STUDY OF HAZARDOUS WASTE TREATMENT AND MANAGEMENT FOR THE OIL AND GAS INDUSTRIES

by

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ABSTRACT

Study of hazardous waste treatment and management for the oil and gas industries has been conducted by Lemigas Team to observe the existing guidelines and the implementation of the guidelines in hazardous waste management. The study also includes a selection of the government regulation that should be considered in the hazardous waste treatment and management for the oil and gas industries.

Results of the study indicate that the oil industry does not conduct treatment processes for all hazardous wastes that are generated. Some of them, expecially those of non-specific hazardous wastes are stored in a temporary storage facility and managed off site for treatment or disposal to a commercial hazardous waste facility. The off-site waste management requires the use of a document termed a manifest for tracking its transport on a "cradle-to-grave" basis. The most prominent problem faced by the oil production industries, however, is the vast generation of wastes from production operation activities such as drilling mud, oil contaminated soil, and oil tank sludge and pit sludge. All of these wastes need to be handled properly.

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 hazardous waste management and the technologies that can be applied in mitigating the hazardous wastes generated by the oil and gas industries.

I. INTRODUCTION

Land disposal of untreated hazardous waste fell into disfavor following the promulgation of the Government Regulation (*Peraturan Pemerintah*) PP 19/1994 (Anonymous, 1994). This regulation envisaged an administrative system to track and to regulate hazardous wastes from the time of their generation to the time of disposal. Increased attention has therefore been paid by both industry and government to alternative hazardous waste treatment technologies to immobilize and/or destroy the wastes, either in situ for previously disposed wastes or at the waste generation site. This increased attention has led to the passage of Ministerial Decree No. 01/BAPEDAL/09/1995 through No. 05/ BAPEDAL/09/1995 (Anonymous, 1995) which are intended to encourage the development and adoption of hazardous waste treatment and destruction process that would eventually eliminate the need for land disposal of hazardous waste, except for the disposal of residues from treatment operations. Encouragement to the industries for managing the hazardous wastes by themselves has led to the revision of the Government Regulation PP 19/ 1994, which has now been replaced by the Government Regulation of PP 18/1999 jo PP 85/1999 (Anonymous, 1999a and Anonymous, 1999b).

Many exciting new technologies using physical, thermal, chemical, biological and combination of these means have been developed or are being developed for the treatment of hazardous wastes. Interest in these new technologies has produced a lot of literature and experiences in the hazardous waste treatment field relating to treatment methods, storage and disposal of wastes. The accumulated body of knowledge concerning waste treatment technology is rapidly growing. No systematic effort focusing on the application and relevance of these technologies to a specific industry, however, has yet been attempted. Though the market is fully filled with hundreds of new innovative treatment processes, industries have difficulties of approach to tackling hazardous wastes because little organized information is available to adequately assess the feasibility of using these technologies.

The current study is intended to gather more information about existing technologies for waste treatment, especially as they have been applied or can be made to apply to wastes that are especially problematic in the oil and gas production industry. In addition to the available processes that can be applied for treatment of the hazardous waste, the waste management itself should be developed. These would comprise the development of the manual guideline or standard operating procedure (SOP) that includes several aspects, such as collection, transportation, and storage. The study will focus on the possible solution on mitigating oil production wastes, which have been designated as hazardous under code number of D220 by PP 18/1999.

II. HAZARDOUS WASTE REGULATION IN INDONESIA

A. *Hazardous waste definition and classification*

The term hazardous waste by itself is ambiguous. A feature of any regulatory program is to provide a legal definition to determine what is and what is not a hazardous waste. The hazardous waste regulation in Indonesia was first promulgated in 1994 through PP No. 19/1994. The definition of hazardous waste in PP 19/1994 was revised and redefined in PP 18/1999. The hazardous waste in PP. 18/1999 (Anonymous, 1999a) is defined as: "*waste containing toxic and/or hazardous substances, which because of its properties and/or concentration and or quantity may directly or indirectly pollute and/or deteriorate the environment, and/or pose potential hazard to the environment, human health, sustainable human life or other life being*".

This definition of hazardous waste uses broad term to denote industrial by-products and waste materials discarded from homes, commercial establishment, and institutions that pose an unreasonable risk to human health and safety, property, and the environment. Hazardous waste can include solids, sludges, liquids, and containerized gases. It is important to note that hazardous waste excludes that which is discharged directly into the air or water; these wastes are regulated under air and water laws.

It can be seen that the form of a waste is not important when defining whether or not it is hazardous. The basis for determining that a waste is hazardous typically is either of the following three ways. First, it may be on a list of specific wastes compiled by the government because it is known or suspected of having the potential to exhibit hazardous characteristics. Second, laboratory tests may indicate that it exhibits one or more of the characteristics deemed to make a waste hazardous. Third, toxicological testing is supposed to determine acute and chronic properties of the waste.

Hazardous waste characterization

Any of the following characteristics will make a waste hazardous, i.e. being explosive, ignitable, reactive, toxic, infectious, corrosive, or radioactive. Ignitable wastes are liquids with a flashpoint below 60 °C, or solids capable of causing fire under standard temperature and pressure (25 °C, 760 mmHg). Ignitable wastes also include wastes that are ignitable in a high pressure and those of having oxidation properties. Corrosive wastes are aqueous wastes with a pH below 2 or above 12.5, or which corrode steel at a rate in excess of 6.35 mm per year. Reactive wastes are normally unstable, react violently with air or water, or form potentially explosive mixtures with water. The category of reactive waste also includes wastes that emit toxic fumes when mixed with water and materials capable detonation.

Among the four characteristics - reactivity, corrosivity, ignitability, and toxicity - of the hazardous waste, the potential for toxicity, particularly to humans, has caused the greatest public concern and has prompted the massive regulatory initiatives in hazardous waste management. The objective of this parameter is to determine whether toxic constituents in a solid waste sample will leach into ground water. If this is the case, then the waste will be declared hazardous. There are several methods of leaching test applicable for this purpose. PP 18/1999 mandates use of TCLP (Toxicity Characteristic Leaching Procedure) testing for determination of leachable organics and inorganics in the wastes. When the leachate solution of the waste contains any of the constituent and its concentration equals or exceeds the concentration limit as stated in the Attachment II of the regulation, then the waste is hazardous. If the concentration of the pollutant in the leachate solution is less than the concentration limit, however, the waste should undergo toxicological testing.

Toxicological testing of the waste is conducted through Lethal Dose Fifty (LD-50) determination. LD-50 is the dose, usually expressed as mg per kg body weight, at which only 50% of organisms remained alive. Although LD-50 is a measure for evaluating the toxicity characteristic of the wastes and it has been mandated in PP 18/1999, its implementation is impractical and still controversial. Figure 1 represents a simplified diagram

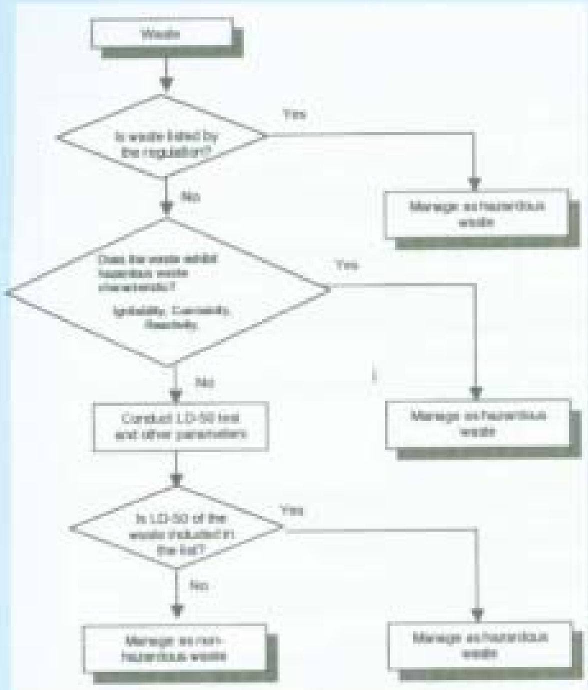

Figure 1
A simplified hazardous waste characterization diagram according to PP 18/1999

to characterization whether a waste is hazardous or non-hazardous.

B. *Hazardous waste management*

Hazardous waste management is a series of activities that includes reduction, collection, transportation, recycling, treatment, and storage of the hazardous wastes. Hazardous waste management is intended to prevent and control pollution and/or environmental damage due to hazardous wastes, and to remedial action for the deteriorated environment. Two principle prohibitions are regulated in PP 18/1999. First, any generator of hazardous wastes is prohibited to discharge the hazardous waste directly to the environment without prior treatment of the waste. Second, under no circumstances any series of hazardous waste management can dilute the hazardous waste in order to reduce either the concentration of toxic substances or the dangerous properties of the wastes.

After a waste is generated, the generator can either manage the waste on site or transport it off site for treatment, disposal, or recycling, typically to a commercial hazardous waste facility. Hazardous waste managed on the site where it is generated is termed on-site waste. Waste managed at a site other than where it is generated is termed off-site waste, and requires the use of document termed a manifest for tracking its transport on a "cradle-to-grave" basis.

Generators of hazardous waste may store temporarily hazardous waste for up to 90 days before transferring it to other activities of collection, reused, recovery, recycle, treatment, or dumping. When generation of hazardous wastes is less than 50 kilogram per day, generator may store the hazardous wastes for more than 90 days with a permit. The regulation issued under PP 18/1999 also requires that a generator of hazardous waste prepare a manifest system for tracking the waste and submit a semestral activity summary. Likewise generators, any collector, transporters, as well as any commercial unit that carries out reuse, recycle, recovery, treatment, and storage of hazardous waste has to prepare a manifest system and submit a semestral report to the government. Regulation concerning with the hazardous reduction, containers and labelling, temporarily storage, dumping, as well as recovery, reuse and recycle of hazardous wastes are issued under Ministerial Decree No. 04/BAPEDAL/09/1995.

III. HAZARDOUS WASTE GENERATED BY OIL AND GAS INDUSTRIES

Oil and gas production industries generally generate many different kind of wastes. These include both hazardous and non-hazardous wastes from Production, Drilling and Workover, Gas Plants, Laboratory and Medical, Industrial, and Community. In order to manage properly the hazardous wastes the oil industry establishes a manual guideline called "Waste Management Guideline"(Anonymous, 1998). The guideline is intended to serve as a guidebook for all unit and corporate employees as well as all of business partner in the safe and lawful handling and disposal of these wastes.

The objective of the guideline is to encourage employees and business partner to reduce the amount of waste generated and to decrease the toxicity of hazardous waste as the results of the operation. The guideline recommends not to waste any material being used, to use as much as possible non-hazardous material in order not to produce any hazardous waste, to avoid spill of hazardous material that will result in a hazardous waste, and to apply Pollution Prevention concept that includes source reduction, reuse/recycling/recovery, and responsible disposal concepts.

Table 1
Engineering classification system for hazardous waste

Major category	Characteristics	Examples
Inorganic aqueous wastes	Liquid waste composed primarily of water but containing acids/alkalis and/or concentrated solutions of inorganic hazardous substances (e.g., heavy metals, cyanide	- Spent sulfuric acid - Spent caustic baths - Washings of reactors and formulation tanks - Rinse water from pesticide containers - Etc.
Organic aqueous wastes	Liquid waste composed primarily of water but containing admixtures or dilute concentrations of organic hazardous substances (e.g., pesticides)	- Washings of reactors and formulation tanks - Rinse water from pesticide containers
Organic liquids	Liquid waste containing admixtures or concentrated solutions of organic hazardous substances	- Spent halogenated solvent - Distillation residues
Oils	Liquid wastes comprised primarily of petroleum-derived oils.	- Used lubricating oils - Used cutting oils
Inorganic sludges/solids	Sludges, dust, solids and other non-liquid waste containing inorganic hazardous substances	- Wastewater treatment sludge - Fly ash, bottom ash
Organic sludges/solids	Tars, sludges, solids and other non-liquid waste containing organic hazardous substances	- Sludges from Oil tanks - Slop oil emulsion solids - Soil contaminated with spilled solvent

The waste management guideline also covers general waste classification, waste management and disposal requirement, and waste manifesting. Beside the general consideration of hazardous waste classification, treatment and disposal, the guideline classifies and defines the specific wastes generated according to the sources. These are Production Waste, Drilling and Workover Waste, Gas Plants Waste, Laboratory and Medical Waste, and Community Waste.

Production Waste is a waste produced by Production Operation of Oil and Gas activities. While there are specific production wastes such as pit and tank bottom, the production operation activities also produce related wastes such as acid, battery, and rags. Drilling and Workover Waste is a waste produced by Drilling and Workover activities with specific wastes such as drilling mud, excess cement during cementing, radioactive tracer, bailing sand, and workover fuids. Gas Plant Waste is a waste produced by Gas Plant Operation such as glycol and pigging waste. Laboratory and Medical Waste is a waste produced by laboratory activities such as Acids, Caustics, solvents, Mercury, solid and medical waste, and Community Waste is a waste produced by Communities activities such as Clean Soil, garbage and food waste, office trash and paper, paint, pesticides and herbicides, thinner, water filter media, water treatment chemicals, etc. Not all of the wastes classified according to the source are hazardous. Some of them are non-hazardous, such as cement, glycol, office trash and paper, etc.

For engineering purposes, it is simply grouped the wastes having similar physical and chemical characteristics and general treatment requirements. Table 1 shows the basic classes of an expandable system used in several statewide studies to define the need for new hazardous waste treatment and disposal facilties (LaGrega, et al., 1994).

Upon examining and surveying to the oil industry (Mulyono, et al., 2001c) it is observed that not all of the hazardous wastes generated by the oil industry are managed and treated on site. Some of them are managed off site for treatment or disposal to a commercial haz

Table 2
Summary of technologies for treatment of hazardous waste commonly used in the petroleum industries

Treatment Method	Process Description
Thermal Treatment	
Liquid Injection Incineration	Liquid wastes are introduced into the primary chamber and burnt using vortex burner
Thermal Dehydration and Filtration	After screen filtration, liquids and low molecular weight hydrocarbons are removed by thermal distillation
Chemical Treatment	
Chemical Oxidation and reduction	Reaction in which the oxidation states of at least one reactant is raised, while that of another is lowered. A changed in oxidation state is the result of an electron transfer from the oxidized compound to the reduced compound.
Solvent treatment	After dehydration by flash distillation, solvents such as methyl ethyl ketone, supercritical ethane etc. is added to remove metals like lead from the wastes.
Dechlorination	Chlorine atoms presents in organic compounds like PCBs are stripped away by using metallic sodium reagent (naphthalene based compound)
Stabilization and Solidification	The solubility or mobility of the constituents is limited by adding substances to wastes, which produce a high-strength monolithic block. Setting and curing agents added to control the rate and extent of solidification
Physical Treatment	
Centrifugation	Centrifugal forces are used along with filters to separate liquids from solids and to separate liquids of different densities.
Decanting	Particles are allowed to settle in motionless tank. The clarified liquid is decanted from above the settled solids
Filtration	Pressures differences or gravity force the liquid through screen or cloth filters to remove fine solids from liquids. Chemical conditioning or heating filter medium is done to prevent clogging.
Thickening	The physical environment of the waste (e.g.: temperature) is altered to decrease solubility; the precipitant is coagulated using coagulants like alum, lime etc.
Ultrafiltration and Reverse Osmosis	Under a large hydrostatic pressure, the solvent passes through the membrane filter; the solute remains in the more concentrated solution. Reverse osmosis results in small sediments.
Distillation and Evaporation	Boiling of a mixture of liquids to extract a vapor of the lower boiling components
Biological Treatment	
Activated Sludge	Waste stream is fed continuously into an aerated tank where microorganisms metabolize the organics. The resulting microbial floc (activated sludge) settles from the aerated liquor under quiescent condition in a final clarifier.
Aerated Lagoons	Oxygen required for photosynthetic oxidation of organic wastes and degradation of wastes by bacteria is supplied through aeration units.
Aerobic Composting	Composting is the aerobic digestion of organic materials on land or within a structure (silo or digester); uses oxygen dependent organisms which can break down organic contaminants into carbon dioxide, water and lower molecular weight hydrocarbons

ardous waste facility. These wastes include crushed drums and containers, steam generator ash, insulation or refractory brick, mercury, pesticides and herbicides, radio active tracer, solvent or thinner, water and well treatment chemicals, asbestos, used battery, and used chemicals.

In order to manage the hazardous wastes off-site, the oil industry establishes a management guideline and build a temporarily storage facility. This temporarily storage facility is intended to receive wastes from all unit of operation and store the hazardous wastes temporarily not to exceed 90 days. The hazardous wastes are then transported to a commercial hazardous facility, and are accompanied with documents termed a manifest for tracking its transport on a "cradle-to-grave" basis.

IV. HAZARDOUS WASTE TREATMENT TECHNOLOGY

Waste treatment methods that can be used for treating hazardous wastes are commonly broken down into four major categories: (i) physical, (ii) thermal, (iii) chemical, and (iv) biological. Physical treatment involves the separation of solids from liquids. Thermal treatment depends essentially on the generation of heat. Chemical treatments exploit differences in chemical properties and generally involve one or more of chemical reactions such as neutralization, precipitation, hydrolysis, photolysis, and reduction-oxidation. In biological treatment, the contaminants are absorbed and usually decomposed by microorganisms (Burton and Ravishankar, 1989).

A wide range of technologies is available in each of these waste treatment categories. A summary of some of the treatment technologies commonly used for treating hazardous wastes generated by petroleum industries is presented in Table 2

A. *Oily sludge treatment through thermal process*

Oily sludge treatment through thermal process becomes very popular since it reduces significantly the amount of waste. The wastes are transformed through thermal process to produce less toxic substances and more importantly to valuable materials such as "syngas". Two typical thermal processes are often used in hazardous waste treatments. These are incineration and gasification. It is worth to note that gasification differs considerably from incineration that has been used for destroying hazardous pollutants. Both gasification and incineration are capable of converting hydrocarbon-based hazardous materials to simple, non-hazardous byproducts. However, the conversion mechanisms and the nature of the byproducts differ considerably, and these factors should justify the separate treatment of these two technologies in the context of environmental protection and economics. Modern, high temperature slagging gasification technologies offer an alternative process for the recovery and recycling of low-value materials by producing a more valuable commodity, syngas. The multiple uses of syngas (power production, chemicals, methanol, etc.) and the availability of gas clean up technologies common to the petroleum industry make gasification of secondary oil-bearing materials a valuable process in the extraction of products from petroleum.

Gasification is a technology that has been widely used in commercial applications for more than 50 years in the production of fuels and chemicals. Current trends in the chemical manufacturing and petroleum industries indicate that use of gasification facilities to produce synthesis gas ("syngas") will continue to increase. Attractive features of the technology include: (1) the ability to produce a consistent, high-quality syngas product that can be used for energy production or as a building block for other chemical manufacturing processes; and (2) the ability to accommodate a wide variety of gaseous, liquid, and solid feedstocks. Conventional fuels such as coal and oil, as well as low- or negative-value materials and wastes such as petroleum coke, heavy refinery residuals, secondary oil-bearing refinery materials, municipal sewage sludge, hydrocarbon contaminated soils, and chlorinated hydrocarbon byproducts have all been used successfully in gasification operations (Ref. Texaco).

Waste gasification is an innovative extension of conventional fuels gasification technology that reacts carbonaceous materials with a limited amount of oxygen (partial oxidation) at high temperatures. Hazardous waste gasification offers an environmentally attractive alternative to other thermal and stabilization technologies. The gasification process destroys any hydrocarbons in the feed and effectively recycles the waste by transforming it into clean gas for use as fuel for power generation or an intermediate product for the manufacture of transportation fuels, fertilizers, or chemicals. The residual mineral matter solidifies into small pieces of glassy slag. Extensive testing on the gasification wastes has shown that the aqueous effluent streams are free of priority pollutants and acceptable for discharge after pretreatment by conventional wastewater technology. None of the effluent streams contained measurable concentrations of dioxins or furans. Given its ability to deal with a variety of feedstocks, destroy organic compounds, produce a useful synthesis gas, and solidify inorganic compounds into potentially inert glassy slag, waste gasification offers an effective treatment alternative for hazardous wastes.

Incinerators typically operate at atmospheric pressure and temperatures at which the mineral matter or ash in the waste is not completely fused (as slag) during the incineration processes. Ash solids will either exit the bottom end of the combustion chambers as bottom ash or as particulate matter entrained in the combustion flue gas stream. Combustion gases from hazardous waste incineration systems are typically processed in a series of treatment operations to remove entrained particulate matter, heavy metals, and acid gases such as HCl and other inorganic acid halides. Systems that process low ash or low halogen content liquid wastes may not require any downstream process controls. However, one of the more common gas cleanup configurations used at waste incineration facilities is a gas quench (gas cooling), followed by a venturi scrubber (particulate removal) and a packed tower absorber (acid gas removal). Wet electrostatic precipitators and ionizing wet scrubbers are used at some facilities for combined particulate and acid gas removal. Fabric filter systems are also used for par ticulate removal in some applications. Demisters are often used to treat the combustion gases before they are discharged to the atmosphere to reduce the visible vapor plume at the stack. These clean up systems typically operate at atmospheric pressure and must process a large volume of flue gas produced as a result of the large excess air requirements of incineration systems.

B. *Oily sludge treatment through solidification process*

Stabilization and solidification are a proven technology for treatment of hazardous wastes and hazardous waste site. Technical reasons for the selection of stabilization and solidification as a remediation technology include: (i) it improves the handling and physical characteristic of wastes: e.g., sludge are processed into solids, (ii) it reduces transfer or loss of contained pollutants by decreasing the surface area, (iii) it reduces pollutant solubility in the treated waste, generally by chemical changes, (iv) technologies for processing sludge are well established, and (v) residues from the treatment of hazardous waste by physical, chemical, biological, or incineration technologies can be further treated by stabilization/solidification method.

Thus stabilization and solidification has considerable technical merit. Basically, stabilization and solidification technologies can be grouped as *inorganic* stabilization/ solidification, which is then divided into cement-based and pozzolanic stabilization/solidification, and *organic* stabilization/solidification, which is then divided into thermoplastic and organic polymerization stabilization/solidification.

Cement-based stabilization/solidification is a process in which waste materials are mixed with portland cement. Small amounts of fly ash, sodium silicate, bentonite, or proprietary additives are often added to the cement to enhance processing.

Pozzolanic stabilization/solidification involves siliceous and aluminosilicate materials, which do not display cementing action alone, but form cementitious substances when combined with lime or cement and water at ambient temperatures. The primary containment mechanism is the physical entrapment of the contaminant in the pozzolan matrix. Examples of common pozzolans are fly ash, pumice, lime kiln dust, and blast furnace slag.

Organic polymerization stabilization/solidification relies on polymer formation to immobilize the constituents of concern. Urea formaldehyde is the most commonly used organic polymer for this purpose.

Lemigas has conducted a laboratory study concerning with the treatment of oily sludge. Upon investigating the available treatment methods through literature search, it has been found that stabilization/solidification process treatment seems to be a suitable method for treating the oily sludge. The consideration of using stabilization and solidification method for sludge processing is based on a fact that, beside the technology itself is well proven, the product resulted from the treatment process is used as paving or patching material for road (Cote, 1989; Barth, et.al., 1990). Thus, in addition to the environmental consideration, economic considerations are also included in the study (Mulyono, et .al., 2000a; Mulyono, et al., 2000b; Mulyono, et al., 2001a, Mulyono, et al., 2001b).

Stabilization/solidification process used for field application in the study is the immobilization technique called CHAMP (Combine Heat and Mixing Process). Basically the CHAMP uses a thermal mixing in which sludge and Asbuton (an asphalt material generated from Buton Island) are mixed for approximately 30 minutes. Water is evaporated and the asphalt binds the remaining residues. In some cases, kerosene is added to facilitate a homogenous mixture. After having been bound by the asphalt, the mixtures are then mixed with aggregates. The product is tested for Marshall Tests which is described in the ASTM Method D1559-89 and for TCLP and LC-50.

LC-50 values of sludge samples are 350,000 ppm and 460,000 ppm to the test species of *Shrimps* and *Daphnia*, respectively. These LC-50 values are categorized as practically non-toxic. The value of LC-50's of those of sludge-asphalt mixture as solidified products are more than 1,000,000 ppm for both products resulted from hot-mixed and cold-mixed processes. As with the value of LC-50 of the sludge sample, these values of the solidified products can also be categorized as practically non-toxic.

Parallel with the LC-50 tests, TCLP tests have also been conducted both to the sludge sample and the sludge-asphalt mixture. Results of the TCLP testings indicate that the sludge sample does not contain heavy metals in a significant amount. Arsenic and Mercury are not detected. Very small concentrations of heavy metals in the leachate solution are also shown by the sludge-asphalt mixtures as solidified products. In comparison with the maximum allowable concentration of heavy metals in the leachate solution as stated in the Appendix II of PP

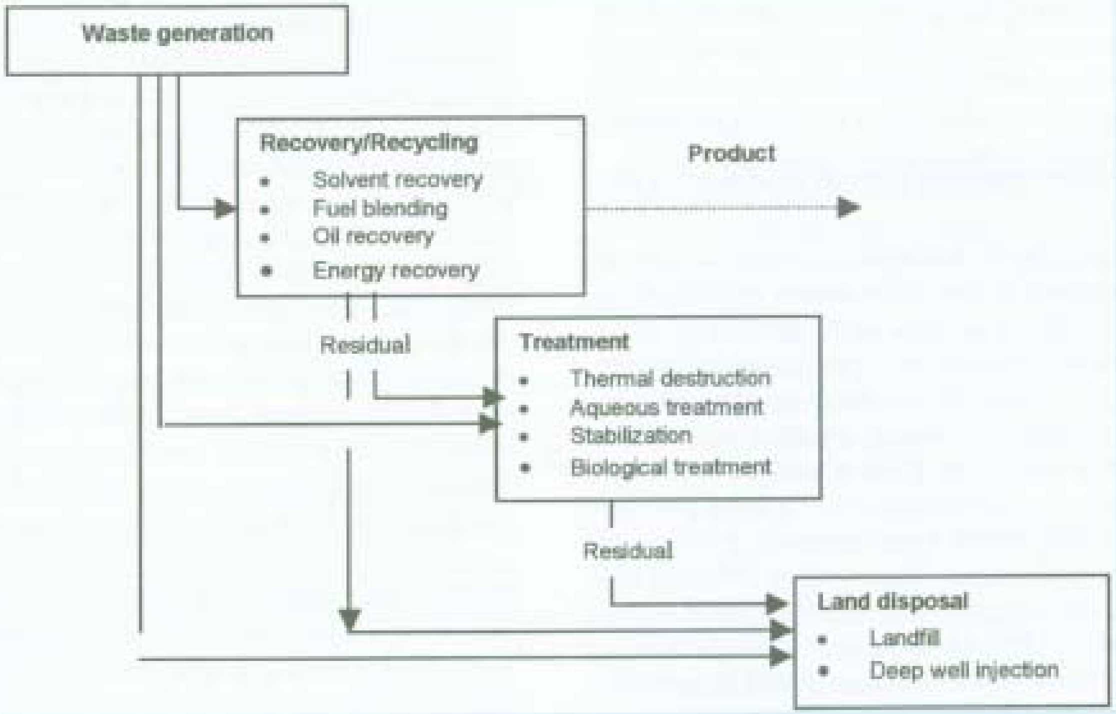

Figure 2
Hazardous waste recovery, treatment and disposal facilities

18/1999, it is concluded that both the sludge sample and the solidified products are environmentally safe to be applied in the field.

As the technologically implied, thermoplastic stabilization and solidification method for treatment of oily sludge used in the study was incorporated with the need of road building. Comparison of the cost effectiveness was performed to those of road buildings that use ordinary road building technology with common asphalt as the aggregate binder. Based on the unit price per m^2, the developed structure used in the study has a lower cost than the conventional structure using common asphalt.

V. DISCUSSIONS

A. *On-site hazardous waste treatment and guidebook*

Oil industries generates many kinds of hazardous wastes ranging from those that are generated in a relatively small quantity, which are categorized as non-specific hazardous wastes such as batteries and used chemicals to those that are generated in larger quantity, which are categorized as specific hazardous wastes such as tank bottom sludge. In order to minimize the risk in handling all of the hazardous wastes, the oil industry establishes a manual guideline entitled "Waste Management Guideline". This guidebook is very useful and helpful for all of the unit and the corporate employees as well as all of business partner in the safe and lawful handling and disposal of these wastes.

The oil industry does not conduct treatment processes for all hazardous wastes that are generated. Some of them, especially those of non-specific hazardous wastes such as battery and used chemicals, are stored in a temporary storage facility and managed off site for treatment or disposal to a commercial hazardous waste facility.

The off-site waste management requires the use of a document termed a manifest for tracking its transport on a "cradle-to-grave" basis. However, although this off-site management complies with the regulation, under the cradle-to-grave concept, oil industry as a generator of hazardous waste can no longer avoid liability by contracting with a third party to dispose of the waste. Even if it can be shown that the waste was mishandled through the action of this commercial hazardous waste facility, oil industry as the original generator will remain liable for improper disposal. It is not specifically described in detail in the regulation, but it is suggested that a witness from a competence agency shall accompany the transport of the waste and investigate the proper handling and treatment of the waste that are handled by the commercial hazardous waste facility. For off-site waste management purposes oil industry builds a storage building for the temporary hazardous waste storage that receives the hazardous wastes from all units of operation.

B. *On-site hazardous waste treatment*

The most prominent problem faced by the oil production industries is the vast generation of wastes from production operation activities. Examples of these waste are drilling mud, oil contaminated soil, and oil tank sludge and pit sludge. On-site treatment of hazardous waste especially for the wastes that are generated in a vast quantity is considered more economical rather than transport it to off-site facility.

Moreover, the cost will be much higher when the commercial hazardous waste is located far from the generator. When the vast quantity of the waste has to be transported by ship, followed by trucks to reach the commercial hazardous facility, this would be an impractical work. Regarding that oil industry is considered as a big company, it is encouraged to oil industries that they develop an on-site hazardous facility. A facility means the contiguous land, structures, and other improvements and appurtenances used for storing, recovering, recycling, treating, and disposing of hazardous waste.

The concept of a facility dedicated to the management of hazardous waste is not new. In USA many generators recognize the need for special treatment and disposal of these wastes. Many generators construct and operate their own captive facilities referred to as on-site facilities. The predominant types of facilities, other than storage facilities, are depicted in Figure 2 that cover three major categories: Recovery/recycling Facilities, Treatment Facilities, and Land Disposal Facilities.

Recovery/recycling facilities recover material as a salable product, some recover energy values in waste. Treatment facilities change the physical or chemical characteristics of a waste, or degrade or destroy waste constituents, using any of a wide variety of physical, chemical, thermal, or biological methods. While land disposal facilities are permanent emplacement of waste on or below land surface.

Just as there are many types of hazardous waste, there are many ways in which hazardous wastes can be managed. In fact, there are many commercially proven technologies for the recovery and treatment of hazardous waste. A hazardous waste facility may function with just one technology, or it may combine multiple technologies. Study regarding with the application of these technologies that suitable for a particular purpose is necessary. The study is not only useful for economical consideration, but also for modification purposes when the chosen technology does not completely meet the requirement.

VI. CONCLUSIONS AND RECOMMENDATIONS

A. *Conclusions*

1. As a big company an oil production industry generates many kinds of hazardous wastes ranging from those that are generated in a relatively small quantity, which are categorized as non-specific hazardous wastes to those that are generated in larger quantity, which are categorized as specific hazardous wastes such as tank bottom sludge.
2. Oil industry does not conduct treatment processes for all hazardous wastes that are generated. Some of them, especially those of non-specific hazardous wastes are stored in a temporary storage facility and managed off site for treatment or disposal to a commercial hazardous waste facility. The off-site waste management requires the use of a document termed a manifest for tracking its transport on a "cradle-to-grave" basis. Under the cradle-to-grave concept, however, oil industry as a generator of hazardous waste can no longer avoid liability by contracting with a third party to dispose of the waste.
3. The most prominent problem faced by the oil production industries is the vast generation of wastes from production operation activities. Examples of these waste are drilling mud, oil contaminated soil, and oil tank sludge and pit sludge. All of these wastes need to be handled properly.

B. *Recommendations*

1. It is recommended that oil industries encourage themselves to manage and treat the hazardous wastes. On-site treatment of hazardous waste especially for the wastes that are generated in a vast quantity is considered more economical rather than transport it to off-site facility. Moreover, the cost will be much higher when the commercial hazardous waste is located far from the generator, it is encouraged to oil industries that they develop an on-site hazardous facility that includes the contiguous land, structures, and other improvements and appurtenances used for storing, recovering, recycling, treating, and disposing of hazardous wastes.
2. Waste treatment technology that can be chosen depends on the demands of the industry. When incorporated with road building project within the petroleum fields, the stabilization/solidification process seems to be adequate. Thermal techniques through gasification process can be associated with the need of converting wastes to energies and other valuable and salable products.

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