post-closure plan seems not to be included in the guidelines yet.

B. *Recommendations*

Upon examined overall reviews cited in this report, several actions are recommended to be conducted. These are:

a. More detailed study on the contaminant concentration levels that shall be used as an acceptable contaminant level of pit content which is used for determining which landfill category that should be followed.
b. More detailed study on land use category by including factors such as distance to ground water, native soil type, annual precipitation, distance to nearest public water well, distance to surface water, and potentially affected populations.
c. Establishment of post-closure program in the Pit Management Guidelines that will include ground water monitoring and maintaining waste containment system.

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