# ECONOMICS OF REMEDIATION OF CONTAMINATED SITES IN THE CZECH REPUBLIC

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**Anotace:**

Long-term, intensive industrial activity in the Czech Republic has led to environmental damage in the form of contamination of the rock environment, groundwater, and surface water.

In May 2026, the Contaminated Sites Registry (SEKM) recorded more than 10,000 such sites. In addition to general information about the site, SEKM contains a range of other data (e.g., information on morphology, geology, hydrogeology, contamination levels, and risk). However, there is no systematic overview of the costs associated with implementing remedial measures. Therefore, the authors focused on the economic aspects.

This paper proposes a data-driven approach to the economic assessment of contaminated site remediation, based on the analysis of real project data. The study uses a dataset of 80 remediation projects financed from public sources (authors' own processing). Specifically, these included 20 site projects carried out under the Environment Operational Program and 60 decontamination projects funded by the Ministry of Finance of the Czech Republic. In terms of the types of contaminated sites, these included a municipal solid waste landfill, a contaminated area, production/storage/handling of petroleum substances, an industrial landfill,

and production/storage/handling of hazardous substances (other than petroleum). Statistical and regression methods are applied to evaluate unit remediation costs and their relationship to site-specific characteristics.

When correlations were analyzed between decontamination costs and the areas of decontaminated sites, the areas affected by contamination, the volume of waste, and the volume of hazardous waste, the resulting relationships were generally very weak. It is therefore clear that, in individual cases, multiple analytical, decontamination, and monitoring methods were used, each with varying durations.

The results show high variability of remediation costs and limited predictive capability of current models. These findings contribute to the development of a more standardized and transparent framework for contaminated site management and support more efficient decision-making in public administration.

**Key words:** contaminated sites, remediation, cost analysis, public administration

## Introduction

Industrial production has led to a fundamental transformation of society. In addition to the undeniable positive effects (e.g., new technologies, new industries, demographic changes), it is impossible to ignore the significant negative impacts. Technical progress has been bought off by the intensive use of natural resources, the transformation of the landscape, and the deterioration of the quality of the environment due to air, water and soil pollution.

Since in the second half of the twentieth century, environmental protection was a marginal issue in the Czech Republic, while extensive industrial activity was taking place, a large number of contaminated sites are emerging in the Czech Republic. Their emergence is a result of waste, chemical leakage, and the need to store by-products or hazardous products of industrial processes.

In the conditions of the Czech Republic, some sites have a very long and complicated history, which is why these sites are referred to as old ecological burdens. We consider old ecological burdens to be serious contamination of the rock environment, groundwater or surface water, which occurred in the past due to improper handling of hazardous substances, such as petroleum substances, pesticides, polychlorinated biphenyls, chlorinated and aromatic hydrocarbons, heavy metals, etc. [17].

In European Union countries, including the Czech Republic, the management of contaminated sites is a growing priority. This trend is driven by stricter environmental legislation and increased pressure on sustainable land use. The regulatory framework is defined mainly by the Waste Framework Directive (2008/98/EC), the Landfill Directive (1999/31/EC), and recent initiatives on soil monitoring and protection [1–3]. These policies require systematic identification of contaminated sites and long-term planning of remediation financing.

The issue of contaminated sites and old ecological burden is currently under the responsibility of the Ministry of Environment of the Czech Republic (MoE CR), which is trying to deal with the problem.

The Czech Republic Ministry of Environment is also a professional guarantor of the implementation of survey work and remediation interventions implemented from public funds, through the Operational Programme for the Environment or the so-called Ecological Contracts, but also from private funds [17].

The economic impact of contaminated sites is not limited to direct remediation costs. It also includes externalities such as health risks, loss of ecosystem services, and decreased land value [5]. Standard valuation approaches based on market prices are not sufficient to capture these impacts. More advanced methods, such as willingness-to-pay and hedonic pricing, improve the robustness of economic assessment [7].

At the international level, several approaches have been developed that integrate economic assessment into remediation decision-making. In the United States, the Superfund programme applies a risk-based framework that combines economic and health risk assessment. However, studies show that the costs of strict remediation standards can be very high and are not always proportional to the benefits achieved [8]. In Europe, cost–benefit analysis is commonly used, especially for publicly funded projects [5]. Some countries, such as Sweden, the Netherlands, and the United Kingdom, apply sustainability-based approaches integrating economic, environmental, and social criteria [9]. Recent studies further emphasise the need for integrated and data-supported decision frameworks that combine environmental risk, cost efficiency, and long-term sustainability outcomes [15; 16].

Despite these developments, remediation assessment remains highly complex. This complexity is driven by the nature of the contamination.

The selection of remediation technology further contributes to this complexity. Physical, chemical, and biological methods differ in their efficiency, cost, and time requirements. In practice, remediation projects often combine multiple technologies. This increases both technical and economic uncertainty [11].

A major limitation of current approaches is the availability and quality of the data. Existing databases often lack detailed and standardised cost information. This problem is evident in the Czech Republic, as well as in other European countries and in the United States [4, 6, 12]. As a result, statistical modelling is limited, and cost prediction remains uncertain. Recent research highlights that inconsistent datasets and missing cost parameters are among the key barriers to developing reliable predictive models for remediation planning [15].

Another critical issue is the structure of the remediation costs. Projects typically include several phases, such as site investigation, design, implementation, monitoring, and management. Some cost components, especially investigation and long-term monitoring, are often underestimated [13]. This leads to budget overruns and reduces the effectiveness of remediation strategies.

This paper proposes a data-driven approach to the economic assessment of contaminated site remediation, based on the analysis of real project data. The study uses a data set of 80 remediation projects financed from public sources (authors' own processing). Statistical and regression methods are applied to evaluate unit remediation costs and their relationship to site-specific characteristics.

The analysis aims to better understand the variability of remediation costs and to identify key cost-driving factors.

The research team set the following initial hypothesis at the beginning of their study:

H1: The sources of financing for remediation of contaminated sites do not affect the amount of planned costs.

## Theoretical foundations, methodology and data base

Human anthropogenic activity causes contamination of the environment and its adverse effects. Despite legislative, technical, and economic measures, human activity causes irreversible damage on the one hand, but on the other hand, activities are being developed to eliminate the ecological burden by reducing the concentration of undesirable substances to an acceptable level.

In the Czech Republic, data on contaminated sites are recorded in the Contaminated Sites Registry (SEKM). As of May 20, 2026, a total of 10,209 contaminated sites were recorded in the system. This number not only defines the severity of the problem but also implies that considerable financial resources will be needed to carry out the necessary remediation at the given locations.

The difficulty of remediation is determined not only by the extent of the affected site but also by the specific contaminants found in-situ and their volumes.

The diversity of the ecological burden is then reflected in the diversity of decontamination methods and technologies developed and applied, see Table 1.

*Table 1 Types of remediation methods according to the* directive *(EU) 2025/2360*

| **Group of methods or measures** | **Specific remediation method (technology, technique)** |
|---|---|
| **Physical remediation methods** | venting, aeration / air sparging<br>heat treatment, steam injection, thermal desorption, vitrification<br>soil washing and flushing<br>electrokinetic extraction (electroremediation)<br>liquid layer removal |
| **Biological remediation methods** | stimulation of aerobic or anaerobic degradation: bioremediation, biostimulation, bioaugmentation, bioventing, biosparging<br>phytoextraction, phytovolatilisation, phytodegradation // phytoremediation |

| | |
|---|---|
| | composting, soil amendments, landfarming, bioreactor systems<br>biofiltration, biotreatment wetlands, biobeds<br>monitored natural attenuation |
| **Chemical remediation methods** | chemical oxidation<br>chemical reduction and reduction-oxidation (redox) reactions |
| **Physico-chemical remediation methods** | pump and treat groundwater<br>photochemical oxidation, (photo)catalytic oxidation,<br>electrochemical oxidation |
| **Isolation and sorption methods** | surface capping, reactive barriers, encapsulation<br>chemical stabilisation, solidification and immobilisation<br>geo-hydrological isolation and containment<br>phyto-stabilisation |
| **Dig and dump** | dig and dump |
| **Control and aftercare** | control and aftercare through monitoring wells |
| **Other remediation methods** | other remediation methods (e.g., adsorption, ion exchange, liquid extraction, use of chelating agents, membrane technologies, ...) |

*Source: [10,14], own processing*

The choice of appropriate technology is influenced by specific conditions (e.g., decontaminated medium, contaminant, efficiency of the technology). For the sake of completeness, it is also necessary to state that one technology is usually not enough to remove the burden and that a combination of methods and technologies occurs. This fact is also reflected in the structure and budgets of the projects addressing decontamination.

The total costs of eliminating the consequences of the ecological burden of contaminated sites consist, in aggregate form, of the following costs: risk analysis costs, remediation costs, monitoring costs, and supervision costs.

To answer the research questions and verify the research hypotheses, the author team chose the following procedure:

1. Creation of a database
2. Determination of universal decontamination processes
3. Determination of average costs per unit
4. Description of selected processes
5. Regression and correlation analysis
6. Comparison of Operational Programme Environment (OPŽP) / Ministry of Finance of the Czech Republic (MF CR) datasets

Ad1)

The database was created using an agile approach. This means that it was created gradually as the research team managed to obtain the necessary data. The database consists of budgets for selected decontamination projects that were addressed within the Operational programme environment and the Ministry of Finance of the Czech Republic.

The research team first focused on the OPŽP calls. In these calls, decontamination projects that had received funding were identified. These records were then matched with SEKM records.

From this set of projects, a selection was made of those that were key in determining the costs of typical sites. The selection was based on primary selection criteria (e.g., site types, source of contamination and type of remediation technology) and a secondary criterion (year of remediation) to classify individual remediation projects.

The selection of sites of interest was made from the available completed decontaminations carried out on the basis of the OPŽP. Given the number of site types, it was also necessary to eliminate the less significant sites.

The significance of the site type was determined based on the percentage representation of the type in the SEKM database.

In the SEKM database 85% of all records are of 5 main types. These are:

- municipal solid waste landfill,
- contaminated site,
- production/storage/handling of petroleum substances,
- industrial landfill,
- production/storage/handling of hazardous substances (excluding petroleum).

The research team had at its disposal the budgets of 20 locality projects addressed within the Operational Programme Environment and 60 decontamination projects financed by the Ministry of Finance of the Czech Republic.

Ad2)

Although individual decontamination projects are different (location, scope, decontamination technology, duration of remediation), it can be assumed that there are crucial decontamination processes that are universal in nature.

The identification of universal processes was carried out based on the analysis of project budgets available to the research team.

Ad3)

The diversity of decontamination processes and the specifics of individual remediated sites make it impossible to objectively compare their costs. A certain starting point is the determination of average costs per unit. In our case, this unit can be, for example, a process, a tonne of waste, a tonne of soil, the length of the borehole, the volume of backfill. The average costs per unit are determined by the following relationship:

$$n_j = \frac{CN}{jv} \ , \qquad (1)$$

where:

$n_{jj}$ – average cost per unit [CZK/t], [CZK/m$^3$], [CZK/m],

$CN$ – total cost [CZK];

$j_v$ – unit of quantity [t], [m$^3$], [m].

Ad4)

The description of the average unit costs per unit of key decontamination processes provides a basic understanding of the issue under study. At the same time, this description can serve as a guide for determining the acceptability of the average unit costs of key processes in new projects.

The following indicators will be used for the description:

- arithmetic mean, which is, however, influenced by the occurrence of extreme values,
- median as a value in the middle of an ordered data, which is not influenced by extremely large or small values,
- variation range, which expresses the variability of a statistical set and is determined as the difference between the largest and smallest value of a quantitative characteristic.

Ad5)

Regression and correlation analysis will provide us with a deeper insight into the research issue. Thanks to these analyses, it will be possible to reveal whether there are indicators that have a strong influence on the total amount of costs.

With regression analysis, we try to describe the relationship (dependence) between two statistical variables using a mathematical function, the so-called regression function.

The regression function should be chosen based on a factual analysis of the relationships between statistical variables. We applied power, logarithmic, and exponential regression.

We assess the quality of the regression function and the intensity of the dependence using the determination index:

$$I_{yx}{}^2 = \frac{s_{\hat{y}}{}^2}{s_y{}^2} \tag{2}$$

where:

$s_{\hat{y}}{}^2 = \frac{\sum_{i=1}^{n}(\hat{y}_i - \bar{y})^2}{n}$ is variance of adjusted values, (3)

$s_y{}^2 = \frac{\sum_{i=1}^{n}(y_i - \bar{y})^2}{n}$ is variance of empirical values, (4)

$y_i$ are the empirical values of the dependent variable $y$,

$\hat{y}_i$ are the adjusted values of the dependent variable $y$ ,

$\bar{y}$ is the average of the empirical values $y_i$.

The determination index takes on a value from the interval ⟨0;1⟩, the closer the determination index value is to 1, the stronger the dependence is, and therefore well described by the selected regression function. The closer the determination index is to 0, the weaker the dependence is and the less accurate the regression function. If low values of the determination index are obtained, this does not necessarily mean a low degree of dependence between the variables, but it may signal an incorrect choice of the regression function.

Ad6)

A comparison of the OPŽP and MF ČR datasets was performed by testing the equality of the average unit costs of the individual decontamination processes for the projects funded by OPŽP and MF ČR. A classic two-sample test was used to test the equality of two means $\mu_1$ and $\mu_2$ , where we test

the null hypothesis $H_0$: $\mu_1 = \mu_2$

against the alternative hypothesis $H_1$: $\mu_1 \neq \mu_2$

in the case where we do not know the variances of the basic sets, but we can assume that

a) they are the same
b) they are different.

It is clear that the hypothesis of variance agreement was first tested for all decontamination processes.

In case a), the test criterion was used

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{(n_1-1)s'_1{}^2 + (n_2-1)s'_2{}^2}{n_1+n_2-2}}\sqrt{\frac{1}{n_1}+\frac{1}{n_2}}} \tag{5}$$

where:

$s'_1{}^2$, $s'_2{}^2$ sample variances,
$n_1$, $n_2$ sample ranges,
$\bar{x}_1$, $\bar{x}_2$ sample means.

The test criterion has a $t$ distribution with $\nu = n_1 + n_2 - 2$ degrees of freedom under the null hypothesis.

In case b), the test criterion was used

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s'_1{}^2}{n_1}+\frac{s'_2{}^2}{n_2}}} \tag{6}$$

This test criterion has approximately a $t$ distribution with $\nu$ degrees of freedom under the null hypothesis, where $\nu$ is calculated according to the following formula:

$$\nu = \frac{\left(\frac{s_1'^2}{n_1}+\frac{s_2'^2}{n_2}\right)^2}{\left(\frac{s_1'^2}{n_1}\right)^{\frac{1}{n_1+1}}+\left(\frac{s_2'^2}{n_2}\right)^{\frac{1}{n_2+1}}} - 2 \quad (7)$$

**Results and discussion**

Based on the analysis conducted and the subsequent comparison of the decontamination structure in terms of individual processes, the following were identified as "universal" key processes:

- sampling
- laboratory analysis
- waste removal
- soil extraction
- drilling
- backfilling
- demolition
- water discharge
- rubble recycling
- soil handling
- mass transfer
- excavation
- waterproofing
- trenching
- concreting foundations
- water pumping
- well disposal
- material handling
- waste disposal

Unit costs were calculated for individual key processes and described using descriptive characteristics, see Tables 2 and 3. The calculation was carried out on the basis of the processed budgets of the OPŽP projects (see Table 2) and the projects financed by the Ministry of Finance of the Czech Republic (see Table 3). If only one value was found for individual processes, the process was not taken into account further.

*Table 2 Description of key processes – OPŽP projects*

| Process | Median | Arithmetic Mean | Value Range | Number of values |
|---|---|---|---|---|
| Sampling (CZK/pcs) | 306 | 432 | 60 – 1 673 | 20 |
| Laboratory analysis (CZK/kpc) | 943 | 1 105 | 426 – 2 440 | 19 |
| Waste removal (CZK/t) | 1 485 | 3 643 | 163 – 24 141 | 20 |
| Drilling (CZK/m) | 2 217 | 2 995 | 779 – 11 097 | 14 |
| Backfilling (CZK/m$^3$) | 172 | 218 | 70 – 783 | 15 |
| Demolition (CZK/m$^3$) | 1 200 | 2 373 | 475 – 7 732 | 9 |
| Soil handling (CZK/m$^3$) | 112 | 150 | 60 – 289 | 5 |

| | | | | |
|---|---|---|---|---|
| Mass transfer (CZK/t) | 565 | 565 | 95 – 1 034 | 2 |
| Excavation (CZK/m$^3$) | 95 | 119 | 55 – 231 | 4 |

*Source: own processing*

*Table 3 Description of key processes – MF projects*

| Process | Median | Arithmetic Mean | Value Range | Number of values |
|---|---|---|---|---|
| Sampling (CZK/pcs) | 278 | 360 | 50 – 1 160 | 57 |
| Laboratory analysis (CZK/pcs) | 539 | 724 | 65 – 3 713 | 58 |
| Waste removal (CZK/t) | 1 029 | 2 692 | 41 –22 040 | 51 |
| Soil extraction (CZK/m$^3$) | 145 | 281 | 3 – 1 659 | 17 |
| Drilling (CZK/m) | 2 238 | 2 397 | 968 – 4 850 | 33 |
| Backfilling (CZK/m$^3$) | 96 | 151 | 7 – 874 | 32 |
| Demolition (CZK/m$^3$) | 1 000 | 2 167 | 301 – 9 850 | 25 |
| Rubble recycling (CZK/t) | 291 | 291 | 182 – 400 | 2 |
| Soil handling (CZK/m$^3$) | 78 | 139 | 11 – 630 | 23 |
| Mass transfer (CZK/t) | 171 | 253 | 9 – 1 053 | 16 |
| Excavation (CZK/m$^3$) | 271 | 341 | 20 – 954 | 16 |
| Waterproofing (CZK/m$^2$) | 92 | 158 | 72 – 349 | 5 |
| Concreting foundations (CZK/m$^3$) | 2 822 | 2 757 | 297 – 4 403 | 6 |
| Well disposal (CZK/m) | 270 | 242 | 102 – 353 | 3 |
| Material handling (CZK/m$^3$) | 108 | 108 | 24 – 192 | 2 |

*Source: own processing*

The conditions under which individual remediation activities are carried out are the decisive cause of the identified cost variances. However, errors made by humans during the calculation itself cannot be ruled out.

How conditions affect the cost of remediation activities is evident from the examples below, see Table 4. The above influencing factors were identified on the basis of statements of individual budget items that the authors had at their disposal.

*Table 4 Examples of factors influence the cost of redevelopment activities*

| Remediation activity | Influencing factors |
|---|---|
| **Sampling** | – different prices of sampling equipment purchased from different suppliers |
| **Laboratory analysis** | – different prices of chemicals, or materials and equipment used in laboratory analyses |
| **Waste removal/Waste disposal** | – type of waste (hazardous waste, other waste)<br>– method of handling waste (e.g., transhipment)<br>– length of transport to the waste disposal site |

| | |
|---|---|
| | – method of waste disposal |
| **Soil extraction** | – type of soil being excavated<br>– mechanization used<br>– depth from which the soil is being excavated<br>– necessity of lining the excavation walls |
| **Drilling** | – type of rock being drilled<br>– type of well (e.g., drainage)<br>– diameter of well, depth of well<br>– method of drilling (e.g., vertical, inclined)<br>– well rig<br>– type of drilling system<br>– core or full-profile well |
| **Demolition** | – type of building to be demolished<br>– material of the building to be demolished<br>– type of mechanization used<br>– demolition in whole or by gradual dismantling |
| **Concreting foundations** | – type of concrete used<br>– amount of concrete used |

*Source: own processing*

These influencing factors may have resulted in varying average values and ranges for individual decontamination operations.

To illustrate this, we selected several activities that occurred at multiple sites and that, based on their names, did not include any additional cumulative activities.

This resulted in Table 5 that contains the average costs and ranges for selected activities within the relevant types of decontamination.

The probable causes of the spread can be assessed as follows:

Smallest range: surface water sampling. It can be assumed that the cause is relatively simple sampling technology that does not involve any additional activities.

*Table 5 Average costs and valves ranges for selected activities*

| Activities | OPŽP | | Industrial areas | | Petroleum substances | | Except petroleum substances | | Industrial landfills | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ∅ | range | ∅ | range | ∅ | range | ∅ | range | ∅ | range | ∅ | range |
| Surface water sampling | 246 | 200 | 190 | 260 | 221 | 254 | 95 | 10 | 180 | 200 | 204 | 310 |
| Ground water sampling | 463 | 590 | 180 | 220 | 228 | 318 | 313 | 450 | 100 | 100 | 301 | 750 |
| Heavy metal analysis in water | 741 | 450 | 158 | 165 | | | | | 796 | 0 | 582 | 975 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Soil sampling | 226 | 750 | 250 | 350 | 136 | 264 | 113 | 60 | 117 | 100 | 188 | 750 |
| Demolition brick | 1 122 | 226 | 123 | 0 | 338 | 0 | | | 1 000 | 0 | 741 | 1 112 |
| Demolition reinforced concrete | 1 855 | 2 515 | 367 | 0 | 1 788 | 1 525 | 4 875 | 0 | | | 2 030 | 4 508 |
| Dynamic groundwater sampling | 1 056 | 500 | 950 | 1 250 | 493 | 779 | 953 | 1 720 | 800 | 0 | 884 | 1 800 |

*Source: own processing*

The largest range: demolition of reinforced concrete structures. In these cases, the cause may be the varying proportion of heavy machinery used in demolition work. This proportion was quantified in some cases and was not uniform.

The second largest range is for groundwater sampling in a dynamic manner. The sampling technology can play a role here – pumping from wells, use of a sampling pump.

The third largest share is in the demolition of brick buildings. Here, the influence of the mechanisation used or the gradual dismantling of the building can be assumed.

There is a considerable range in the analysis of heavy metals in water. The influence may be due to the number of metals analysed.

The range of soil sampling can be expected to be influenced by the type of soil and the sampling method.

Soil and water contamination can be caused by a variety of industrial activities using a variety of substances. This is reflected in a number of decontamination procedures and activities.

The analysis further focused on determining the dependence of the price of total decontamination excluding VAT of OPŽP projects on the following indicators:

- affected area (for all areas)
- area of the site (only for OPŽP projects and industrial areas)
- amount of waste in tonnes;
- amount of hazardous waste in tonnes

The strength of the dependence can then be assessed from the correlation relationship.

The reason why the studies focused on OPŽP projects is that the author team had relevant data available. This was not the case for the projects of the Ministry of Finance of the Czech Republic.

The dependence of the cost of decontamination on the contaminated area is expressed by the power function

$$y = 2\,811\,487{,}3425 \cdot x^{0{,}3792};\ R^2 = 0{,}4393 \qquad (8)$$

where:

$y$ – cost of decontamination of the site in CZK,
$x$ – affected (contaminated) area in m²,
$R^2$ – coefficient of determination.

The dependence graph is shown in Figure 1.

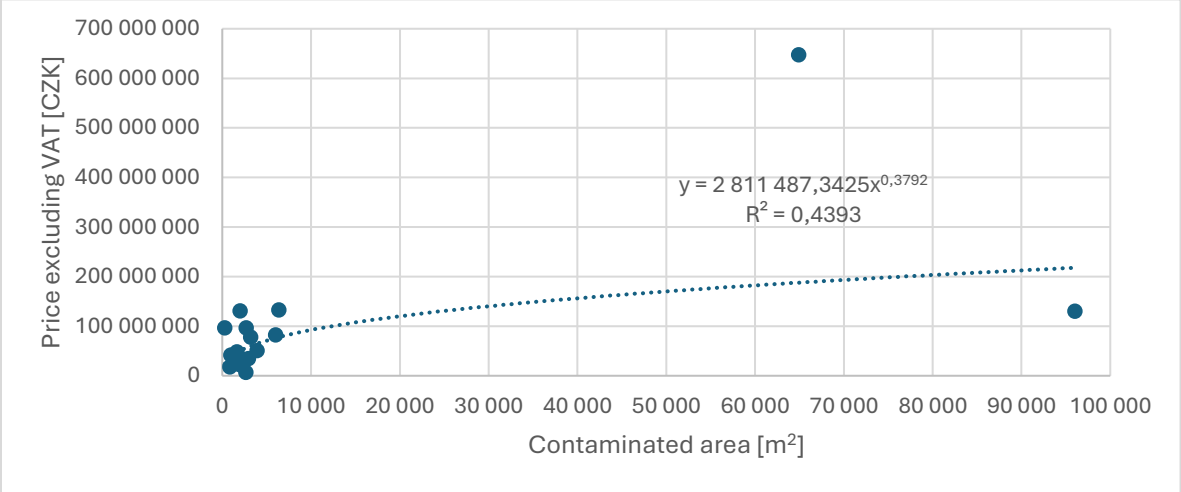


*Figure 1 Dependence of decontamination price on contaminated area*

*Source: SEKM, own processing*

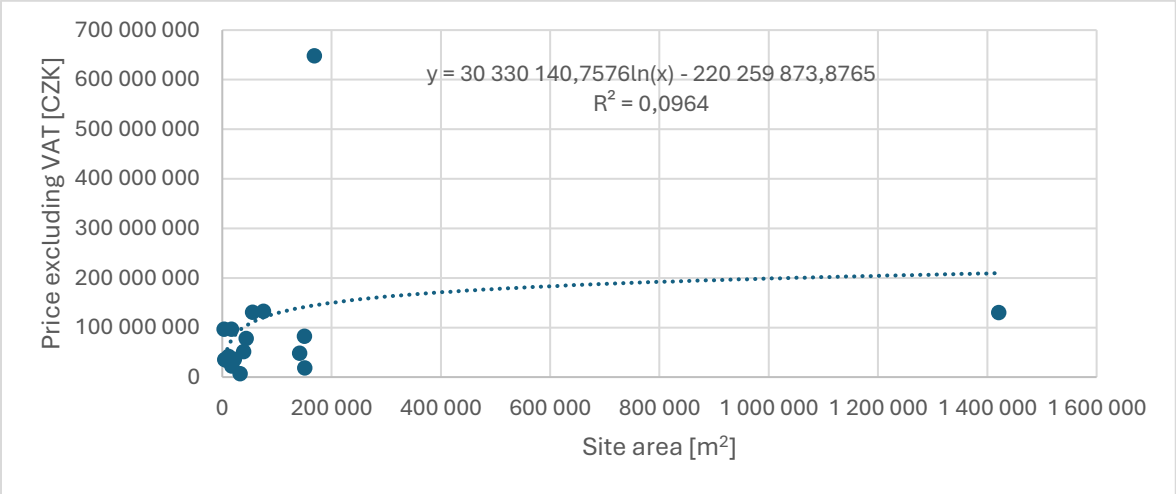


*Figure 2 Dependence of decontamination price on the area of the site (OPŽP)*
*Source: SEKM, own processing*

The dependence of the price of decontamination on the area of the site is expressed by a logarithmic dependence, which is expressed by the relation (9) and is shown in Figure 2.

$$y = 30\,330\,140{,}7576 \cdot \ln x - 220\,259\,873{,}8765;\ R^2 = 0{,}0964 \qquad (9)$$

where:

$y$ – cost of site decontamination in CZK,
$x$ – site area in m²,

$R^2$ – coefficient of determination.

The dependence of the price of decontamination on the area of the site is much weaker than in the case of the affected area.

The dependence of the decontamination price on the amount of waste is described by an exponential function:

$$y = 31\,329\,217{,}1508 \cdot e^{0{,}0001x}\ ;\ R^2 = 0{,}1631 \qquad (10)$$

where:

$y$ – cost of decontamination of the site in CZK,
$x$ – amount of waste in tonnes,
$R^2$ – coefficient of determination.

The dependence graph is shown in Figure 3. It shows a weak dependence, mathematically caused by the price movement of most actions in a relatively narrow range over a wide range of waste quantities.

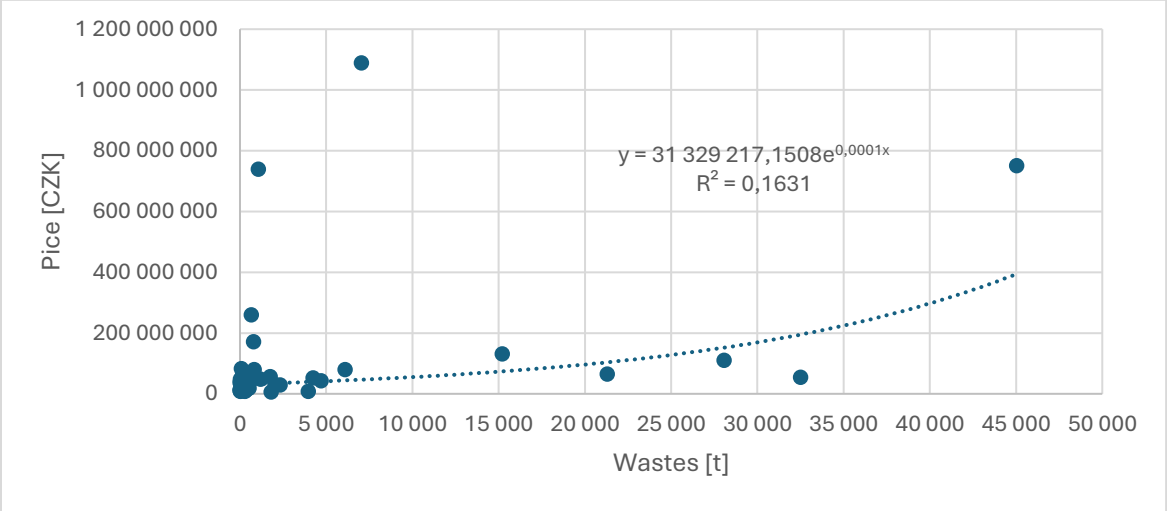


*Figure 3 Dependence of decontamination price on the amount of waste in tons*
*Source: SEKM, own processing*

The dependence of the price of decontamination on the amount of hazardous waste is described by an exponential function

$$y = 27\,870\,330{,}89976 \cdot e^{0{,}0004x};\ R^2 = 0{,}19176 \qquad (11)$$

where:

$y$ – cost of site decontamination in CZK,
$x$ – quantity of hazardous waste in tons,
$R^2$– coefficient of determination.

The dependence presented in Figure 4 is only slightly stronger than the previous dependence on the amount of waste and is again very weak. It can be concluded that decontamination processes have a wider scope than the removal of waste or hazardous waste. In the case of this

dependence, a trend of increasing the price of decontamination on the amount of hazardous waste can be observed, which is more pronounced than in the previous case.

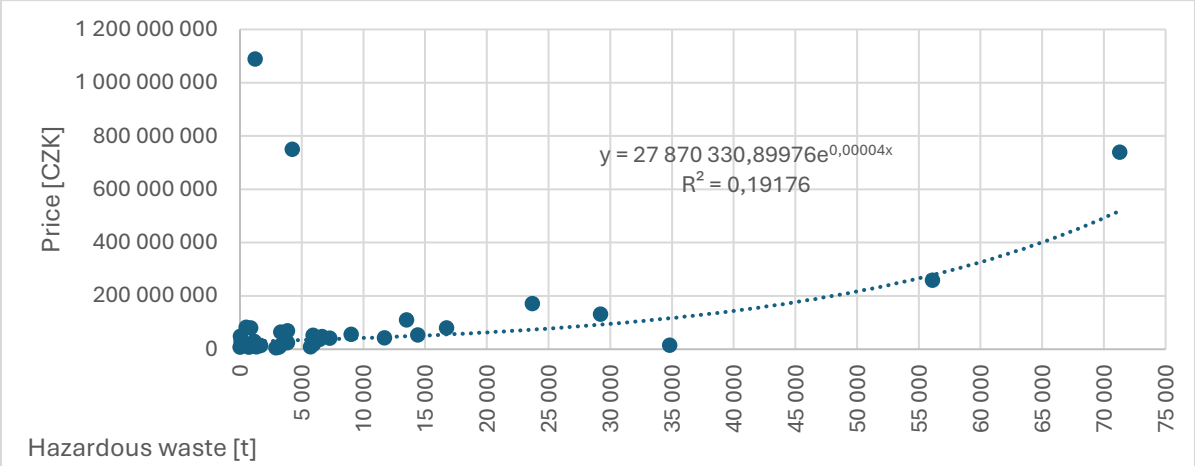


*Figure 4 Dependence of the price of decontamination on the amount of hazardous waste in tons. Source: SEKM, own processing*

To verify hypothesis H1, it was tested whether the average unit costs of individual decontamination processes differ statistically significantly in projects financed from the Operational Programme Environment and from the resources of the Ministry of Finance of the Czech Republic.

The implementation of the tests was limited mainly by the lack of necessary data or a small number of data, especially for the data set of the Operational Programme Environment.

This fact is evident in Table 6, which lists the quantities needed for the testing.

*Table 6 Overview of input variables*

| **Process** | | **Mean** | | **Sample variance** | | **Number of values** | |
|---|---|---|---|---|---|---|---|
| | | MF dataset | OP Environment dataset | MF dataset | OP Environment dataset | MF dataset | OP Environment dataset |
| Sampling | CZK/pcs | 360 | 432 | 56 277 | 158 795 | 57 | 20 |
| Laboratory analysis | CZK/pcs | 724 | 1 105 | 481 623 | 328 479 | 58 | 19 |
| Waste disposal | CZK/t | 2 692 | 3 643 | 18 184 805 | 35 719 821 | 51 | 20 |
| Drilling | CZK/m | 2 397 | 2 995 | 779 656 | 7 421 195 | 33 | 14 |
| Backfilling | CZK/m$^3$ | 151 | 218 | 27 681 | 35 837 | 32 | 15 |
| Demolition | CZK/m$^3$ | 2 167 | 2 373 | 5 315 825 | 6 707 193 | 25 | 9 |
| Soil handling | CZK/m$^3$ | 139 | 150 | 24 232 | 8 562 | 23 | 5 |
| Mass transfer | CZK/t | 253 | 565 | 74 989 | 440 135 | 16 | 2 |
| Excavation | CZK/m$^3$ | 341 | 119 | 72 274 | 6 451 | 16 | 4 |

*Source: own processing*

Therefore, testing was carried out only for the processes listed in Table 7, which also shows the result of the testing at the five percent significance level.

The average unit prices of individual processes were tested whether to differ statistically significantly in the data set of the Operational Programme Environment and the Ministry of Finance of the Czech Republic.

The implementation of the tests was limited mainly by the lack of necessary data or a small number of data, especially for the data set of the Operational Programme Environment.

*Table 7 Testing results*

| **Process** | **Testing results** |
|---|---|
| Sampling | the difference is statistically insignificant |
| Laboratory analysis | the difference is statistically significant |
| Waste disposal | the difference is statistically insignificant |
| Drilling | the difference is statistically insignificant |
| Backfilling | the difference is statistically insignificant |
| Demolition | the difference is statistically insignificant |
| Soil handling | the difference is statistically insignificant |
| Material handling | the difference is statistically insignificant |
| Excavation | the difference is statistically significant |

*Source: own processing*

The results of the testing therefore show that only the unit costs of laboratory analyses and the unit prices of excavation differ statistically significantly in both data sets.

Therefore, hypothesis H1 cannot be unequivocally confirmed.

## Conclusion

Determining the objective costs of decontamination is of considerable importance in practice. The implementers of these actions are selected through tenders.

On the one hand, there is a risk of underestimating the decontamination processes to obtain a specific contract, since the cost of decontamination (decontamination price) is one of the important criteria of the tender. In this case, requirements for cost increases can appear during the contract implementation.

On the other hand, there is a risk that, with little competition or with priority given to criteria other than the price of decontamination, the bid price will increase unjustifiably, primarily due to the influence of the human factor.

As part of the research we conducted, we tried to find out whether there are certain dependencies in this area and what can influence the price of decontamination.

When using correlations between decontamination costs and areas of decontaminated sites, areas affected by pollution, amounts of waste, and amounts of hazardous waste, the relationships obtained were mostly very weak. It is therefore clear that in individual cases multiple analytical, decontamination, and monitoring methods with different durations were used.

Therefore, we attempted to reduce this heterogeneity of activities by selecting individual processes within decontamination for which higher homogeneity could be assumed, i.e. the identity or similarity of the processes could be assumed.

The results in Table 5 show that within each type of decontamination, processes with the same names differ significantly in terms of average values and cost ranges. This means that even this level of homogenisation is not sufficient.

Another possible approach would be to describe the individual activities in more detail, for example in terms of equipment used, procedures, etc. The reason is that the budgets and reports of decontamination actions are not detailed enough to allow the selection of completely comparable activities. The detailed analysis of these materials is a way to check whether the budgeted and reported activities are correct. However, this approach is relatively laborious.

It seems more acceptable to determine the average costs and cost ranges of individual decontamination activities from a larger number of data (but comparable) and to check in cases where these values are significantly exceeded for an individual decontamination action.

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