April 2021

Reduction of UPOPs emissions by improving waste management practices at landfills

Management of waste oil and oil contaminated wastes

Resources & Waste Advisory Group[SCE]

Reference number: BCRC#5558_2019_002

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PROJECT NO.	CLIENT.
BCRC# 5558_2019_002	BCRC

VERSION	DATE OF ISSUE	DESCRIPTION	PREPARED	CHECKED	APPROVED
Final	23 April 2021	Waste oil management	DG	BM	BM

Contents

List of Acronyms

BAT	Best Available Technique
BCRC-Caribbean	Basel Convention Regional Centre for Training and Technology Transfer for the Caribbean
BM	Brian McCarthy (Team Leader)
DG	Diana Gheorghiu (Deputy Team Leader)
PAHs	Polyaromatic Hydrocarbons
PCBs	Polychloride biphenyls
POPs	Persistent Organic Pollutants
RWA	Resources and Waste Advisory
UPOPs	Unintentionally produced Persistent Organic Pollutants
VOCs	Volatile Organic Compounds

1 Introduction

Oil contaminated waste can occur throughout all oil-related operations: from extraction, transport, refining, storage, processing, use, reuse, to disposal, etc. Waste oils and oil contaminated waste constitute a significant source of pollution and often a problematic waste stream. When landfilled, due to their flammability and combustion characteristics, such wastes can lead to increased frequency and magnitude of landfill fires. This is one of the main reasons why waste oils contribute to the POPs/UPOPs generation from landfills. Even when not ignited, waste oils and oil contaminated wastes have a high potential to contaminate the environment when unsoundly managed.

The present report aims to present possible solutions for the management of waste oils and oily wastes, providing information on currently available treatment techniques, their applicability and limitations.

This report is not meant to be exhaustive or provide the only basis for the decision on a technology to be applied, as it is not based on actual quantities, compositions and content of waste. In addition, local conditions and enabling factors (or lack thereof) may affect the applicability of the presented solutions, thus further research and analysis are likely necessary.

The report is elaborated based on 'Basel Convention Technical Guidelines on waste oils from petroleum origins and Sources'[1], 'Basel Convention Technical Guidelines on used oil re-refining or other re-uses of previously used oil'[2], 'Best Available Techniques (BAT) Reference Document for the refining of mineral oil and Gas'[3], BAT Reference document for waste treatment[4], as well as other relevant publications and applicable technology specifications.

Note: Polychlorinated biphenyls (PCBs) and PCB and other POPs contaminated oils are not the focus of the current report. Environmentally sound management measures for these types of wastes are described in the respective Basel Convention Technical Guidelines[5].

[1] http://synergies.pops.int/Portals/4/download.aspx?d=UNEP-CHW-WAST-GUID-WasteOilsPetroleum.English.pdf

[2] http://synergies.pops.int/Portals/4/download.aspx?d=UNEP-CHW-WAST-GUID-RefiningReusesUsedOil.English.pdf

[3] http://publications.jrc.ec.europa.eu/repository/bitstream/JRC94879/ref_bref_2015.pdf

[4] https://eippcb.jrc.ec.europa.eu/sites/default/files/2019-11/JRC113018_WT_Bref.pdf

[5] Technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with polychlorinated biphenyls, polychlorinated terphenyls, polychlorinated naphthalenes or polybrominated biphenyls including hexabromobiphenyl (PCBs, PCTs, PCNs or PBBs, including HBB). http://www.basel.int/Portals/4/download.aspx?d=UNEP-CHW.13-6-Add.4-Rev.1.English.pdf

General technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with persistent organic pollutants (General POPs) http://www.basel.int/Portals/4/download.aspx?d=UNEP-CHW.14-7-Add.1-Rev.1.English.pdf

Technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with hexabromodiphenyl ether and heptabromodiphenyl ether, or tetrabromodiphenyl ether and pentabromodiphenyl ether (POP-PBDEs) http://www.basel.int/Portals/4/download.aspx?d=UNEP-CHW.12-5-Add.6-Rev.1.English.pdf

Technical guidelines on the environmentally sound management of wastes containing or contaminated with unintentionally produced polychlorinated dibenzo-p-dioxins, polychlorinated dibenzofurans, hexachlorobenzene, polychlorinated biphenyls, pentachlorobenzene or polychlorinated naphthalenes (Unintentionally produced POPs). http://www.basel.int/Portals/4/download.aspx?d=UNEP-CHW.13-6-Add.5-Rev.1.English.pdf

2 Sources of waste oil and oil contaminated waste

In the context of this report used oil means any semi-solid or liquid used product consisting totally or partially of mineral oil or synthesised hydrocarbons (synthetic oils), oily residues from tanks, oil-water mixtures and emulsions. These arising from industrial and non-industrial sources where they have been used for lubricating, hydraulic, heat transfer, electrical insulating (dielectric) or other purposes and whose original characteristics have changed during use thereby rendering them unsuitable for further use for the purpose for which they were originally intended.

Figure 1 presents common uses for oil-derived products containing mineral or synthetic oils and the common purposes they are used for. Used oils and oil contaminated waste may result from such uses, as well as associated operations, in an industrial or non-industrial setting.

Oil containing products and common use

- Fuels
- Lubricants
- Hydraulic and transmission fluids
- Heat transfer fluids
- Insulants
- Other

Figure 1 Typical oil derived and containing products and some of the common uses

As per their many uses, each oil type has its own specification, usually based upon the hydrocarbons occurring within a specific boiling point range from the distillation of crude oil. Oils that need to be stable at high temperatures will not include large quantities of low boiling point hydrocarbons whereas oils used as fuel are more likely to include these lower boiling point hydrocarbon mixtures.

Before marketing, most base oils produced in mineral oil refineries are blended with a variety of additives to give them the required properties. Typical additive packages comprise between 5 % and 25 % of the base oil. However, probably at least half of the additive package is base oil used as solvent. Lubricating oils contain large numbers of additives, but the actual formulae are in most cases trade secrets. Data on the components and additives in new oils are given in the Safety Data Sheet which accompanies fresh products as supplied; however, precise details of the formulations are company property. Hydraulic oils contain very few additives.

The most common types of additives used in oils include a series of compounds, each with specific roles: anti-corrosion, anti-foam, antioxidants, anti-wear, detergents, dispersants, viscosity modifiers, etc.

Used oil primarily contains hydrocarbons but it may also contain initial or later-added additives, impurities collected along the use cycle through physical contamination or chemical reactions, or contamination that occurred through the mixing of waste oil with other fluids or liquid wastes. During use, the composition of the oil will change markedly, due to the breakdown of the additives, the formation of additional products of combustion and unburnt fuels, the addition of metals from wear and tear on the engine and the breakdown of the base oil itself.

Common sources of waste oil and oil contaminated wastes include:

- Tank bottom sludge from storage of oil and oil-based products

- Residues from oil/fuel or lubricating fluids purification
- Separated waste from oil and fuel filtering equipment
- Waste hydraulic and lubricating oils
- Waste oil collected in drip trays
- Absorbent materials contaminated with oils
- Contaminated fluids from installations and storage vessels cleaning operations
- Oily bilge and ballast water from ships

Several treatment/disposal options may be applied for the management of waste oil and oil contaminated wastes, depending on the type of waste, the source, the composition, the final purpose as well as local conditions and enabling/restricting factors.

Depending on the size and capacity of treatment facilities, these may screen the incoming waste for flashpoint, metal and chlorine levels; smaller sites will typically just accept the oil waste. There is a distinct shortage of analytical data for incoming wastes, although documented screening activities of a few sites in Europe show that industry anticipates high metal levels and contamination by flammable solvents, giving a measurable flashpoint.

Used oils collected by high-volume users can be more tightly controlled and may hence be more consistent in composition.

The present report will be focusing mostly on management options for waste oil and oil sludges, as these types of waste are most prevalent and are usually generated in larger quantities than, for example, oil-contaminated absorbent materials from small generators. Nevertheless, when unsoundly managed, such as mixing with municipal solid waste (see Figure 2 below), even low quantities of these oil-contaminated absorbent materials can cause problems in the landfill. As such, source separation of oil-contaminated waste is a mandatory practice for all generating entities.

Figure 2 Oil contaminated absorbent materials mixed with municipal solid waste

3 Options for management of waste oils and oil contaminated waste

As in the case of other types of waste, when it comes to the management of waste oil and oil contaminated waste, following the Waste hierarchy takes prevalence, as shown in Figure 3 below. Preventing and reducing the generation of waste oils and oil contaminated waste should always be the goal, followed by looking for less hazardous alternatives for use.

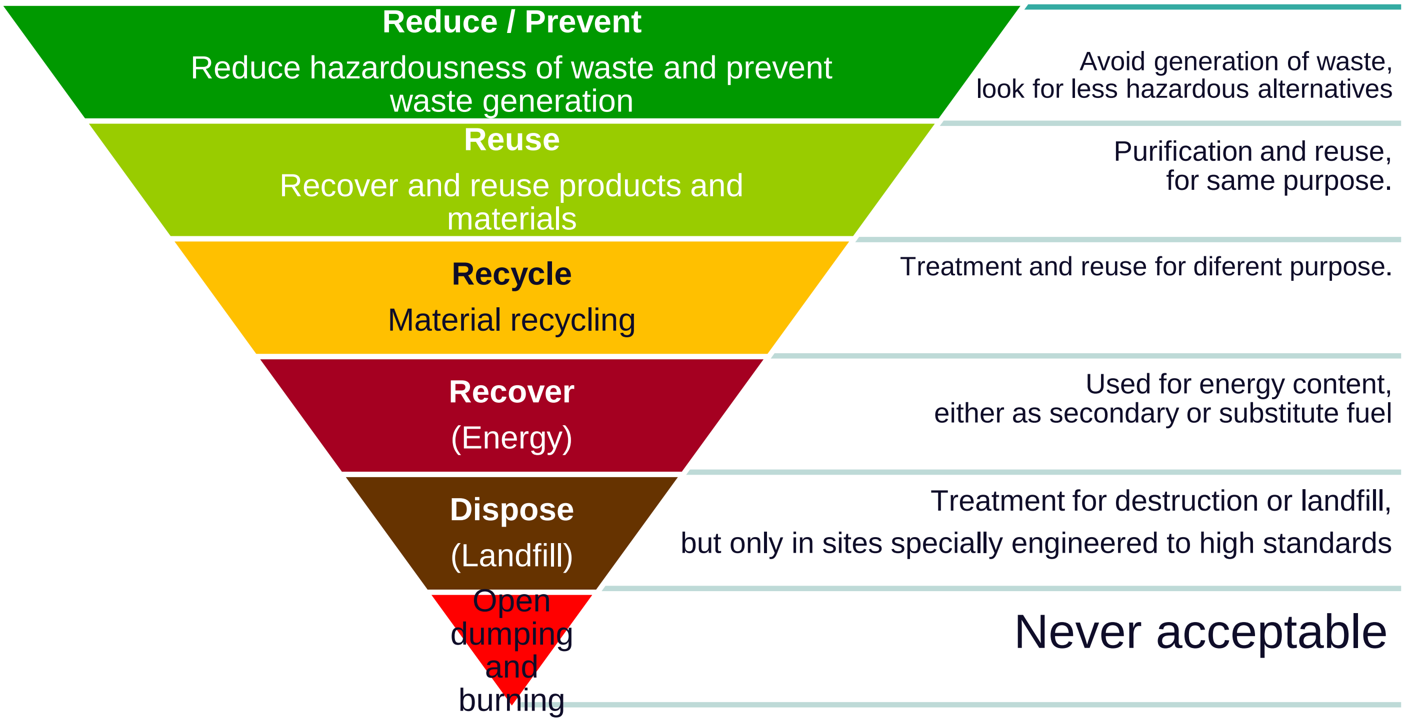

Figure 3 The waste management hierarchy

3.1 Waste avoidance and minimization

Waste generation can be avoided or minimised by improving the efficiency, design and performance of installations, or by planning preventive maintenance.

Improved efficiency and practices in all areas in which oils are used should lead to significant reductions in waste generation. Improvements in the design and performance of engines result in reduced oil change frequencies, and hence a reduction in the generation of waste from these sources.

Preventive maintenance of installations and machinery is a good practice to avoid leaks and spills of oil-based fluids, prolong the optimally operating service life of machinery and avoid contamination of waste oils resulting from normal operations.

3.2 Reuse

Installations and operational procedures can be optimized to minimize the quantities of waste produced, such as using oil/water separation and recycling/reuse of water. Oil/water mixtures and in emulsion form, such as metal cutting oils and emulsions, also can be reused to some extent, thus reducing quantities requiring disposal.

Settlement and filtration of the used material and removal of the abrasive material usually allow reuse many times over.

3.3 Recycling and recovery (treatment) of waste oils

There are two main options for the treatment of waste oils:

- The recovery of waste oil to be used as a fuel or reductant. This includes treatments such as thermal cracking and gasification, but also milder treatments of waste oils
- The treatment of waste oil to reconvert it into a material that can be reused or used as a base oil to produce lubricants. This is often referred to as 're-refining'.

The purpose of waste oil treatment is to reuse the waste oil or to convert it to base oil to produce a lubricant. It requires cleaning operations (i.e. laundering or reclamation) or re-refining to obtain a suitable resulting product.

Table 1 below presents the most significant treatment processed for waste oil and the main products obtained, adapted from the Best Available Techniques Reference Document for Waste Treatment (2018)[4]. The technical and economic feasibility of application of any of these treatment options would need to be further researched on a case by case basis.

Table 1 Waste oil treatment options and products obtained

Waste oil input	Type of treatment	Treatment process	Products obtained
Waste oil for re-refining			
Clean waste oil, especially hydraulic or cutting oil	Re-use	Laundering	Hydraulic or cutting oil - Electricity companies - Shipping industry - Major engineering companies
		Reclamation	Mould release oil or base oil for the production of chainsaw oil
Engine waste oil + clean waste oil - Engine oils without chlorine - Hydraulic oils without chlorine - Hydraulic mineral oils - Mineral diathermic oils	Re-refining	Pre-treatment Cleaning Fractioning Finishing	Lubricant base oil (quality depends on treatment)
Waste oil as fuel			
All types of waste oil, including synthetic oils	Thermal cracking	Spring oil conversion process	Distillate gasoil products - Gasoil (also called heating oil, diesel oil, furnace oil, etc.) - De-metallised heavy fuel oil - Marine gasoil (MGO) - Re-refined light base oil
		Great Northern Inc. processing process	
		other	
Mixed wastes	Gasification		Synthetic gas - Hydrogen - Methanol
All types of waste oils, especially heavy polluted ones	Severe processing	Chemical processes (with no finishing steps) - Acid/clay - Solvent extraction - Propane extraction - other	De-metallised heavy fuel oil or heavy distillate - marine diesel oil (MDO) - fuel for heating plants
		Thermal processes, including distillation - various techniques	
	Mild processing, then burning		Replacement fuel oil (RFC; treated oil still containing heavy metals, halogen and sulphur contained in the original waste oil) - road stone plants - cement kilns (substitutes other secondary liquid fuel or heavy fuel, coal, or petroleum coke) - large marine engines - pulverised coal power stations (as furnace start-up fuel)

The processes start with pre-treatment and cleaning, which involve the removal of impurities, defects, and any leftover products from the waste oil's former use. Reuse treatment usually involves only these two steps, but some substances may be added to the cleaned waste oil subsequently, to attain the specifications of a virgin product.

The re-refining process involves additional steps of fractionation and finishing, which use similar techniques and unit operations to refineries and chemical (e.g. olefins) processing.

Re-refining treatments may differ depending on the technology used for one or several of the following operations: pre-treatment, cleaning, fractionation and finishing. Each of these operations is briefly described below.

3.3.1 Pre-treatment of waste oil

This operation entails a simple physical/mechanical treatment to remove water and sediments from the waste oil. Settling is used in some cases to remove water and sludge from waste oil and in the effluent treatment systems for removing oil and solids from the effluent. Generally, settling takes place gravitationally in settling tanks, clarifiers or plate separators, but centrifuges or distillation can also be used.

This pre-treatment process does not yield an end product, nor does it achieve the final aim of the treatment, it is an initial step needed for subsequent treatment options.

3.3.2 Cleaning of waste oil

Cleaning includes de-asphalting and the removal of asphaltic residues: heavy metals, polymers, additives, and other degradation compounds. This is mostly done by distillation, solvent extraction and addition of acids.

Acid cleaning consists of additives, polymers, and oxidation and degradation products being removed by contact with sulphuric acid or precipitated as sulphates (e.g. metals). Clarified oil can also be mixed with clay to remove by absorption any polar and undesirable compounds still present.

3.3.3 Fractionation of waste oil

This involves the separation of the base oils using their different boiling temperatures, to produce two or three cuts (distillation fractions). Vacuum distillation units can range in complexity from a simple splitting column to a full fractional distillation column, as used in mineral oil refineries.

3.3.4 Finishing of waste oil

This is mainly the final cleaning of the different cuts (distillation fractions) to achieve specific product specifications (e.g. improve colour, smell, thermal and oxidation stability, viscosity).

Finishing techniques include alkali treatment, use of bleaching earth, clay polishing, hydro-treatment and solvent cleaning. Each of these techniques has different purposes for use as well as limitations. For example, severe hydro-finishing (high temperature and high pressure) or solvent extraction (low temperature and low pressure) may be used for the removal of polyaromatic hydrocarbons (PAHs).

3.3.5 Waste oil use and oil contaminated waste used as substitution fuel

The use of waste oil as a substitution fuel without any treatment is one option that is used across several parts of the world, varying in popularity depending on local economic and legislative circumstances. In Europe for example, most national regulations allow the burning of waste oil in cement kilns, with various level of restriction/imposed conditions.

In addition to waste oil, other oil-contaminated wastes with calorific value can be used as substitution/secondary fuel. These apply to oil sludges or oil contaminated absorbent materials, or even oil contaminate municipal solid waste. The preparation of different types of waste fuel needs to consider the technical characteristics of the combustion plant/process using it (e.g. cement plant, lime plant, power plant (hard coal, lignite), specialised waste fuel combustion). These combustion processes have different technical characteristics.

Depending on the state (pasty, powder, solid) and composition of these oil contaminated waste (hazardous/non-hazardous), as well as the form of presentation of the derived secondary fuel (solid or liquid) these will need to undergo different processing techniques to be suitable for use as fuel. These operations may include:

- For solid outputs: drying, pelletising and agglomeration, shredding, homogenisation, impregnation, etc.
- For liquid outputs: physical processes involving a combination of homogenization, phase separation and mixing/blending steps; fluidification processes or emulsification processes.

3.4 Disposal options for waste oils and oil contaminated wastes

3.4.1 Incineration

Incineration, ideally with energy recovery, provides a preferred final disposal option for oil wastes - solid, liquid and sludge - which cannot for technical or commercial reasons be recovered. In the case of waste oils containing levels of PCBs above a defined level, and which do not merit application of clean-up technologies, incineration is the preferred and recommended form of final disposal[5]. Whilst many oil products are burnt without the application of clean-up technologies to combustion gases, this may well not be acceptable for oil wastes. Such wastes may contain heavy metals, chlorine or sulphur-based contaminants, or particulate matter which would not easily burn. Incineration of such materials is likely to require emission control/gas cleaning equipment to achieve environmentally sound emission standards.

Chapter 3.6 below mentions examples of common pollution abatement technologies. Different types of thermal treatments are applied for different types of waste. Most common technologies include grate incinerators, rotary kilns, fluidised bed incinerators or pyrolysis and gasification systems. Details on specific techniques and emission value ranges for incineration of waste are detailed in the Best Available Techniques Reference Document for Waste Incineration, published in December 2019[6].

3.4.2 Landfilling

Landfill sites, even when specially engineered to high standards, and with advanced controls on leachate, gas generation must be carefully evaluated by the national authority for their suitability for the disposal of oily wastes in bulk. Landfill may however be appropriate for some thick, semi-solid or solid sludges, tarry residues, tank and cleaning scale, particularly if subjected to a solidification process.

In case of minimal quantities of oily waste in small containers, such as the ones present in household-generated wastes, these could be disposed of in the landfill. In some cases, such as in containment sites and depending on site characteristics and absorptive and biodegradable potential, landfilling may be acceptable for highly aqueous oil containing wastes.

In all cases, great care is needed and landfill licenses and permits may be needed to ensure that such activities can be undertaken without harm to the population and the environment.

3.5 Particular case: management of petroleum sludges

Petroleum sludges are a common product in the oil and gas industry, creating major challenges in recent years.

The remains found at the base of the tank and other storage facilities are generally referred to as sludge. For crude oil storage vessels, this kind of sludge found at its base is comprised of hydrocarbons, asphaltenes, paraffin, water, and inorganic solids such as sand, iron sulphides and iron oxides. Crude oily sludge is a recurrent problem leading to corrosive effects and a reduction in oil storing capacity. Oil sludge is considered hazardous waste and entails great expenses in sound treatment and disposal.

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[6] https://eippcb.jrc.ec.europa.eu/sites/default/files/2020-01/JRC118637_WI_Bref_2019_published_0.pdf

An assortment of methods for processing and disposing of petroleum sludge is used globally, including thermal, mechanical, biological, and chemical. Altogether, these are not economically sustainable. In summation to the cost of removing, transferring, and landfilling involved in cleaning up the petroleum sludge, the sludge also contains several hazardous contaminants. These contaminants can include besides high fractions of petroleum hydrocarbons, also polychlorinated biphenyls and heavy metals.

In addition to significantly affecting soil quality and groundwater for long periods of time, improper disposal of petroleum sludge can have adverse health consequences, as petroleum hydrocarbons and polyaromatic hydrocarbons are genotoxic to humans and animals.

The most common treatment methods fall within three main categories, as per their purpose:

- Reduction of petroleum sludge production through the use of technologies
- Oil recovery from the petroleum sludge
- Disposal of unrecoverable waste.

A succinct presentation and review of the existing sludge management options are presented in Table 2 below[7]. As discussed in the referenced article, some methods are very good in oil recovery but are associated with a high cost of operation and their application at a large scale may be limited. Other methods, such as landfarming are simple in application with low operational cost, but remediation will take on average 2 years to achieve a complete treatment.

[7] Olufemi Adebayo Johnson, Augustine Chioma Affam, 'Petroleum sludge treatment and disposal: A review', Environmental Engineering Research 2019; 24(2): 191-201., DOI: https://doi.org/10.4491/eer.2018.134

Table 2 Comparison of treatment and disposal methods for oily sludge[7]

Treatment method	Application level	Average oil recovery rate (%)	Advantages	Disadvantages
Oil recovery from petroleum sludge				
Solvent extraction	Field	70	Simple, efficient, and time saving	For large scale extraction, low efficiency and high variability
Centrifugation	Field	< 50	Clean and efficient, does not require high energy consumption	Large space for the installation of the plant, it is very costly and pose environmental concern
Surfactant enhanced oil recovery	Field	80	Fast and cost effective	Environmental toxicity and resistance to biodegradation
Freeze/thaw	Laboratory	60	Suitable for cold regions	Temperature, duration, high energy consumption
Pyrolysis	Field	70	Easy and simple	High energy consumption, high maintenance and operating cost, product may contain high concentrations of PAHs
Microwave irradiation	Field	90	Fast and efficient	High energy consumption, high maintenance and operating cost, application limited at industrial level
Electrokinetic	Laboratory	60	Fast and efficient	Complicated application and only in small scale
Ultrasonic irradiation	Laboratory	70	Fast, highly efficient method without environmental pollution	Very costly
Froth flotation	Laboratory	60	Simple application and low energy consumption	Low efficiency
Petroleum sludge disposal methods				
Incineration	Field	90	Fast and efficient	High cost of equipment and environmental pollution
Stabilization/ solidification	Laboratory	90	Fast and efficient	Only for oily sludge with low moisture content(or dry state) and the end product needs proper management
Oxidation	Laboratory	90	Fast and efficient	High cost of operation, environmental pollution
Bioremediation				
Land farming (see figure 4)	Field	80	Low cost of operation and supports large scale treatment	Slow process, require a very large land plot and can pose environmental concerns
Biopile/composting	Field	80	Large capacity, faster treatment than land farming	High cost of operation and require large land area
Bioslurry	Field	90	Fast treatment and require small land area	High cost of operation and proper management of the end product

The selection of the best treatment method may be based on various elements such as oily sludge composition, method capacity, costs, and available disposal standard.

Figure 4 ‘Land farming’ of oil-contaminated waters (Photo: RWA Group, 2019)

3.6 Pollution abatement measures

Irrespective of the treatment method chosen and technology employed, management of waste oil and oil contaminated waste has the potential to generate air, water and soil pollution.

Air pollution abatement techniques for channelled emission sources (from point sources, such as exhaust stacks from furnaces), are mostly focused on reducing the emissions of volatile organic compounds (VOCs) to air, as well as mercury, hydrogen sulphide, particle matter or odorous compounds. For the removal of VOCs, techniques employed include adsorption, biofiltration, condensation, thermal oxidation and wet scrubbing.

Removal of oil contamination from water can include operations such as oil-water separation (gravitational or using separation equipment or emulsion breaking chemicals) or stripping with steam followed by condensation.

Excavated soil contaminated with oil-based compounds is treated through thermal desorption. Typical operating temperatures are between 175 °C and 370 °C, but temperatures from 90 °C to 650 °C may be employed. Thermal desorption promotes physical separation of the components rather than combustion. The treated solids may be recovered, landfilled or treated further. Off-gas arising from the heating process (i.e. the gas given off from the waste during the heating process, containing the vaporised contaminants and water vapour) is collected and cooled, in order to condense out the contaminants to enable their collection and potential recovery. Thermal desorbers effectively treat soils and remove volatile and semi-volatile organic compounds. Some higher boiling point substances such as PCBs and dioxins may also be removed (if present).

Often prior to treatment or disposal, waste oils and oil contaminated wastes are stored for long periods of time. Ensuring storage conditions are suitable for the stored products, regular maintenance is kept and safety measures in case of accidents are in place are all necessary steps to avoid possible harm to population and the environment (see Figure 5, Figure 6 and Figure 7 below).

Figure 5 Waste oil storage in tank and drums, leaking in concrete containment bund (Photo: RWA Group, 2019)

Figure 6 Waste oil leaking from damaged drums into the environment (Photo: RWA Group, 2019)

Figure 7 Non-functional oil-water separation tanks, prone to rainwater ingress and waste oil overflow in the environment (Photo: RWA Group, 2019)

4 Final remarks

As it can be perceived, the above-described technologies for the recovery of waste oils can be complex installations that require considerable amounts of capital and operational expenditures. In lack of a suitable enabling environment, these types of installations will not be economically viable. Apart from economic considerations, oil regeneration technologies depend to some degree on the quality of waste oil and particularly in there not being significant concentrations of difficult oil products such as heavier fuel oils. The presence of such materials can seriously disrupt the technical performance of the regeneration process, and its ability to produce lubricating or similar products of sufficiently good quality. Regeneration processes are constrained both by feedstock and product prices dictated by oil product prices generally, and the margin between feedstock costs and product income must cover the total regeneration process costs if the activity is to be economically viable.

This is why waste oils are most often used as secondary fuel. This activity, however, should be as far as possible regulated so that initiatives that improve the quality and control are encouraged and at least minimal standards are applied to ensure this type of waste is managed in a sound manner. Ideally, a licence, permit or authorization process should be in place, allowing for the specification of control measures, pollution abatement, reporting, monitoring and verification.

In the particular case of dealing with waste oils and oil contaminated waste which is considered hazardous (i.e. PCB containing) and in lack of sound treatment/disposal options available nationally, these types of wastes need to be sent for treatment to an approved facility abroad. In such cases, as with other transboundary shipments of waste and hazardous waste in particular, prior informed consent procedures need to be carried out, as per Basel Convention provisions.

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