Green Future – An Optimized Simply Designed Approach to the Soil Status Monitoring for the Purposes of Baseline Report Preparation

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Abstract: Industrial Emission Directive, as the most important EU instrument for regulating pollutants emissions from industrial installations, requires among others also preparation of a baseline report as precondition to granting an environmental permit. Baseline report is an information on the state of soil and groundwater contamination by relevant hazardous substances and at the same time a practical tool that permits a quantified comparison between the state of the site described in that report and the state of the site upon definitive cessation of activities. In this paper, we briefly present an optimized simply designed approach to the soil status monitoring for the purposes of baseline report preparation according to the Slovenian legislation. Particular emphasis is given to the presentation of the methodology for the determination of the variability, which comprises a heterogeneity of sampling area and uncertainty of analytical methods. The presented approach we used in several commercial studies. The received operators' feedback information have fully confirmed that the presented approach to the soil status monitoring ensures high quality information of baseline soil status and regulatory compliance within acceptable cost budget.

Key-Words: Industrial emission, IED directive, Baseline report, Slovenian environmental legislation, Soil status monitoring, sampling design

1 Introduction

2.1 EU instrument for industrial emissions regulation

Industrial production processes account for a considerable share of the overall pollution in Europe due to their emissions of air pollutants, discharges of wastewater and the generation of waste [1]. Therefore, industrial production processes, especially those which are based on older wasteful technologies, present one of the most significant matter that needs to be addressed within the frame of ensuring sustainable development globally. In order to make more significant shift towards more sustainable society, we should globally continuously strive among others to reduce emissions from industrial installations.

The most important EU instrument for regulating pollutants emissions from industrial installations is Directive 2010/75/EU of the European Parliament and the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control [2], known also as Industrial Emission Directive or as IED. According to the provisions of IED, in order to ensure the prevention and control of pollution, each installation should operate only if it holds a permit or, in the case of certain installations and activities using organic solvents, only if it holds a permit or is registered [2].

The environmental permit should include all the measures necessary to achieve a high level of protection of the environment as a whole and to ensure that the installation is operated in accordance with the general principles governing the basic obligations of the operator. The permit should also include emission limit values for polluting substances, or equivalent parameters or technical measures, appropriate requirements to protect the soil and groundwater and monitoring requirements. Permit conditions should be set on the basis of best available techniques [2].

2.1 Slovenian Legislation

Individual provisions of IED are transferred into Slovenian legislation through a number of national environmental legislative documents – Act, Decrees and Rules. The main national legislative document in the field of environmental protection is Environmental protection act [3]. The primary Slovenian national instrument for regulating industrial installations within the scope of IED is Decree on activities and installations causing large-scale environmental pollution [4].

Air emissions are nationally regulated by Decree on the emission of substances into the atmosphere from stationary sources of pollution [5] and large number of other special decrees connected with certain types of activities, for instance: Decree on the emission of substances into the atmosphere from installations for the manufacture of aluminium using an electrolytic process [6], Decree on the emission of substances into the atmosphere from foundries of aluminium and magnesium [7], Decree on the emission of substances into atmosphere from installations for the production of light alloy, ferrous and steel [8], Decree on the emission of substances into the atmosphere from small and medium combustion plants [9], Decree on limit values for emissions from large combustion plants into the atmosphere [10], etc.

Wastewater emissions are nationally regulated by Decree on the emission of substances and heat when discharging waste water into waters and the public sewage system [11] and more than thirty other special decrees connected with certain types of activities, for instance Decree on the emission of substances and heat in the discharge of waste water from non-ferrous metal foundries [12], Decree on the emission and heat in the discharge of waste water from plants for the production of non-ferrous metals [13], Decree on the emission of substances in the discharge of waste water from plants and facilities for the manufacture of metal products [14], etc.

Monitoring of air emission, wastewater emission, groundwater state and soil state are nationally regulated separately by Rules on initial measurements and operational monitoring of the emission of substances into the atmosphere from stationary pollution sources and on the conditions for their implementation [15], Rules on initial measurements and operational monitoring of wastewater [16] Rules on groundwater status monitoring [17] and Rules on soil status monitoring [18]. Official monitoring according to mentioned rules can be in Slovenia preformed only by performers, which have authorization by Slovenian Environmental Protection Agency.

2.2 Baseline Report

IED requires the preparation of a baseline report as precondition to granting a permit for an industrial installation [2]. Baseline report is an appropriately documented written information on the state of soil and groundwater contamination by relevant hazardous substances. In general, the baseline report is a practical tool that permits, as far as possible, a quantified comparison between the state of the site described in that report and the state of the site upon definitive cessation of activities [2].

Since IED includes and introduces in practice among others also so called ‘polluter pays’ principle, the operator shall assess the state of soil and groundwater contamination by relevant hazardous substances used, produced or released by the installation upon closure of the installation. In case that installation has caused significant pollution of soil or groundwater by relevant hazardous substances compared to the state established in the baseline report, the operator shall take the necessary measures to address that pollution so as to return the site to that state [2]. Therefore, the baseline report should contain two basic set of information. The first one should contain the data on the present use and, where available, on past uses of the site. The second one should contain existing information on soil and groundwater measurements that reflect the state at the time the report is drawn up or, alternatively, new soil and groundwater measurements having regard to the possibility of soil and groundwater contamination by those hazardous substances to be used, produced or released by the installation concerned.

1.4 Soil Status Monitoring for the Purposes of Baseline Report Preparation

Monitoring of initial (baseline) soil status within the area of industrial installation present especial expert challenge in the preparation of baseline report. In fact, there is a lot of available literature and guidance including standards (group of ISO 18400 standards), which deals with the soil sampling and methods of analysis [19, 20, 21]. However, there are always some open issues and challenges in soil status monitoring especially due to, for instance, dilemmas of choosing of an appropriate soil sampling method and design (number and size of sampling area, number of investigated soil layers, etc.), heterogeneity of soil sampling area, etc.

According to Slovenian environmental legislation, the zero state of soil status should be determined by the concentration of each parameter of soil status and its variability [18]. The last one comprises a heterogeneity of sampling area and uncertainties of analytical methods. In order to determine the heterogeneity of soil sampling area in the zero state, it should be taken and analysed at least three average soil samples from each soil layer so that the each average soil sample cover proportional part of soil area meanwhile all samples together have to entirely cover sampling area.

The main aim of this contribution is to briefly present an optimized simply designed approach to the soil status monitoring for the purposes of baseline report preparation according to the Slovenian environmental legislation. Particular emphasis is given to the presentation of the methodology for the determination of the variability, which comprises a heterogeneity of sampling area and uncertainty of analytical methods.

2 An Optimized Simply Designed Approach to the Soil Status Monitoring

2.1 Soil Sampling Design

The size of soil sampling area should be according to requirement of provision from Rules on soil status monitoring [18] between 5 m^2 and 100 m^2. Additionally, the mentioned regulation requires soil analysis on two soil layers – surface layer and lower layer – and determination of heterogeneity of soil sampling area using at least three average soil samples from each soil layer so that the individual average soil sample cover proportional part of soil area, meanwhile all samples together entirely cover sampling area.

Based on legislation requirements we propose (an optimized simply designed approach) that the soil sampling area with surface for instance 12 m^2 (3 m x 4 m) is virtually divided into uniform square net with twelve sampling points on three segments of sampling area (segments marked with 'A', 'B' and 'C'; each segment includes four sampling points). The scheme (including ground plan view and cross-section view) of such so-called general simply designed soil sampling area is presented on Fig. 1.

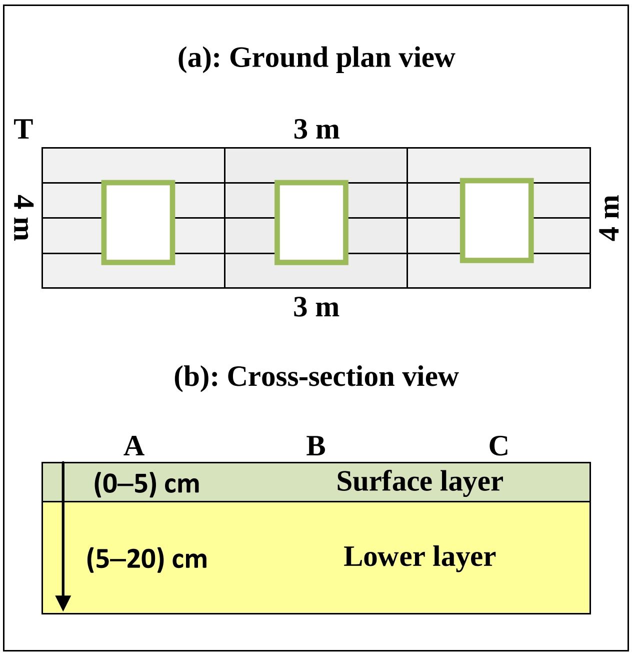

Fig. 1: Scheme of optimized simply designed soil sampling area – (a): Ground plan view, (b) Cross-section view.

2.2 Sampling and Pre-treatment of Soil Samples

Soil samples on both layers (surface and lower layer) are primarily sampled using soil probes. Based on our user-experiences, we prefer usage of soil probes produced by Eijkelkamp Soil & Water B.V. Nevertheless, sampling equipment have to completely meet requirements in accordance to standard EN ISO 10381-2 [33].

In case of specific composition properties of the soil in the sampling area (presence of larger pieces of natural or anthropogenic material), the soil samples can be alternatively sampled from excavated vertical soil profile. However, if such a sampling method is used, them it is necessary remove from the sample large pieces, for instance the remains of bricks or other building material, debris, metal and plastic residues, etc.

For the evaluation of baseline soil status of sampling area on two different layers (surface layer: (0–5) cm and lower layer (5–20) cm), equal amount of soil should be taken uniformly from total surface of both layers, yielding two combined (average) soil samples marked with signs T_0 and T_{20},, where subscript '0' present surface layer and '20' lower layer. Additionally, equal amount of soil should be also taken uniformly from total surface of each segment of sampling area, yielding six so-called segment sub-samples marked with signs A_0, B_0, C_0, A_{20}, B_{20} and C_{20}.

Main average soil samples marked with signs T_0 and T_{20} are used for the determination of average concentration of each parameter of soil status, meanwhile the sub-samples marked with signs A_0, B_0, C_0, A_{20}, B_{20} and C_{20} are used, in combination with uncertainties of analytical methods, for the determination of the variability.

All samples have to be delivered to the laboratory within 24 hours. The storage temperature during transportation should be below 15 °C. Afterwards, the soil samples have to be pre-treated in accordance to the standard ISO 11464 [34] and ISO 14507 [35].

2.3 Parameters of Soil Status

According to requirement of provision from Rules on soil status monitoring [18], the list of parameters of soil status in the frame of soil status monitoring for the purposes of baseline report preparation should basically contains the following parameters:

- basic parameters of soil status,
- parameters of soil status depending on actual soil pollution due to existing and past use and
- parameters of soil status as regards to the anticipated soil load.

On the other hand, the list of parameters of soil status in the frame of soil status monitoring for the purposes of preparation of baseline report for industrial installation should also include the following parameters:

- parameters of soil status from regulation governing soil status, for which existing quality standards and
- parameters of soil status by which relevant hazardous substances can be efficiently monitored.

Decree on status of soil, where soil quality standards should be defined, is still in the preparation phase at the time of preparation of this contribution and have not been yet accepted by Government of the Republic of Slovenia (the first draft has been withdrawn from public debate). Therefore we propose, as alternative, to include into abovementioned list of parameters of soil status some parameters from existing Decree on limit values, alert thresholds and critical levels of dangerous substances into the soil [22]. This chemical parameters are as follows: metals – antimony (Sb), arsenic (As), copper (Cu), cadmium (Cd), chromium (Cr), nickel (Ni) and lead (Pb), mercury (Hg), fluorides (total, F), benzo(a)pyrene (BaP), cyanides (total), sum of hexachloro-cyclohexanes (alpha-HCH, beta-HCH, gama-HCH and delta-HCH), hexachlorobenzene (HCB), sum of polychlorinated biphenyls (PCB-28, PCB-52, PCB-101, PCB-118, PCB-138, PCB-153 and PCB-180 and organochlorine and other pesticides.

2.4 Analytical Methods

For the chemical analysis of soils samples, we should use analysis methods, validated and documented according to the ISO/IEC 17025 standard [23].

We propose to use validated analytical methods for the chemical analysis of the soil samples based on the following standards:

- EN ISO 17294-2 [24] for metals (Sb, As, Cu), Cd, Cr, Ni and Pb): – sample preparation: modified standard ISO 11466 [25] (digestion of soil sample in closed container using microwaves prior to analysis),
- ISO 17852 [26] for mercury (Hg) – sample preparation: homogenization and mine-ralization of soil sample by aqua regia prior to analysis,
- ISO 10359-2 [27] for fluorides (total, F),
- ISO 18287 [28] for benzo(a)pyrene (BaP),
- ISO 6703-1 [29] for cyanides (total) – sample preparation: leaching,
- ISO 10382 [31] for polychlorinated biphenyls (PCBs) – sample preparation – internal method,
- EPA 8081B [30] for hexachloro-cyclohexanes (HCHs), hexachlorobenzene (HCB) and other organochlorine pesticides – sample preparation: internal method and
- EN 15637 [31] for other pesticides – sample preparation: internal method.

2.5 Mathematical Formulation for the Determination of Baseline Soil Status

The proposed mathematical formulation for the determination of baseline soil status includes heterogeneity of sampling area as well as enlarged uncertainties of analytical methods and, therefore, it is in fully accordance with Rules on soil status monitoring [18].

Baseline concentration of j-th parameter of soil status in soil layer k (surface soil layer (0–5) cm or lower soil layer (5–20) cm) is expressed with the following Eqs. (1) or (2):

$$y_{j,k} = x_{\mathrm{T},j,k} \pm v_{j,k} \text{ ……… if } x_{\mathrm{T},j,k} > \mathrm{LOQ}_j \quad (1)$$

$$y_{j,k} = x_{\mathrm{T},j,k} \text{ ……………… if } x_{\mathrm{T},j,k} \leq \mathrm{LOQ}_j \quad (2)$$

where are:

$$v_{j,k} = x_{\mathrm{T},j,k} \cdot \sqrt{\left(\frac{\sqrt{\sigma_{j,k}}}{\overline{x_{j,k}}}\right)^2 + \left(\frac{U_j}{100}\right)^2} \quad (3)$$

$$\sigma_{j,k} = \frac{\sum_i \left(x_{i,j,k} - \overline{x_{j,k}}\right)^2}{2};\ i = \mathrm{A, B \text{ and } C} \quad (4)$$

$$\overline{x_{j,k}} = \frac{\sum_i \left(x_{i,j,k}\right)}{3};\ i = \mathrm{A, B \text{ and } C} \quad (5)$$

The symbol in Eqs. from (1) to (5) have the following meanings:

$y_{j,k}$ Baseline concentration of j-th parameter of soil status in the soil layer k;
$x_{\mathrm{T},j,k}$ Average concentration of j-th parameter of soil status in the soil layer k;
$x_{i,j,k}$ Concertation of j-th parameter of soil status in the i-th segment of soil layer k;
U_j Enlarged measurement uncertainty of analytical method for j-th parameter of soil status;
LOQ_j Limit of quantitation for j-th parameter of soil status;
$v_{j,k}$ Variance of j-th parameter of soil status in the soil layer k;
$\sigma_{j,k}$ Standard deviation for j-th parameter of soil status in the soil layer k;
k Soil layer – surface layer ((05) cm), lower layer ((5–20) cm);
i Segment of soil layer – 'A', 'B' and 'C'.

3 Reference Studies

Recently we have used optimized simply designed approach to the soil status monitoring for the purposes of baseline report preparation according to the Slovenian environmental legislation, presented in this contribution, in several commercial studies [36, 37, 38].

We have performed baseline soil status monitoring in cooperation with sub-contractors for different existing and new planned IED industrial installations across Slovenia, for instance:

- existing IED installations TALUM d.d., Kidričevo (Business units Aluminij, Livarna, Rondelice and Ulitki) – high energy efficient production of primary aluminium and global recognized top quality value-added aluminium products, including alloys, slags and castings;
- existing IED installation TAB d.d., Mežica – production of worldwide known high quality starter and industrial batteries, especially in Europe, Asia and America;
- existing IED installation STEKLARNA HRASTNIK d.o.o., Hrastnik – production of top quality and world renowned glass products and solutions that boast modern design;
- existing IED installation MESSER SLOVENIJA d.o.o., site Črnuče – highly efficient and fully optimised sustainable production of acetylene;
- new planned IED installation MAGNA STEYR d.o.o., Hoče-Slivnica – new planned industrial installation for surface treatment of metals using an electrolytic process (Cathodic dip piping)

4 Conclusion

Efficient regulated control over emissions from industrial processes could significantly contribute towards ensuring greener future and maintaining healthy living environment. In this contribution, we focused on short overview of Slovenian environmental legislation and technical presentation of an optimized simply designed approach to the soil status monitoring for the purposes of baseline report preparation as required by Industrial Emission Directive, which represent the main EU instrument for regulating pollutants emissions from industrial installations. We have used presented approach to the soil status monitoring in several commercial studies.

The results of all commercial studies finished so far as well as operators' feedback information have fully confirmed that the presented an optimized simply designed approach to the soil status monitoring for the purposes of baseline report preparation ensures high quality information of baseline soil status and regulatory compliance within acceptable cost budget.

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