Oil Shale, 2013, Vol. 30, No. 2S, pp. 363–370
doi: 10.3176/oil.2013.2S.13
ISSN 0208-189X

SUSTAINABILITY ASSESSMENT OF ESTONIAN OIL SHALE MINING

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Abstract. *The global importance of and demand for oil shale are currently rapidly growing. Deposits of oil shale are widespread around the world. All this necessitates assessment of the sustainability of existing open-pit and underground mining technologies to improve oil shale mining management.*

The aim of the present study is to elaborate a method for assessment of the sustainability of oil shale mining to develop advanced mining technologies on this basis. Sustainability assessment has earlier been applied to two exploited Estonian carbonate rock deposits – dolostone and limestone. It was shown that a three-level matrix monitoring scale gives structured results. This paper considers the applicability of a sustainability assessment matrix to Estonian oil shale mining.

Keywords: *Sustainability Assessment Method, Module Analysis, carbonate rock aggregates, oil shale mining.*

1. Introduction

In Estonia, oil shale has been used for over 90 years mainly for production of electricity and oil, with the generated waste ash being used for cement and light brick production. Oil shale usage has always been dependent on available mining and processing technologies on the one hand and world oil and petroleum prices on the other. This also holds true today when new technologies are being applied at a power or oil processing plant. For example, the separation plants built in Estonian new and reconstructed underground mines and Aidu surface mine allowed employment of oil shale finishing hand mining techniques and hand sorting, which increased production [1].

Since sustainable development has become a catchword in international discussions, several approaches to sustainability assessment have been worked out. In order to measure or predict the sustainability of a land use system or a society, one must consider the inherent problems of analysis and

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its complex systems. Appropriate scales and time horizons must be chosen; preconditions and requirements for operationalization and quantification of sustainability must be defined; and the philosophy and value system behind this concept and its translation into policies must be made explicit.

On the other hand, ethical and political convictions behind the multitude of policy recommendations made under the umbrella of sustainable development often remain obscure. There is a need to develop criteria that can be used to indicate to what degree strategies and policies contribute to sustainable development [2].

The current paper considers the possibility of applying a sustainability assessment method to Estonian oil shale mining. The method was developed during a doctoral study and approbated for Estonian carbonate stones deposits. In this work, Module Analysis is used to measure and compare different parameters – economic, environmental and socio-cultural. For gradation of specially selected indicators and parameters a three-level risk matrix scale from British Standard BS OHSAS 18800 „Occupational health and safety management systems“ was adopted to consider how often each hazard is likely to occur. In this standard, a minimal risk level is considered as “I” and “V” means a very high risk. Risk evaluation following Table 1 indicates that non-existent risk (I) could be ignored, because its effect is insignificant. However, one must ensure that it will remain stable in the future. Slight risk (II) suggests that it may not be necessary to apply measures. However, the aim is to find a better solution that would not bring about additional expenses. In the case of acceptable risk (III) necessary measures should be taken to reduce risks, including also informing the staff. Acceptable risk with monitoring (IV) requires immediate steps to be taken to reduce the risk, informing the staff as well. In the case of unwarranted risk (V) swift actions must be implemented to remedy the situation. The Sustainability Assessment method uses the evaluation system which is similar to that of the Safety Risk Assessment Method [3].

Usually risk analysis is used to assess the safety of different technical systems. So far it has not been applied to the sustainability assessment of mining. Many authors [2, 4, 5, 6] have described the sequential steps of the risk analysis of technical systems. Most researchers are in general agreement on the basic elements the risk analysis should include. Description of the system, and the scope and expectations of the risk analysis should be defined at the start. An iterative approach should be adopted with qualitative

Table 1. Risk evaluation and damage occurrence

Dangerous	Insufficient damage	Dangerous or harmful	Very insecure damage
Unlikely	Non-existent risk (I)	Slight risk (II)	Acceptable risk (III)
Likely	Slight risk (II)	Acceptable risk (III)	Acceptable risk with monitoring (IV)
Very likely	Acceptable risk (III)	Acceptable risk with monitoring (IV)	Unwarranted risk (V)

methods being employed at the early stages of the process. If more information becomes available, use of quantitative analysis will be necessary.

Risk identification is the process of determining what can go wrong, why and how. Failure can be described on many different levels. Conceptualization of different possible failure modes for a technical system is an important part of risk identification. One should first take into account as many types of failures as possible. The initial list can then be reduced by eliminating those types of failures considered implausible.

Risk estimation entails the assignment of probabilities to the events and responses identified under risk identification. Assessment of appropriate probability estimates is one of the most difficult tasks of the entire process. Probability estimation can be grouped into three general approaches depending on the type and quality of available data:

1. analytical approach uses logical models for calculating probabilities;
2. empirical approach uses existing databases to generate probability;
3. judgmental approach uses experience of practicing engineers in guiding the estimation of probabilities.

Attaining an exact value of probability for technical systems and processes is not a realistic expectation. Component event probabilities may be assessed using a subjective degree-of-belief approach [3].

2. Sustainability assessment method for oil shale deposits development

In order to carry out an optimal analysis of the sustainability of an oil shale deposit a module analysis should be used [3]. This analysis uses a matrix table containing influence risk values, where the final product considered as a process and overall matrix is divided into modules or parts: Economic, Environmental and Socio-Cultural (Fig. 1).

For assessment of the economic sustainability of oil shale, different parameters should be used, taking Pareto principle as a basis. Pareto principle, or the 80/20 Rule, means that in many events, the few (20%) is important and majority (80%) is trivial. Pareto principle, the 80/20 Rule, serves as an everyday reminder to focus 80% of one's time and energy on the 20% of work that really is important [3].

For an additional Economic Indicators analysis it is recommended to use SWOT, PESTLE or Ratio analysis.

SWOT analysis (also SLOT analysis) is a strategic planning method used to evaluate the Strengths, Weaknesses/ Limitations, Opportunities, and Threats involved in a project or in a business venture. It involves specifying the objective of the business venture or project and identifying internal and external factors that are favorable or unfavorable for achieving that objective. The technique is credited to Albert Humphrey, who led a convention at the Stanford Research Institute [8].

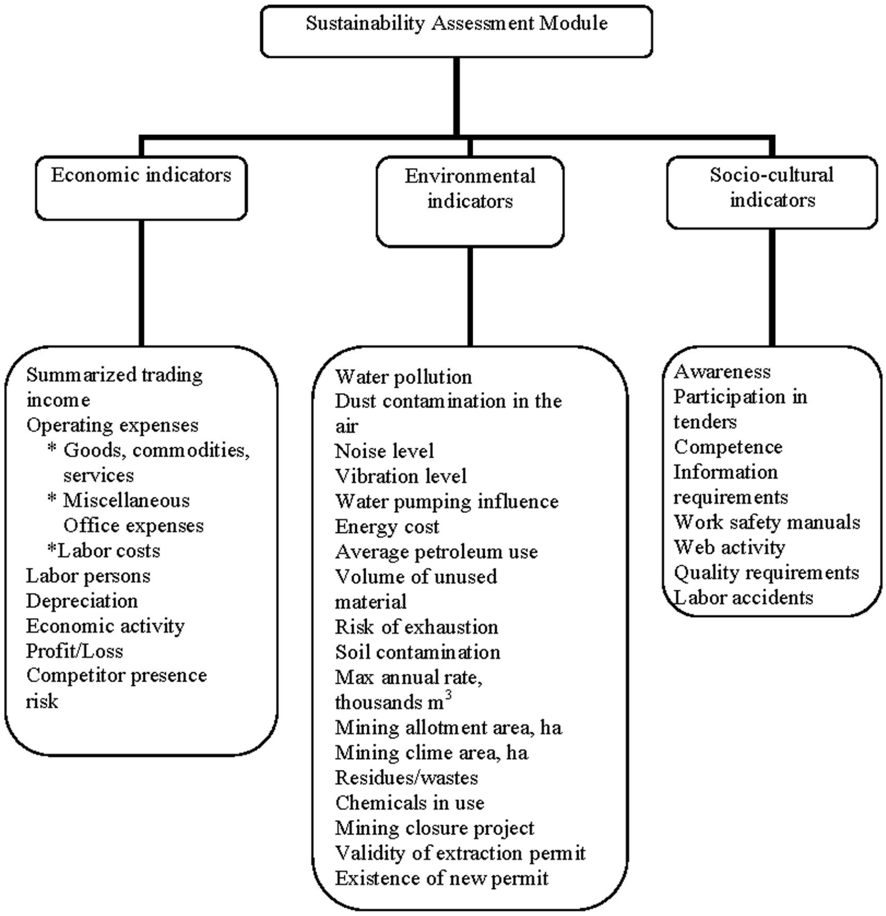

Fig. 1. Indicators used in Module Analysis.

PESTLE stands for business analysis including Political, Economic, Social, Technological, Legal and Environmental analysis. The term PESTLE has been used regularly during the last 10 years and its true history is difficult to establish. PESTLE analysis is particularly popular in introductory marketing courses in the United Kingdom. PESTLE analysis is in effect an audit of an organization's environmental influences with the purpose of using this information to guide strategic decision-making. The assumption is that if the organization is able to audit its current environment and assess potential changes, it will be better placed than its competitors to respond to changes [8].

Ratio analysis is a tool used by individuals to conduct a quantitative analysis of information in a company's financial statements. Ratios are calculated from current year numbers (evaluate a company's present performance and its possible future performance) and are then compared to previous years, other companies, the industry, or even the economy to judge the performance of the company. Ratio analysis is predominately used by proponents of fundamental analysis. There are many ratios that can be calculated from the financial statements pertaining to a company's performance, activity, financing and liquidity. Some common ratios include the price-earnings ratio, debt-equity ratio and earnings per share, asset turnover and working capital [9].

Financial sustainability is a reflection of stable predomination of income over expenses and provides broad manipulation of financial assets of companies by their effective and smooth process of oil shale development and oil products realization. The Financial assessment examines viability of oil market and the economic value of land use. It incorporates Economic Growth, Research and Development, Codes of Conduct, Compliance, Corporate Governance, Risk and Crisis Management techniques [10].

Environmental indicators should be based on Environmental annual reports of the company to protect and improve environmental conditions in and around facilities. Good environmental practices prevent undesired phenomena from occurring, such as ground and surface subsidence and hazards related to them and emissions to sensitive receptors. Sustainable mining in densely populated regions requires rehabilitation of mined areas to accommodate leisure, agricultural or industrial facilities [10]. Influence of geological parameters and features on mining efficiency and environmental protection is significant. In underground mining, stability of the immediate roof by a mining face or stope is determined by geological features. The presence or vicinity of karst, joints or fissures, and an aquifer in the overburden rock at the face in the mines Estonia and Viru determines the stability of the immediate roof. These factors, in general, have been determined for the Estonian oil shale deposit and are cartographically mapped. To a great extent, karst and joints inside a mining block area are undetermined, because it is practically impossible to determine. Risk management and assessment methods allow solving these complicated problems. Seismic activity in Estonia is at such a low level, practically negligible, that it has been considered in this study only to a limited extent [11].

Socio-cultural well-being indicators describe the relationship between appropriate technology of mining activities and assessment of its social impact and incorporate Standard of Living and Basic Human Needs, Community and Equal Opportunities [12].

There are a number of other indicators and methods which may be used for assessment of mining sustainability. However, most of them are still in the developing stage. There have been a few tests carried out to develop the technological level assessment of a mining company during the study. The tests have been primarily induced by economic or legal problems, such as search for a new investor, promotion for selling the company, etc. However, it is mostly taxation, penalties and business reputation that guide the choice of indicators. There are organisations or individuals who have other motivators [14].

The parameters used in the module analysis are determined by Estonian legal acts and standards. Being mostly based on European Union standards, directives and regulations, these include the Mining Law, the Water Statute, the Waste Statute, the Waste Oil Management Requirements, the Municipal Waste Sorting Procedures, the Fire Safety Requirements, the Occupational Health and Safety Act, etc., 39 in total [3].

Gradation of company wellness could be estimated by the average of all Sustainability Assessment indicator values as equation 1 shows, where Ec_i is the average value of economic indicators of sustainability assessment, En_i is the average value of environmental indicators of sustainability assessment and SC_i is the average value of socio-cultural indicators of sustainability assessment:

$$MS_i = (Ec_i + En_i + SC_i)/3 \quad (1)$$

Thereafter Mining Sustainability Index (MS_i) can be estimated by five basic grades: V means that the Company is Sustainably Developed, IV denotes Successful Company, III stands for Quite Successful Company, but additional actions should be taken in order to improve the situation, II designates no positive activity, I signifies no outcome activity.

3. Sustainability assessment techniques

The module analysis used for sustainability assessment of oil shale deposits differs from that applied to carbonate rock deposits in resource characterisation techniques and quality indicators. The techniques of sustainability assessment of oil shale mining (open pit and underground) in terms of resource characterisation (product quality) and mining profitability can be summarized as follows:

- application of numerical quality indicators corresponds to the techniques and methods of mining (crushers selection, sieving process regulation, selective mining and excavation, blasting, etc.);
- conducting of mineralogical, chemical and oil yield studies of oil shale;
- scheduling of oil shale production in a plan that applies appropriate capital and operating costs to determine economic viability;
- design of systems and technology for surface mining, underground mining, modified in-situ retorting, true in-situ retorting and determining requirements for infrastructure;
- in-situ process thermal and chemical reactions modeling, kerogen oil recovery modeling, geomechanics reservoir simulation;
- investigation of bedrock hydrological and mineral-related elements, soil formation, sediment transport and deposition aids in understanding of the structure and function of natural ecosystems:

- definition of in-situ stress regime through geotechnical monitoring;
- geotechnical assessment of open and underground mining and the stability of in-situ retorted areas;
- identification of opportunities for economic mine waste management;
- integration of life-cycle models of oil shale and energy commodities to describe global geologic occurrences, genetic processes, present and future use, recycling potential, possible substitutions, disposal strategies and associated environmental effects:
  1. identification of the impact of ecosystem loss or damage on local flora and fauna;
  2. long-term environmental monitoring of the leaching process ("spent" shale-co-product of in-situ retorting) and its influence on water quality; land use and reclamation [10].

4. Conclusion

This study treats of the sustainability assessment of oil shale mining in Estonian conditions, taking into account oil shale characteristics and mining parameters. The sustainability assessment used earlier for Estonian carbonate rocks served as a basis. Although the sustainability assessment of oil shale differs from that employed for carbonate rock in some of the techniques and parameters used, module analysis can be applied to both cases to grade company wellbeing and to improve mining management, as well as to find out weaknesses of operations.

Acknowledgement

The author expresses her deep gratitude to Väo Paas OÜ for providing necessary data, and for great teamwork. She is thankful for the opportunity to watch work procedures at a successfully operating mining company.
This research was supported by the Estonian Science Foundation (grants No ETF8123 "Backfilling and waste management in Estonian oil shale industry" and No ETF7499 "Conditions of sustainable mining"), and the project DAR8130 "Doctoral School of Energy and Geotechnology II" interdisciplinary research topic "Sustainable mining".

REFERENCES

1. Väli, E., Valgma, I., Reinsalu, E. Usage of Estonian oil shale. *Oil Shale*, 2008, **25**(2S), 101–114.

2. Becker, B. *Sustainability Assessment: A Review of Values, Concepts, and Methodological Approaches*. Consultative Group on International Agricultural Research, 1997, 1.
3. Šommet, J., Pastarus, J.-R. Comparison of Dolostone and Limestone Assessment Methods for Estonian Deposits. In *Environmental and Climate Technologies*, Riga Technical University, 2012, **9**, 35–39.
4. Balkema, A. J., Preisig, H. A., Otterpohl, R., Lambert, F. J. D. Indicators for the sustainability assessment of wastewater treatment systems. *Urban Water*, 2002, **4**(2) , 153–161.
5. Bergh, J. C. J. M. van den, Straaten, J. van der (Eds.). Towards Sustainable Development: Concepts, Methods, and Policy. International Society for Ecological Economics. Island Press, Washington DC and Covelo California, ISBN 1559633492, 1994.
6. Long, K. Issues Related To Sustainable Development. http://et.articlesnatch.com/Article/Issues-Related-To-Sustainable-Development/820580, 13.05.13.
7. Pastarus, J.-R., Sabanov, S. Concept of risk assessment for Estonian oil shale mines. In *Proceedings of the 5th International Conference "Environment. Technology. Resources"*, Rezekne Augstskolas Izdevnieciba, Rezekne, Latvia, June 16–18, 2005, 237–242.
8. *SWOT Analysis*. http://en.wikipedia.org/wiki/SWOT_analysis, 28.08.12.
9. *PESTLE Analysis*. http://www.cipd.co.uk/hr-resources/factsheets/pestle-analysis.aspx, 28.08.12.
10. *Ratio Analysis*. http://www.investopedia.com/terms/r/ratioanalysis.asp#ixzz24ph8Xu1G, 28.08.12.
11. Sabanov, S. Sustainability assessment methods for development of oil shale deposits. *Proceedings of the Twentieth International Symposium on Mine Planning and Equipment Selection MPES.* Almaty, October 12–14, 2011, 711–718.
12. Sabanov, S., Tohver, T., Väli, E., Nikitin, O., Pastarus, J.-R. Geological aspects of risk management in oil shale mining. *Oil Shale*, 2008, **25**(2S), 145–152.
13. Laurence, D. Optimization of the mine closure process*. J. Clean. Prod.,* 2006, **14**(3–4), 285–298.
14. Valgma, I., Leiaru, M., Karu, V., Iskül, R. Sustainable mining conditions in Estonia. *11th International Symposium "Topical Problems in the Field of Electrical and Power Engineering", Doctoral School of Energy and Geotechnology*, Pärnu, Estonia, 16–21.01.2012. Tallinn: Elektriajam, 2012, 229–238.

Received October 24, 2012