An analysis of the remediation of oil contaminated refinery sites

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Abstract
Petrochemical and refining operations can cause severe environmental damage due to emissions to soil, air and ground- and surface water. The general framework for remedial actions is primarily determined by the legal framework and the actual risks associated with levels of contaminants present at a site. Within the basic framework of legal procedures, site specific constraints and economic motives, the best available techniques (BAT) for remedial action will have to be evaluated. In most cases this is part of an overall environmental improvement and investment program for a facility. This paper describes the general background of soil remediation at refineries and provides an overview of applicable remedial technologies.

Introduction
Stringent environmental and safety regulations are applied to all oil and gas related activities within Europe (European Commission, 1996). These include regulations concerning contaminated land, oil spills and discharges of cuttings and oil mud.

Since the margins on refining and distribution activities have been weak in recent years, most oil companies examine their refining and distribution activities very closely. As a result, a number of refineries within Europe are being closed, while others are being modernised or brought back into operation. These activities on refinery sites together with the more stringent contaminated land legislation results in an increasing demand for cost-effective consultancy and remedial services. This paper shows the general environmental and economic background for remedial actions at refinery sites and suggests the application of state of the art cost-effective remedial technologies.

Industry background
The oil refining industry manufactures refined petroleum products (e.g. naphtha, gasoline, aviation fuels, gasoil, lubricants) from crude oils or semi-finished petroleum feedstocks. Trends in production from European refineries in general follow the pattern of market demand (see Table 1). Since the early 1980s the refining industry adapted itself very well to the needs of the market, both by bringing production capacity into line with demand and also by investing in new production processes to ensure a broad mix of products which suit the market.

Environmental pressures on refining and distribution activities increased as the EU committed itself to stabilising CO₂ output at the 1990 levels (European Commission, 1991; 1997b; 1998). Also the trend towards a reduction of emissions of toxic substances, such as SO₂, NOₓ, CH₄, particulates and VOCs (volatile organic compounds) has a significant economic impact on the refining industry (European Commission, 1997a; IPPC Directive, 1996). In order to address environmental aspects of the oil refining process properly, environmental management procedures (e.g. on waste water) are implemented. Best available techniques (BAT) have been formulated for oil refining processes.

Environmental authorisations of individual refineries include air emission norms and other requirements based on BAT.

Legal framework
National soil quality legislation has developed in most European countries (see Appendix). In case of contaminated land in most cases a risk-based approach is chosen. Risk-based soil quality standards tend to become integrated in national or regional planning and building regulations.

The actual risks associated with contaminated land may, under circumstances, be practically negligible. In these cases no full-scale remediation will be necessary and the land still may be used for certain purposes (e.g. heavy industry). National or regional legislation or guidelines give the framework for the actual use of soils and subsurface. Remedial actions are a way of restoring the intended use of land. For refinery sites EU regulations and permits may give additional standards or guidelines.

Remedial approach
Petrochemical and refining operations can cause severe environmental damage due to emissions to soil, air and ground- and surface water. Most emissions take place during
normal operations as a result of air emissions, small scale spills, outdated technology (surplus of waste production and emissions). Soil of groundwater at refineries is often contaminated by oil products (lubricants, heavy and light fuels), VOCs (mainly volatile aromatics), PAH (polycyclic aromatic hydrocarbons) and metals (a/o. lead). Most risks are associated with mobile compounds, such as VOCs and light fuels, since these compounds might migrate off site or leach out into groundwater or surface water systems. Also off-site disposal of waste materials (e.g. sludge) in public landfills are considered a risk. However the remedial approach of off-site landfills is considered an issue separate from the treatment of refinery sites.

The remedial approach on a refining facility is site specific and depends on factors such as:
- national and regional legislation;
- background of remediation (full-scale restoration of site compared to local spills at operational facilities);
- levels of and risks associated with contaminants;
- hydrogeological settings;
- economic factors.

The general framework for remedial actions is primarily determined by the legal framework and the actual risks associated with levels of contaminants present at a site. When a major contamination is detected, groundwater and surface waters are at risk and a full restoration of a site is obligatory, a costly remediation may be the result. On the other hand, at new refinery sites with only minor spilling and clayey subsoil, no actual clean up may be necessary.

Since most refineries are located in industrial areas or will continue to be in operation, contaminated land at most refinery sites will be evaluated on the basis of a risk assessment. This also means that remedial strategies tend to be focused on a risk reduction, rather than a “removal of contaminants”. Such a risk reduction may be quantified on the basis of exposure or migration calculations during the risk assessment. Most immobile compounds (e.g. heavy metals, PAH) just will be contained in order to limit exposure, while mobile compounds (e.g. VOCs) will be removed or actively controlled.

Remediation of contaminated land is an economic factor and even the temporary shut-down of refinery operations in most cases is not acceptable. Long-term remedial activities preferably will have to be integrated in the normal operational processes.

### Remedial technologies

In the past excavation and disposal of contaminated soils and pump-and-treat methods for groundwater were acceptable (AGWSE, 1994), though in case of large-scale facilities such as refineries these were very costly.

Current state of the art remedial technologies are primarily directed towards a risk reduction rather than a full-scale clean up process. In situ technologies such as “natural attenuation” (Essaid et al., 1995) fit very well into this risk-based approach. However, before implementing such in situ methods one has to have a thorough knowledge of the hydrogeology, biogeochemistry and contaminant behaviour in the subsurface. Of course, in certain cases (e.g. removal of hot spots or source zones) excavation of contaminated soil will be the best option. Though by assessing the possibilities for an in situ approach in an early stage of the project, the costs for remediation can be reduced significantly (US EPA, 1994).

The main advantages of in situ technologies are:
- minimisation of impact on ongoing operations;
- optimum use of intrinsic (natural) degradation of compounds;
- reduction of remedial costs.

In situ technology can be divided into three main groups:
- extractive techniques (pump-and-treat; in fact on-site techniques), such as flushing, chemical extraction, soil vapour extraction, in-well air stripping;
- energetic techniques (increase of mobilisation), such as electro reclamation, radiofrequency heating, fracturing;
- biological/geochimical techniques (in situ degradation), such as biorestoration, bioventing, phytoremediation, solidification and natural attenuation.

On the basis of the risk assessment a feasibility study focusing on the remedial objectives and strategy is carried out. Within the basic framework of legal procedures, site-specific constraints and economic motives, the best available techniques (BAT) for remedial
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action are evaluated. In most cases this is part of an overall environmental improvement and investment program for a facility.

The general remedial scheme for operational refinery sites can be described as:

• identification and clean up of source areas;
• prevention of off-site migration of contaminants;
• clean up of other relevant contaminated areas.

In situ technologies are considered to be the most valuable in the approach of non-source areas (Nyer et al., 1996), such as off-site groundwater contamination and diffusive contaminated areas. In source areas (e.g. floating LNAPL-layers) in situ techniques can decrease the levels and mass of chemicals considerably. However in that case a full clean up is rather difficult. Since the main contaminants at refineries are of an organic nature, biological in situ technologies are very promising. By optimisation of existing field conditions, the natural degradation of organic compounds (biological approach) is enhanced, or an environment is created in which further migration of contaminants is limited (geochemical approach).

Conclusions

Currently, stringent environmental and safety regulations are applied to all oil and gas related activities within Europe. These include regulations concerning contaminated land, oil spills and discharges of cuttings and oil mud. The remediation of contaminated land on refinery sites is therefore only a part of overall environmental investments.

Petrochemical and refining operations can cause severe environmental damage due to emissions to soil, air and ground- and surface water. The general framework for remedial actions is primarily determined by the legal framework and the actual risks associated with levels of contaminants present at a site. On the basis of the risk assessment feasibility study focused on the remedial objectives and strategy is carried out. Within the basic framework of legal procedures, site-specific constraints and economic motives, the best available techniques (BAT) for remedial action are evaluated. In most cases this is part of an overall environmental improvement and investment program for a facility.

In the past excavation and disposal of contaminated soils and pump-and-treat methods for groundwater were acceptable, though in case of large-scale facilities such as refineries very costly. Current state of the art in situ technologies are primarily directed towards a risk reduction rather than a full-scale clean-up process.

References


Appendix: National soil quality legislation

A summary of current national soil quality legislation of a number of EU countries is given below.

Belgium (Flanders)

In Flanders, the legislation governing liability in respect of soil remediation has been established on 22 February, 1995 with the publication of the Decree relating to Soil Remediation. The central authority concerning this legislation is the Public Waste Agency of Flanders (OVAM). They deal with all soil surveys and contaminated sites. OVAM must draw up a register of contaminated land and provides soil certificates upon request.

Flemish landowners are obliged to carry out an exploratory soil survey when the land is transferred and in the past there was a soil-threatening activity or an establishment is closed, or operations are suspended and on
the basis of a periodicity for specific categories of establishments or operations.

Like the Dutch, the Flemish authorities apply the “polluter-pays-principle” for soil and groundwater contamination. In case of historical contamination (originated before the Decree) OVAM applies a risk-based approach: these kinds of contamination will only have to be handled in case of certain or probable threats for humans, plants and animals. New soil contamination (originated after the Decree) will have to be cleaned up immediately when remedial values are exceeded. All contaminated grounds will be registered in the Register of Contaminated Lands.

France

As in other European countries, in France comprehensive policy in the field of soil contamination and clean up is relatively young. A first inventory of contaminated sites has been established in 1994, and has identified 669 sites as contaminated. Site clean up has taken place since the early 1990s, on an ad hoc basis.

In 1996, a new ministerial circular was published with regard to contaminated soil. The circular aims to complete the 1994 inventory and to introduce a comprehensive policy in this field. The new estimation for the number of possibly contaminated sites in France was this time in the order of 300,000. A comprehensive methodological guide has been elaborated to provide guidance in the soil investigation and site assessment procedure.

In principle, France applies the polluter-pays-principle for soil remediation. Much remains yet still unclear. The authorities claim that the inventoried sites must be investigated on the costs of the company. The clean-up costs are also reported to be incurred fully by the companies.

Germany

On a state level (Bundesländer) soil quality legislation dates from the early 1990s. In 1998 the Federal Soil Protection Act was formally issued. This act issued national uniform standards for the soil protection and the clean up of contaminated sites.

In general, contaminated land that constitutes a hazard to humans and the environment is to be cleaned up. The responsibility for the clean up lies primarily with the polluter (or legal successors) and current or previous owners of the land.

The tasks of identification of contaminated land and the execution of legal procedures are the responsibilities of the Bundesländer. The legislation is primarily concerned with solid soil; in case of contaminated water bodies, also water legislation may be relevant.

The Netherlands

Environmental legislation in the field of soil and groundwater in The Netherlands dates from the early 1980s. Soil and groundwater quality standards have been issued by the Dutch government in the “Soil Protection Act”, promulgated on 10 May 1994.

In The Netherlands the provincial authorities (including the four largest cities) deal with soil quality matters. They deal with most of the larger soil surveys and contaminated sites. Within the framework of the Building and Planning Acts also the local communities may be involved in minor soil quality and remedial issues.

The Dutch authorities apply the “polluter-pays-principle” for soil and groundwater remediation. However, responsibility/liability questions related to soil and groundwater quality issues are rather difficult and take a lot of time. This formal approach resulted in a stagnation of the Dutch soil remediation program. Currently the Dutch legislation is being re-evaluated. The Dutch will turn to a more risk-based approach. Remedial actions will move to a more functional methodology, focused on the (future) use of a contaminated site. However, new soil and groundwater contamination still has to be removed, which operation in general is enforced on the basis of the environmental permits of facilities.

UK

The statutory regime governing liability in respect of soil quality has been established in 1995 by the Environment Act. This Act refers to the original polluter to be responsible for the costs and the carrying out of (possible) remedial works in case of statutory nuisance. The current owner or occupier will be liable if the original polluter cannot be found. Apart from the Environment Act, also elements of the Town and Country Planning Act, the Environment Protection Act, Water Resources Act may be applicable in the case of contaminated land.

Draft guidance notes dealing with the risks involved with soil contamination are issued by the Department of the Environment. At the present the regional Environment Agencies are using ICRCL standards or where appropriate the Dutch framework of standards for evaluation of soil quality.