EVALUATION OF CLEAN-UP PROCESSES: AN ECONOMIC PERSPECTIVE

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Abstract

The aim of the article is to discuss practical examples of brownfield remediation where economic analysis can be applied. The work contains empirical research and analysis of valuation methods applied to two real case studies in the Czech Republic. The article discusses a problem of economic efficiency of enviromental protection costs needed to remove old ecological burdens. In the first part there are outlined various economic approaches to optimization of stabilization processes. The second part deals with a model of cost efficiency for a specific stabilization technology and its possible accounting records. This paper was prepared with the financial aid of the Czech state budget through the project "Advanced remediation technologies and processes No. 1MO554" from the program "Research Centres PP2-DP01" of the Ministry of Education Youth and Sports.

Introduction

At the end of the 1980´s the Czech territory had to face up not only socio-economic and political changes, but also problems related to the devastation of the natural environment in specific areas. The changes in the political situation (after 1989) and the preparation of the country for the accession to the European Union (1999-2003) contributed to the improvement of the administrative and legal framework related to the protection of the environment. However there are still issues which need to be improved such as the management of historical contamination (*Černíková* 2007, p. 20). Historical contamination appeared, for example, as a result of the stay of the former Soviet army in the Czech territory before 1989. Other cases of historical contamination are the vestiges of former mining activities and mineral extraction. These sites are significant due to their frequent location in the vicinities of ecosystems whose environment might be heavily endangered, so their cleaning-up processes may be costly not only in time, but also in financial terms. The article includes macroeconomic and microeconomic considerations of the analysis of historical contamination and shows two cases within the Czech territory, applying the ideas developed in the first part of the paper. The main objective of the work is to present the theoretical background of economic efficiency of enviromental protection costs needed to remove old ecological burdens, and to show applications of these ideas in two specific cases for the Czech Republic. The methods used in the short case studies include applications of direct revealed market preferences and averting expenditures method for the macroecnomic part, and a model of a cost efficiency for a specific stabilization technology and its possible accounting records in

the microeconomic part. Both case studies correspond to localities where the Center for Advanced Remediatial Technologies of the Technical University in Liberec took part in the research and testing of novel technologies regarding remediation processes.

1 Economic Perspective

Environmental economics might want to set up a monetary expression for the lack of satisfaction that subjects of the society put for decrements of environmental quality (damage) within issues related to brownfields. Neoclassical economics deals with this issue with tools approaching monetary values to non market goods. The methodologies used for these estimations in the branch of brownfields can vary from benefit transfer methods, to non market valuation methods such as hedonic pricing, and contingency valuation among others. The results of cases using these methods are mainly complemented with Cost-Benefit Analysis. A solution diagram for the management of brownfields showed by *Čiháková* (2009, p. 27) suggests the estimation of damages and costs in order to take decisions concerning the remediation techniques to be applied on specific sites.

a. The Cost Side, Replacement Cost, and Substitute Cost Methods

Replacement cost and substitute cost methods are related methods that estimate values of ecosystem services based on either the costs of avoiding damages due to lost services, the cost of replacing ecosystem services, or the cost of providing substitute services.

Other valuation methods can include more elements of the economic value of environmental assets than the protection or decontamination costs. For instance, the Travel Cost Method reflects the use value and in combination with the method of Willingness to Pay, the option and bequest value can be inferred. Even if the replacement cost and substitute cost methods do not give any exact measure of economic values, they assume that the costs of avoiding damages or replacing natural assets or their services can be useful estimations of the value of these assets or services. In absence of the results of estimations from willingness to pay, it may be, therefore, assumed that, if people incur costs to avoid damages caused by lost ecosystem services, or to replace the services of ecosystems, then those services must be worth at least what people paid to replace them.

b. Direct Revealed Market Preferences and Averting Expenditures Method

The averting expenditures method sets the value of a source through the observation of the peoples´ behaviour against health and environmental risks. In other words, how much people are paying in order to avoid damage. A direct revealed preference for sources having a defined market with prices, can also reveal a lot about the value people put in such sources.

1.1 Evaluation of Effectiveness of Remediation Technologies

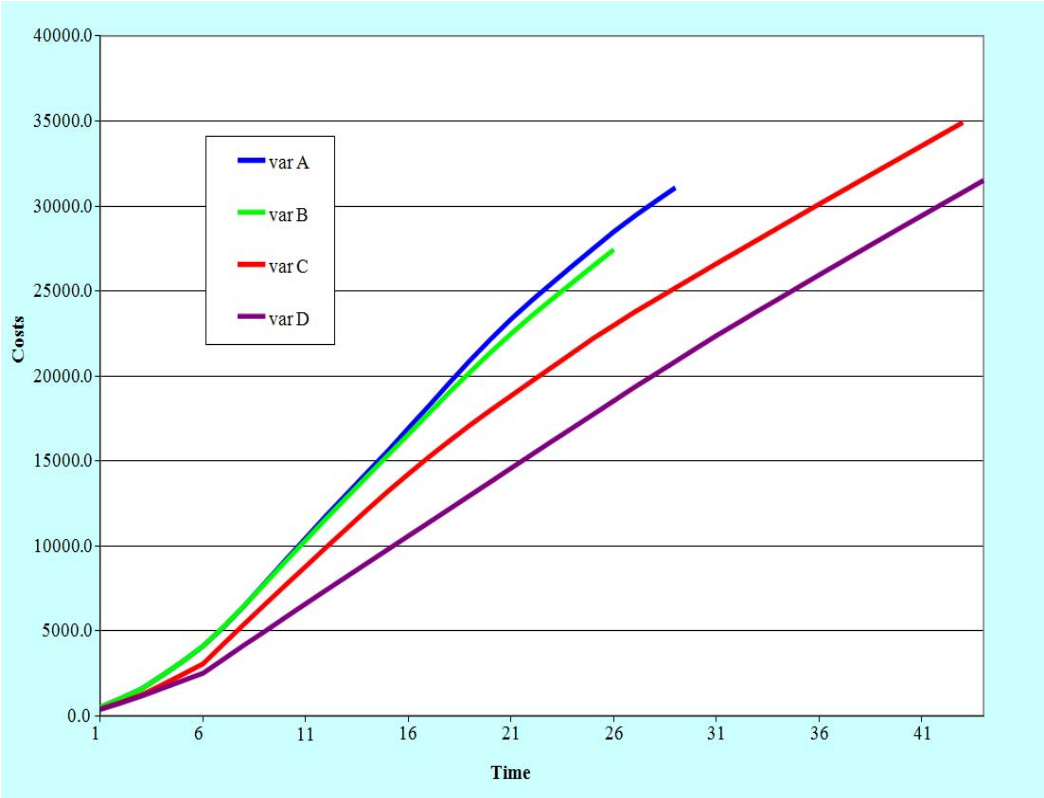
Cleaning-up processes require to clearly establish the target parameters and to formulate the diverse technological methodologies. Cleaning-up processes become extremely prominent projects mainly because of the uncertainty (lack of precise data about the area covered by the contaminants and its potential growth). Therefore, certain tasks are specific for the development of a cleaning-up process:

- continuous updating of the existing documentation;
- continuous analysis of the legislative framework;
- continuous analysis of emerging techlonogies.

In order to achieve a successful cleaning-up process, it is necessary to take into account the following points:

- to choose the appropriate chemical substances according to the contaminated environment (groundwater, soil, etc.) and the specific objectives of the cleaning-up process,
- to evaluate the physicochemical, the toxicological and bioaccumulative characteristics of the most relevant contaminants and establish the adequate concentration of cleaning substances,
- to choose the cleaning-up area according to the location of contaminants and their interaction with the natural environment,
- to develop a feasibility study if there is more than one available technology,
- to replace the cleaning-up technology if it presents ineffective or inefficient results (Aqua 1997, p 35).

One of the most appropriate ways to evaluate effectiveness for cleaning-up technologies is the cost-effectiveness analysis. The advantage of this method is that it is not necessary to express in monetary terms the effects of the incurred environmental costs, because it is enough to express them in terms of physical units (concentration and residual levels of contaminants). The criteria for optimization can be the maximization of positive effects for each unit of incurred costs, or the minimalization of costs for each unit of positive effect (*Šauer* 2005, p 21). The evaluation of the effectiveness of the whole cleaning-up process can be pursued by a technological-economic model. These models can be understood as a detailed cost model in which each specific cleaning-up activity corresponds to a specific cost category. *Figure 1* shows a hypothetical time model (years) of the costs for each remediation scenario.



Source: Černíková 2007, p. 23.

Figure 1 Comparison of the effectiveness of alternative remediation technologies

The information obtained from these models cannot only indicate the economic effectiveness of concrete processes, but it can also be useful in order to compare and select the most appropriate and effective technologies. Examples of criteria for the evaluation of effectiveness in cleaning-up processes can be:

- The minimum value of the total costs incurred for a required target level of contamination;
- The minimum value of average unit costs of the cleaning-up.

The technical-economic cleaning-up model might result at providing enough qualitative information in order to support the decision for the correct selection of the cleaning-up technology in the location in question. As examples of this kind of information we can mention: total costs after reaching the desired level of decontamination, the value of average unit costs during the cleaning-up process, development of marginal costs. These values and the constant comparison of expected and real costs can be also helpful in order to evaluate the effectiveness of single phases and specific operations within the whole process and can facilitate the formulation of alternate technologies if necessary. It becomes important to consider that the less time in which the technical-economic model can be pursued, the more useful it becomes for decision makers to select the most appropriate technology. This will also depend on the data availability.

2 Case studies

The theoretical background discussed above was practically translated into two case studies for clean-up localities in the Czech Republic, where it was mainly tested the technical effectiveness of different cleaning-up methods. Both of the cases correspond to locations where the Center for Advanced Remedial Technologies of the Technical University in Liberec has developed research projects.

2.1 Case Study - Stráž pod Ralskem

Due to the mining activity related to the extraction of uranium in Straz pod Ralskem, contamination (H2SO4, HNO3, NH3, HF, HCl among others) has been spreading into the cenoman basin with the probability of filtration through the turon collector of water. The endangered area is located at the protected natural area of water sources in the North Bohemian cretaceous sedimentary deposit, which is a very important source of groundwater for drinking purposes. (*Čermáková* et al. 2002), (Czech Act on Public Water Supply and Sewerage Systems 274/2001, Edict 428/2001). The actual cleaning up process in the area follows the methodology of draining and cleaning the water at the stations of elimination of acid solutions, and neutralization of pollutants. The technologies applied are at the surface levels through evaporation of water, which results in crystalization and recrystalization and condensation of salts and metals, which are then processed for their further uses or eventually for their disposal. The cleaned water is discharged into the Ploucnice River.

In the officially available information, the state company in charge of the cleaning-up process has presented estimated cleaning-up costs up to 45,623.9 mil. CZK (1990-2040), (DIAMO, 2006). We have chosen the replacement cost method because the costs of cleaning up have actually been estimated in the particular location of North Bohemia, which facilitates the provision of an approximate of reality. Further work has been done in order to estimate the volume of water sources endangered. Our estimation of the volume of water sources endangered took into account the average water yield in the blocked area (cleaning-up area) of the turon basin measured in units of volume vs. area and time. (400 litres per second), (*Herčík* et al. 1999). The information shown in *Table 1* expresses the cost of cleaning up each

cubic meter in the area in question, taking into account the volume of water blocked during the process. The table can be interpreted basically in two ways:

a) Under the assumption that no cleaning-up process would be pursued in this location, the minimum volume of water to be polluted would correspond to the results shown in the table. For illustrative purposes one can imagine that one year of blocked source of water corresponds approximately to the average water consumption of a town compound with 150,000 inhabitants. (The Czech Republic reported by year 2003 a daily water consumption of 200 litres. per person per day). 50 years of "no-action" would represent a potential loss of water sources for about 7.5 million people at the actual rate of water consumption. The natural attenuation process of decontamination is estimated to be 1,500 years.
b) Under the actual conditions, the amount of water shown in the table is the volume of groundwater sources protected. During the whole period of time of the duration of the cleaning-up process, the cost of each cubic meter of source of water protected represents 72 CZK. (Total cleaning-up costs were estimated at about 45 mil. CZK).

Table 1 Estimated Changes of the Volume of Source Water. North Bohemia

Time(Y)	blocked source of water [m3]	cost of cleaning-up [CZC /m3]
1	12 614 400	
50	630 720 000	72
100	1 261 440 000	
1500	18 921 600 000	

Source: Aguilar Bobadilla 2007

The specific quantity of 72 CZK [1] for each cubic meter of groundwater protected could also be interpreted as the Willingness to Pay from the Government in order to keep water sources for future uses; thus it reflects the option value of groundwater in this area until the process of cleaning-up will have reached its end [2]. For our particular case we decided to confront the data obtained from the remediation costs, with the data providing actual consumption patterns of substitutes. As concrete data we used the consumption of bottled water in the Czech Republic. The information gathered about different results of estimations of willingness to pay in other countries confirmed other author's opinions *Goerlach* et al. (2003, p. 58) of the difficulties of the application of this method towards groundwater sources. There is also an evident difference between the results pursued according to water sources that seem to be more tangible for people (such as surface water). Groundwater characteristics are less probable to be recognized by average educated citizens. An exception of this case was presented by *Hasler* et al. 2006, where peoples´ awareness of groundwater values is higher. We also concluded that groundwater valuation becomes difficult due to lack of appropriate information about the characteristics of this kind of water sources. We also applied the method of direct revealed market preferences through the consumption of bottled water in the Czech Republic. It reflects pure direct revealed market preferences and shows the purchasing

[1] The cost of cleaning up takes into account the total amount of investment (45mil.CZK) divided by the total volume of estimated blocked water for the period of time examined.
[2] For the purposes of this analysis we consider the government as a stakeholder, thus another group of the society,that takes decisions regarding the use of financial resources towards the protection of the environment. In this particular case the government is demanding clean-up services to other companies.

power of consumers for drinking water. In year 2006 the average price of a liter of mineral water was about 6 CZK (about 0.21 EUR)[3]. After analysing available statistical data form the Czech Republic, we observed that the average consumption of bottled water for year 2006 (86 litres per year) corresponds to 0. 2% of the total consumption of water (129 litres per day)[4].

Even if this ratio can be taken as insignificant, we may not forget about the fact that the trend of consumption of bottled water has been incrementing in the last years. Protected water sources for the future may therefore represent not only a potential for public water supply, but also as opportunity for markets of beverages, for instance. If a future increasing market of beverages would be considered, it may thus, compensate the remediation costs.

2.2 Case Study - Kuřivody

A comparison of clean-up technologies can be made in locations contaminated after the Soviet military occupation in the Czech territory (until year 1989). The particular case of Kurivody represents a good example of historical contamination where militar activity polluted sources of groundwater. Specifically, this area was used for the cleaning of machine parts and equipment. The clean-up process began in year 1996. At that time prevealed mainly high concentrations of chlorinated hydrocarbons, tetrachloroethylene, trichloroethylene, dichloroethylene, and vinyl chloride. The method pump and treat in combination with the application of potash was used until year 2004 in order to reduce the concentration of contaminants. However, the results where not sufficient to cover the target parameters of the clean-up previously determined. It was, therefore, considered to apply alternative methods for decontamination. The methods compared are:

- in-situ biological reduction through lactactes;
- in-situ chemical reduction through nanoparticles of zero-valent iron (nanoFe).

Both methods require the installation of diffussion and monitoring wells in an area of 22,000 m^2. (AQUA 2007)

We divided the most relevant types of financial expenditures related to clean-up methods into three groups:

1) exploration and preparation works, project working;
2) clean-up process;
3) concluding activities.

Table 2 shows in detail the comparison of both technologies in accordance with the type of financial expenditure and the effectivity of decontamination of the applied technology in order to achieve the established target parameters. The clean-up process has been planned to run from 2009-2013. As a result of the microeconomic comparison of clean-up technologies, we can see how the application of lacatates might be more convenient (10% less costs than by nanoFe). The application of nanoFe requires a double amount of diffussion wells, and, therefore, it becomes more rostly; however, their installation is cheaper because there are required just three dibbles instead of five for the lactates technology. The highest expenditure is the purchase of NanoFe, where actual prices are assumed. There is also the possibility that prices will become lower due to changes in the market. Another factor to consider is the high consumption of water in the case of lactates, which also makes this technology less attractive. This model situation is adapted form the pilot tests of both technologies in other localities and the exploration works in Kurivody.

[3] In year 2010 the average price of municipal drinking water in the Czech Republic was around 64..59 CZK per cubic meter. http://www.cenyenergie.cz

[4] See for instance http://www.pvk.cz/specificka-spotreba-vody.html

It becomes always very difficult (and sometimes controversial) to determine the economic effectiveness of cleaning-up processes. Even under assumptions of clean-up companies about the quantification of the costs and the testing results for different scenarios, it is not possible to confirm the effectivity of the remediation technique applied. The location mentioned above has been under clean-up processes pursued by different companies since 1990. The available information shows only general estimations about the quantity of eliminated contamination. During 1993-1999 there were invested about 30 mil CZK (eliminated 2 t of contaminants). Until year 2011 it is estimated to have cleaned about 9 t of pollutants and invested (mainly from public sources) 26 mil CZK, even if the regular monitoring did still not show indicators of any permanent reduction of the contamination.

For this particular case, it can be concluded that the financial resources invested by public entities are not being used effectively.

Table 2 Expenditures for the specific clean-up technologies for the locality Kurivody

Expenditures in thousands of CZK (without VAT)	**Methods**	
	Lactates	**nanoFe**
1. exploration, preparation and project working	3,975	5,450
Preparation of the wells	2,175	4,050
Pilot tests	500	500
Technology installation	1,000	600
2. Realization	8,485	9,380
Main decontaminating substances	4,000	8,700
Water consumption	3,500	105
Technology operation	925	555
3. Concluding activities	1,854	1,564
Total Costs	14,314	16,394

Source: AQUA 2008

Conclusions

This work intended to illustrate the economic perspective of historical contamination within two locations in the Czech Republic. The first case illustrated an application of the method of substitution of costs in order to present an aproximative of the option value of protecting sources of groundwater in North Bohemia through the cleaning-up process and the actual consumption patterns of drinking bottled water in the Czech Republic. Under the logic of neoclassical economics, the cleaning-up process does not indicate signs of being economically efficient for the present time, since the present use value of the sources becomes zero if one takes into account that the water sources which are being cleaned up, are not used and there is no information about the future use of it. However, the costs that are now being invested in the remediation process can be interpereted as the monetary expression of the existence and option value of the source of water for next generations. We confronted these costs with the actual price of public water supply and also with the behaviour of consumers in

the Czech Republic towards the bottled water demand. The cost of a cubic meter of decontaminated water in the particualr case of the region of Straz pod Ralskem (about 70 CZK) compared with the price of one cubic meter of public water supply (about 40 CZK), might not seem to reflect an economically reasonable trade-off . However, the average price people are paying for each liter of bottled water in the market (6 CZK), reflects the purchasing power towards water for drinking purposes and makes evident that the investment in remediation might be worth if this consumption behaviour is considered. The second case illustrated the microeconomic approach to the analysis of historical contamination. The case showed how important it is to find an instrument that can estimate the effectiveness of the investment related to the solution of the especific environment problems. The selection of the optimal clean-up process is based on the estimations of probabilities and uncertainty mainly due to the impossibility of a detailed and precise description of the complete contaminated area as well as detailed hydrogeological conditions, among others. The correct selection of the revitalization process should be related not only to the most effective technique, but also to its economic efficiency. Inputs (expenses, investments) can be easily expressed in monetary terms. However, outputs (benefits) cannot be directly expressed in that way. That is the reason why it becomes necessary to find an alternative way for the numerical expression of outputs (benefits). One alternative way can be, for instance, the comparison of financial demanads related to the achievment of determined targets. The technical-economic model is one of the instruments for the evaluation of efficiency of each clean up technology. The model might define the expense categories relevant for a concrete revitalization site. The concrete case of our work illustrated how the technical-economic model can become a useful instrument for the decision making process even with a lack of complete information about the locality and details about its clean up process.

Our work can serve as an example how one can make macro and microeconomic analyses on remediation issues. A microeconomic analysis tries to focus on the perspective of a company or a specific industrial branch in the economy. Looking through cost estimations is, therefore, a necessary part of the whole microeconomic analysis. A macroeconomic analysis tries to cover a wider concept of the consequences of cleaning-up for the interested parts (stakeholders) involved in the problem and, therefore, will require to go beyond cost estimations trying to consider also potential and future benefits for the society as a whole. That is why Valuation Methods are suitable for this kind of studies.

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HODNOCENÍ SANAČNÍCH PROCESŮ: EKONOMICKÉ PERSPEKTIVY

Článek zkoumá problematiku ekonomické efektivnosti ochrany životního prostředí v souvislosti s náklady nutnými k odstranění starých ekologických zátěží. Jsou zde nastíněny různé ekonomické přístupy k optimalizaci sanačních procesů. Druhá část se zabývá případovými studiemi a modelem nákladové efektivnosti pro konkrétní technologie sanace i možnostmi účetního zachycení těchto jevů. Dokument byl připraven s finanční podporou ze státního rozpočtu České republiky v rámci projektu "Pokročilé sanační technologie a procesy č. 1MO554" z programu "Výzkumná centra PP2-DP01" Ministerstva školství, mládeže a tělovýchovy.

BEWERTUNG VON SANIERUNGSTECHNOLOGIE: ÖKONOMISCHEN PERSPEKTIVEN

Der Beitrag befasst sich mit der ökonomischen Effizienz der Umweltschutzkosten in Bezug auf Altlasten in der Tschechischen Republik. Präsentiert wurden theoretische und praktische Aspekten des Themas durch zwei Fallstudien mit ökonomischer Orientierung.

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EWALUACJA PROCESÓW SANACYJNYCH: PERSPEKTYWY EKONOMICZNE

Artykuł bada problematykę efektywności ekonomicznej ochrony środowiska w związku kosztami niezbędnymi do usunięcia starego obciążenia ekologicznego. W pierwszej części są naszkicowane różne podejścia ekonomiczne dotyczące optymalizacji procesów sanacyjnych. Druga część zajmuje się modelem efektywności nakładowej konkretnych sanacji technologii i możliwościami podchwycenia księgowego tych zjawisk. Dokument został przygotowany ze wsparciem finansowym z budżetu Republiki Czeskiej w ramach projektu „Zaawansowane technologie sanacyjne i procesy nr 1MO554" z programu "Centra Badawcze PP2-DP01" Ministerstwa Szkolnictwa, Młodzieży i Wychowania Fizycznego.