STUDY ON THE ENVIRONMENTAL ASPECTS OF PIT CLOSURE GUIDELINES FOR OIL AND GAS PRODUCTION ACTIVITIES

by
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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 are 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.

Explicitly, governmental regulation concerning with environmental aspects of pit closure has not been established yet. Nevertheless, environmental management approach of pit construction and closure could be established by referring to the available regulation, namely Governmental Regulation PP. 18/1999 juncto PP. 85/1999 - hazardous waste regulation[1,2], and the related Ministerial Decree, such as Bapedal Decree No. Kep.-04/BAPEDAL/09/19995 decsribing methods of landfilling or land disposal for hazardous wastes[3]. 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. Further more, 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 migrate 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 national references, other world wide references such as those of US-EPA guidelines deserve to be considered in studying pit management.

The author has conducted a short study concerning pit closure management that has been implemented in oil and gas producing companies. Goals of the study are to review the manual guideline or standard operating procedure (SOP) of pit closure applied to the fields. The followings are report concerning with the implementation of the study.

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 a 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 surround-

ing land may suffer from serious oil pollution. Contaminated water from the pits may 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.

1. 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.

2. 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.

C. *Environmental Impacts of Oil Pits*

Oily wastes generated by oilfield production of petroleum can kill birds and other wildlife if the oil and water separation pits are not properly managed and maintained. These wastes can also contaminate surrounding soil and nearby surface water and ground water. Improperly constructed oil pits and ponds, poor housekeeping, and attempts to cut corners can allow oil scum to form on ponds and allow oil to seep into the evaporative ponds. Seepage and overflow can contaminate surrounding soils and surface waters, and even affect nearby groundwater as well. Skim pits are generally required to be covered or include other deterrents that prevent birds from landing on the surface. If these pits are not properly covered, birds can land on the surface where they become trapped and contaminated with oil.

D. *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 should follow the required or generally accepted practices of the region.

1. Pit Cleaning

There are only a few ways to do proper pit cleaning, and even fewer of them will be able to cope with the very old, extremely viscous and debris laden pits. It has to be considered whether the cleaning must 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 must be more

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or less complete. In the rain forest area, for example, 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 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.

2. 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 programs. Land-filled 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. It should be remembered that land-filled wastes are not destroyed, but are actually in long-term 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.

Burial is a logical choice for wastes that have been stabilized, since migration of the constituents of the waste will be retarded by the stabilization process. However, if there is a reason for extra caution at a particular site (either because of the constituents in the original waste, or because of the hydrogeologic characteristics of the site) then additional barriers to migration such as barrier walls around the pit, liners around the pit contents, or a cap to prevent vertical migration, could also be installed. Alternatively, and if available, the waste could be sent to a properly managed facility designed to handle that type of waste.

Consideration of factors such as the depth to groundwater, and the type of soil surrounding the pit should be made before wastes are buried. This ensures proper protection of soil and water resources. 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.

III. METHOD OF THE STUDY

The methodolgy used in the study includes the followings:

- Interact with the oil and gas industry personnel 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.
- Reviewing common practice conducted by similar industry world wide, current technology under research, technology currently available and applied by the industry, current practice in Pit Closure Procedure.
- Reviewing current practice of oil and gas industry in Indonesia for site assessment, pit construction and closure guidelines.
- Data collecting of pit closure method from the Oil and Gas Companies in Indonesia (PSC and PERTAMINA).

IV. RESULTS AND DISCUSSIONS

Explicitly, oil field pit closure regulation has not been established yet by the government of Republic

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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, contaminants 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 principal part of land disposal program in the hazardous waste management regulatory program is designed to protect groundwater[4]. 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[5]. 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 and owners/operators of treatment, storage, and disposal facilities (TSDFs) complete treatment, storage, and disposal operations; apply final covers to or cap landfills; and dispose of or decontaminate equipment, structures, and soils.

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[6].

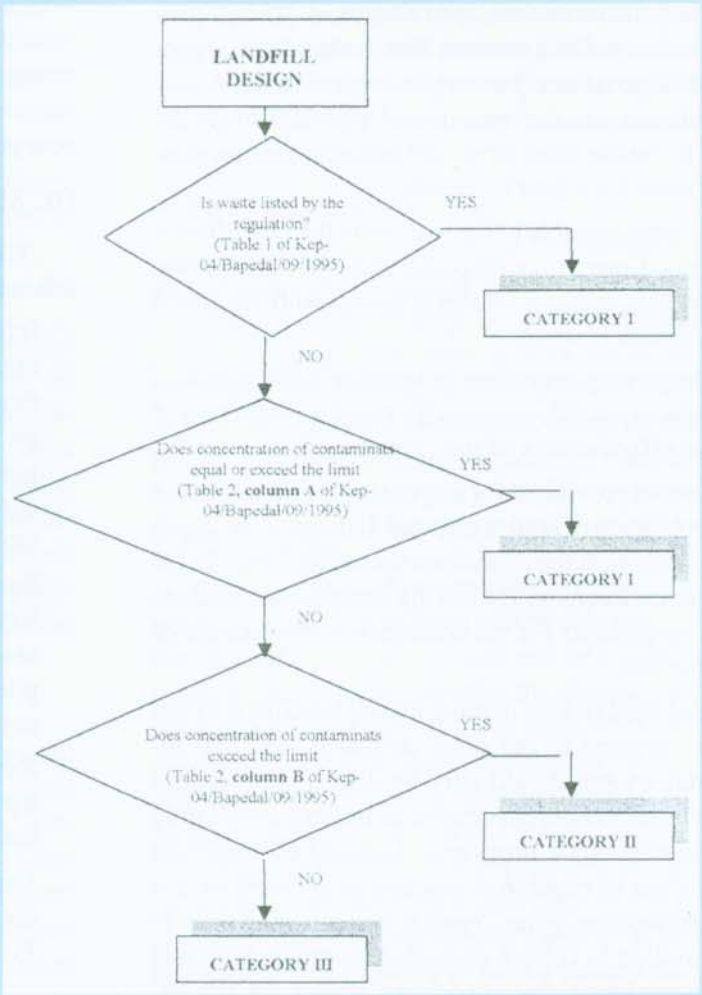

Figure 1
Simplified diagram of category of landfill design according to Kep.-04/Bapedal/09/1995

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Table 1
Type of industries/activities that the hazardous waste landfill should follow Category 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	Adesives	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 Commer-cial Laboratory	Sludge

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 waste 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 of this report).

B. *Landfill Design for Each Category*

Landfill design for each landfill category is depicted in Figure 2. Basic difference 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 geo-membrane layer made of high density polyethylene (HDPE) with a minimum thickness of 1.5 – 2.0 mm. Category I landfill uses two layers of geo-membrane, where one layer (primary geo-membrane) is placed beneath the leachate collection system layer and the other (secondary geo-membrane) is placed beneath the layer of leakage detection system. Category II landfill uses only one geo-mambrane layer that is placed beneath the barrier soil liner, while category III landfill does not use any geomembrane layer.

All three categories of landfill have the same layers, from bottom to top layers, as follows (cf. Figure 3): (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 thickness, (iv) leachate collection sys-

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

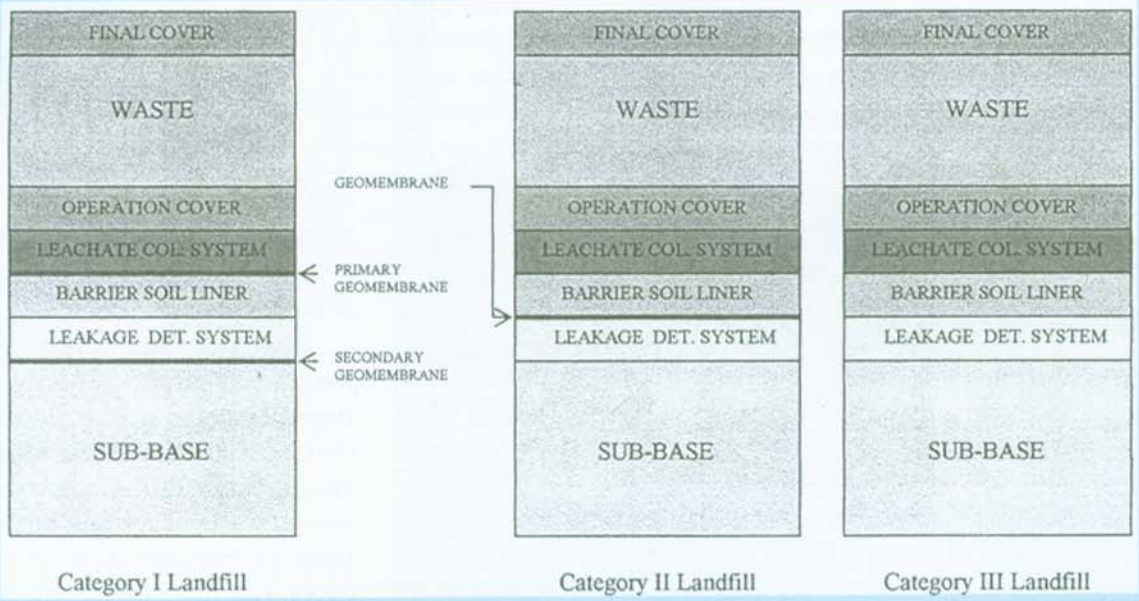

Figure 2
Landfill layer design for waste land-disposal

tem, and (v) operation cover 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 geo-membrane made of HDPE of 1 mm minimum thickness, (iv) vegetative layer of 60 cm (v) vegetation.

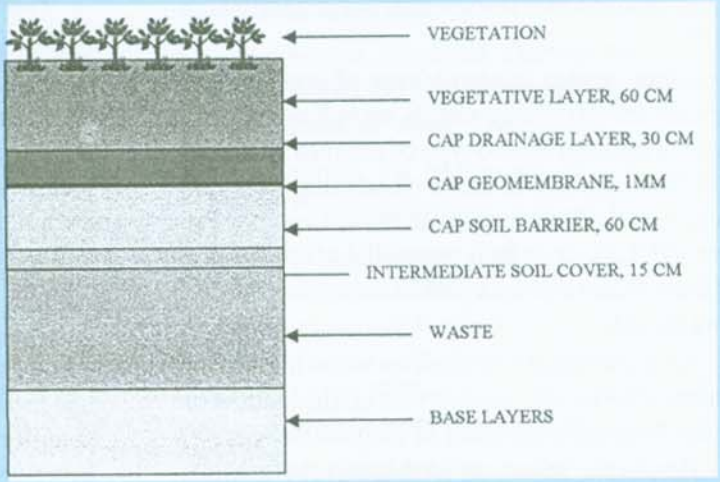

Figure 3
Final cover for all category of landfill[3]

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 analyzed 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.

Generally, salts and hydrocarbons have been identified as the principal limiting constituents of concern relative to onshore exploration and production operations because they may induce a phytotoxicity or,

Figure 4
Poor growing of vegetation on closed pit

in the case of sodium salts, may deteriorate soil structure interrupting normal soil-plant-water relationships and causing 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[8-9].

Another source contaminants of concern is if siginficant 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 closing the pit.

A pit is considered cleaned up when it meets the recommended levels. Such levels could be referred to in 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 meet the standard operating procedure, such as injection in the well. Occasionally, solidification using cementitious/pozzolanic process that envelope the waste solids in a material matrix could be applied before burrying the pit content.

Looking at it from regulation point of view, it can be said that pit management conducted by the oil and gas producing industry complies with the available regulation such as Kep.-04/Bapedal/09/1995. The waste in the pit has undergone such treatment in which the residual materials in the pit has a concentration of the contaminants that meets the acceptable concentrations 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 waste 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 guideline and the other that is stated in the Bapedal regulation (cf. Table 2). Moreover, other parameters that are included in the regulation and are not mentioned in the industry guideline have also to be considered.

Generally, oil and gas producing activity is located in a relatively remote area, in which the area is relatively far from public settlements. Future land use has been used by the industry for considering the risk determination. This risk determination can be devided into two general categories: unrestricted access and restricted access. Dependent on climate, geography/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.

When burial and/or pit closure is complete, the area should be graded to prevent water accumula-

tion, and revegetated with native species to reduce potential for erosion and promote full recovery of the area's ecosystem. It is observed that vegetation at the closed pit visited at the field seems not to grow normally (cf. Figure 4). The soil that cover the pit is obviously dry. This would be caused by the top soil covering the pit has changed due to chemical transformations that might occurs in the closed pit. Accordingly, post-closure care has also to be cosidered in the pit closure program to ensure it does not pose future threat to the environment. The post-closure program will consist of ground water monitoring and maintaining waste containment system.

V. CONCLUSIONS AND RECOMMENDATION

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 is 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. This guideline which is provided to field personnel should include advice on the responsible operation and closure of various types of pits.

Looking at it from regulation point of view, and from the references that has 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 examining 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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