Comparative studies of oil product regulation in polluted soil for several industrialized countries

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Abstract. Oil contaminated sites are the consequence of a long period of industrialization. Oil is a complex mixture including aliphatic and aromatic hydrocarbons, which are known to have negative effects on human health and the environment. Dividing oil products in groups (fractions) of petroleum hydrocarbons that act alike in soil and water, one can better know what happens to them. Being able to understand the behaviour of oil products in soil, it will allow to implement prevention and remediation actions. Interventions on contaminated sites are bound to comply with regulatory limits that each country has set in their own environmental legislation. The different concentration thresholds of oil products in soil for several EU countries and Canada has led to compare: limit values, analytical method, soil characteristics and/or land use. This will allow to evaluate what could be the best regulation approach, assessing if it is better to consider soil matrix in the site or the specific land use or both of them. It will also assess what is the best analytical methodology to be adopted to achieve the pollutant concentrations in the soil in order to have comparable results among different countries, such as: Baltic countries (Latvia, Estonia, Lithuania), Nordic countries (Finland, Sweden, Norway, Denmark), Western countries (Italy and The Netherlands) and Canada, like gas chromatography in the range from C10 - C50. The study presents an overview of environmental regulatory system of several EU countries and Canada and the correlation between different parameters about oil products indicated in each environmental legislation.

1. Introduction
Petroleum hydrocarbons, including crude oils and refined products, enter the environment from a variety of sources. The contamination is not only due to the petroleum industry activity and to the production processes, but also to the storage, tank reloaded and transportation of petroleum hydrocarbon. Site polluted by petroleum hydrocarbon becomes impracticable for the agricultural asset and residential and recreational activities [1].

Exceeding the regulatory limits that each country has established for these products in its environmental legislation, it should require the start of rapid prevention and protection measures for
human and environmental health [2]. In this way it will avoid serious economic losses and environmental disasters.

At the moment, only a few EU member states have specific legislation on soil protection. In fact, regarding soil do not exist complete and coherent rules within the EU. There are, for instance, directives addressed to agriculture, water and waste management, but these have other kind of purposes and are not sufficient to ensure an adequate protection level for all soils in Europe. For all these reasons, the Commission adopted a Soil Thematic Strategy [3] on 22nd September 2006 with the objective to protect soils across the EU. But the Commission in May 2014 decided to withdraw the proposal for a Soil Framework Directive. However the Seventh Environment Action Programme recognises that soil degradation is a serious challenge.

The purpose of this paper is to compare environmental legislation adopted by some European countries and Canada, on site contamination by oil products. The goal is to match regulatory limits and analysis techniques, and to provide a qualitative analysis on the similarities or differences among various regulations.

2. Comparative studies
In the next sections the various regulatory limits will be briefly described that the three groups: Baltic countries (Latvia, Estonia and Lithuania), Nordic countries (Finland, Sweden, Norway, Denmark) Western countries (Italy and The Netherlands) and Canada (considered alone), have adopted in their legislation regarding contaminated sites by oil products.

2.1 Baltic countries
In Baltic countries there are several oil terminals and the quantity of oil products is transferred across the state border as liquid fuel or fuel for transport.

Regulatory limits and methodologies used to analyze oil products adopted by the three Baltic States, are illustrated using triaxial graphs, in figure 1-2.

2.1.1 Case study: Latvia. Environment quality standards (EQS) in Latvia for soil and subsoil have been fixed by Cabinet of Ministers Regulation No 804 “Regulation of the Quality Normative for Soil and Subsoil” (issued on 25th October 2005), which contains values of EQS for different kind of pollutants. In figure 1(a) are indicated the regulatory limits that Latvia has adopted regarding oil products. Regulation No 804 defines three types of EQS for soil and subsoil: target value EQS (A), precaution limit value EQS (B) and critical limit value EQS (C).

The soil is classified as: sand, sand clayous (sandy loam), sandy clay (loam) and clay. The regulatory limits, regarding oil products, are the same for all of four soil types. In Latvia the gas chromatography, to determine the concentration of these products in soil, is used according to ISO 16703:2011 [4].

2.1.2 Case study: Estonia. In Estonia the regulatory limits for soils and groundwater have been set by the Regulation No. 58 (issued on June 16th 1999) by the Minister of Environment, named "Limit values of dangerous substances into groundwater and soil". Figure 1(b) shows that the ground is not classified according to its granulometry as in Latvia, but the limits are directly related to land use that can be residential or industrial.
The Estonian guidance value is 100 mg/kg, while for Latvia is 1 mg/kg, but the highest threshold value is the same for both countries (5000 mg/kg). In Estonia to determine the concentration of the oil products in soil the ISO 16703:2011 [4] is followed.

2.1.3 Case study: Lithuania. Environmental legislation in Lithuania sets regulatory limits for oil products in the soil in a different way respect to Latvia and Estonia. First of all it divides oil products in 3 fractions, and then also takes into account the hydraulic conductivity of the soil and the sensitivity that is a function of the use of the site, for example: protected areas are classified as very sensitive; sensitive areas are agricultural, recreational and living sites; forests and commercial activity are medium sensitive; industrial site is considered as little sensitive. In figure 2 are reported the limit values.

Analytical methods of oil products in soil are according with standards EPA 5021:1996 and ISO 16703:2004 [5, 6].

From the previous paragraphs it is possible to see that there are some differences among polluted soil legislations of Baltic countries. Estonia classifies the site according to the land use, Lithuania divides the soil according to its sensitivity and granulometry and Latvia does not consider the soil characteristics. Furthermore, regarding limit values Latvia has the most conservative target value (1 mg/kg) against Estonia that has 100 mg/kg, instead for Lithuania the limit values in soil depend on the hydrocarbon fractions considered.
2.2 Nordic countries

2.2.1 Case study: Sweden. Sweden has about 80000 contaminated sites due to different activities [7]. In the Swedish Environmental Protection agency general guidelines for contaminated soils it is defined the petroleum hydrocarbons subdivision not only in aliphatic, however in aromatic as well as, whose regulatory limits are shown in figure 3. The aromatic fraction >C10-C16 has the lowest limit, probably because naphthalene (IARC: group 2B), anthracene and phenanthrene (IARC: group 3), contained in this class, are considered the most dangerous. The limit values are referred to the area sensitivity and not to the granulometry of the soil.

![Figure 3](image)

**Figure 3.** Concentration limits (mg/kg) in soil for Sweden: (a) aliphatic hydrocarbons; (b) aromatic hydrocarbons.

In Sweden, accredited laboratories use GC-MS to analyze petroleum hydrocarbons in soil, but there is not a standard method that is followed for the realization of these kind of analysis.

2.2.2 Case study: Finland. In Finland the main activities that cause soil contamination by oil products are linked to the distribution and storage of fuels [8].

Regulatory limits concerning Finnish soils have been established by the Government Decree on the Assessment of Soil Contamination and Remediation Needs (214/2007). Finnish legislation does not differentiate the types of soil that are considered, it only sets a minimum and a maximum limit (beyond which will be implemented remediation actions) that must be respected for different fractions of oil products that are analyzed (figure 4(b)). Furthermore, the decree indicates that series of n-paraffins in the gas-chromatographic analysis is the method used to determine petroleum fraction concentrations according to ISO 16703:2011 [4].

2.2.3 Case study: Norway. In Norway it is very important the production of oil, in fact during last years it yielded several million standard cubic meters of oil equivalents [9].

The environmental regulation in Norway use to classify the land according to the concentration of oil products (table 1). The soil quality standards used in Norway regarding soil contamination from these fractions [10] are shown in figure 4(a).

To determine the concentration of oil products in soil, Norwegian accredited laboratories use methods based on ISO 16703:2011 [4] and NS-EN 14039:2004 [11].
Figure 4. (a) Limit values (mg/kg) in soil for Norway; (b) Limit values (mg/kg) in soil for Finland.

Table 1. Soil classification in Norway.

| Soil classification/Substance | 1 | 2 | 3 | 4 | 5 |
|------------------------------|---|---|---|---|---|
| Aliphatic C8-C10             | < 10 | ≤ 10 | 10 – 40 | 40 – 50 | 50 - 20000 |
| Aliphatic C10-C12            | < 50 | 50 – 60 | 60 – 130 | 130 – 300 | 300 - 20000 |
| Aliphatic C12-C35            | < 100 | 100 – 300 | 300 – 600 | 600 – 2000 | 2000 - 20000 |

2.2.4 Case study: Denmark. In Denmark management of contaminated sites is governed by the Contaminated Soil Act (Act. No. 370 of 2 June 1999).

The Danish environmental protection agency has established the guidance values for soil in residential areas, kindergartens and playing grounds, dividing petroleum hydrocarbons in four fractions as reported in figure 5 [12]. However only for heavy hydrocarbons >C20-C35, the remediation is required, just if the concentration exceeds 300 mg/kg. Usually to analyze these fractions GC-FID is used.

Nordic countries have adopted the limit values for soil pollution according to the petroleum fractions that are considered. Norway has the highest upper limit value (20000 mg/kg) and with
Sweden and Denmark use the same target value 100 mg/kg for the heavy petroleum fractions, against Finland that consider 600 mg/kg as limit value for these substances.

2.3 Western countries

2.3.1 Case study: Italy. In Italy, site pollution by oil products is mainly due to the intense industrial activity all over the Country. The soil and subsoil concentration values of different substances are contained in Legislative Decree 152/2006, also defined as Environmental Act. In figure 6(a) the regulatory limits for hydrocarbons are reported, based on the specific land use and the values of the specific groups of oil products (light and heavy).

![Figure 6. Soil concentration limits (mg/kg) in Italy (a) and in The Netherlands (b).](image)

In this case it is possible to see a similarity to the Estonian environmental legislation: both of them use the different land use for soil classification, but for Italy the upper limit for the hydrocarbon heaviest fraction is much more protective than Estonian limit. The analytical procedure for hydrocarbons C>12 measurement in contaminated soil, has been developed by the Institute for Environmental Protection and Research (ISPRA) and was published in a manual [13]. However the procedure follow the method ISO 16703:2004 [6], the same method which is used by Latvia, Estonia, Lithuania, Finland and Norway, however hydrocarbons using ISO 16703 are in range from C10 - C40.

2.3.2 Case study: The Netherlands. In The Netherlands, the Dutch Target and Intervention Values set the concentration thresholds for contaminated sites. According with the Dutch Soil Protection Act the soil is divided into three quality classes: clean, slightly contaminated and seriously contaminated [14]. In this case regulatory limits are referred to mineral oil which indicates a contamination due to mixtures (e.g. gasoline or domestic heating oil), then not only the alkane content but also the content of aromatic and/or polycyclic aromatic hydrocarbons must be determined. To detect the concentration of the mineral oil is used the NEN 5733 method [15] which is in accordance with ISO 11046 [16]. The Target and the Intervention Value (after which it is required a reclamation intervention) for Dutch soil are shown in figure 6(b).

Italy’s limit value in residential zone for C>12 and The Netherlands’ target value is fixed at the same value of 50 mg/kg, but the upper limit is completely different, in fact from the picture it is possible to see that for Italy is under 1000 mg/kg, while for The Netherlands is 5000 mg/kg (like Estonia and Latvia).

2.4 Case study: Canada

The hydrocarbon pollution is the most common form of soil contamination in Canada [17]. For the management of contaminated soil there is a key act named *Environmental Protection and*
Enhancement Act. Hydrocarbons are divided into four fractions and the limit values are set according to the soil classification (type and grain size) and specific land use[18] (figure 7). Regarding to the classification of the site, in coarse soil the limits are lower than fine soil, because the hydraulic conductivity is the highest in this kind of land. Furthermore the regulatory limits are more protective for agricultural and residential sites, than industrial and commercial land use.

![Figure 7](image)

**Figure 7.** Concentration limits (mg/kg) in soil for Canada: (a) fractions F1 and F2 in fine soil; (b) fractions F3 and F4 in fine soil; (c) fractions F1 and F2 in coarse soil; (d) fractions F3 and F4 in coarse soil.

The analytical method used to determine the concentration of all fractions is reported in *Reference Method for the Canada-Wide Standard for Petroleum Hydrocarbons in Soil – Tier 1 Method* [19].

3. **Conclusions**

The comparative analysis among various environmental legislations regarding soil contamination with oil products, highlighted the main differences and similarities in oil product denominations and regulatory limits used by the European countries (Latvia, Estonia, Lithuania, Finland, Denmark, Norway, Italy, The Netherland) and Canada. The most precautionary limit is adopted by Latvia (1 mg/kg). While the highest target values are adopted by Finland (100-600 mg/kg). A few countries use two limit values as a function of the use of the soil after remediation (Italy), others use even three limits (Latvia and Estonia). In other countries it is allowed that the contamination of oil products overcomes the remediation target value, unless the contaminant concentration is beyond a fixed threshold. Canada to classify polluted soils is the only country to adopt all these parameters: hydrocarbon fractions, grain size and land use.

The study points out that the analysis method used to determine the concentration values of oil products in soil, is in general the same (ISO 16703) or and gas chromatography with a different content of hydrocarbon in the range from C6 to C50.

Further research should focus on the use of new tools for the contaminated site characterization. Geodesy can supply an important contribute in environmental characterization like the use of digital maps to locate the sampling points and GPS to find them within the contaminated site.
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