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Environmental management concepts supported by information technology

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The genesis and development of environmental management concepts are presented. An overview of the current environmental management ideas, programmes and systems, including Sustainable Development, Responsible Care, Cleaner Production, environmental management based on ISO 14000, and EMAS is provided. Selected computer-aided tools and techniques for improving the quality of environmental management are proposed.

Keywords: environmental management, sustainable development, improvement methods and tools.

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INTRODUCTION

Global environmental degradation phenomena affecting, to a smaller or larger degree, all the inhabitants of the earth have generated interest of governments in the protection of the environment in their countries. Some countries have adopted laws concerning harmful emissions to the atmosphere, water and soil, and waste storage and utilization. Appropriate measures have been introduced in the following stages:

Stage I: dilution strategies – reducing pollutant harmfulness through emission concentration or frequency reduction by installing chimneys of proper height, sewage dilution to the allowed amounts of pollutants and so on.

Stage II: limitation strategies – the so-called „end-of-pipe" measures limiting pollution at the places where pollution is generated, through sewage treatment, dust and gas absorption by filter systems, waste burning or deposition on specially prepared landfill sites.

Stage III: prevention strategies – pollution liquidation at the source by applying technologies and measures aimed at reducing the amount of pollutants and their utilization at the place of their generation.

The first two strategies were based on the principle „give orders and control their execution" and were used till the end of the 1970s. But they did not bring the expected results. Adverse global phenomena, such as the growth of the ozone hole and the greenhouse effect not only were not reduced but intensified as a result of the economic growth and the growing human population, leading to the development of industry and agriculture on the one hand and on the other the uncontrolled pollution emissions due to the arms race and tests, e.g. nuclear tests. The third strategy, i.e. prevention at the source, was developed in order to improve the state of the environment and limit the adverse phenomena and it found its embodiment in legal instruments and guidelines contained in such programmes as Sustainable Development, Responsible Care, Cleaner Production and in more formalized standards concerning Environmental Management Systems, i.e. the Eco-Management and Audit Scheme (EMAS).

SUSTAINABLE DEVELOPMENT

The term „Sustainable Development" was introduced by the Norwegian Prime Minister Gro Harlem Brundtland and defined in the documents of the UN World Committee on Environment and Development and in the „Our Common Future" report (the Brundtland report) in Stockholm in 1987. According to this report Sustainable Development is „development which meets our own needs without compromising the ability of future generations to meet their needs". The Sustainable Development philosophy was the basis for researches conducted by many countries and in 1992 its legal foundations were laid in the documents of the World Conference on Environmental Protection held in Rio de Janeiro, Brazil. The principal documents adopted by the Conference in Rio de Janeiro included the Rio 92 Declaration on Environment and Development and Agenda 21[1, 2].

The Declaration on Environment and Development formulated 27 basic principles of global sustainable development. The Declaration specified the basic duties of the signatory countries with regard to „a new social order on the earth".

Agenda 21 (the Rio Declaration on Environment and Development and the Statement of principles for the Sustainable Management of Forests were adopted by more than 178 Governments at the United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro, Brazil, 3 – 14 June 1992), i.e. a comprehensive plan of action for sustainable global development for the 21st century is the principal document which the governments of the signatory countries can take as their model in solving problems connected with the implementation of national strategies. The document was supplemented with a collection of 2500 recommendations for countries, governments, intergovernmental and international agencies and for societies. The governments of particular countries are responsible for implementing the principles of Sustainable Development in their countries. Adhering to the Agenda 21 principles the countries grouped in OECD adopted a new doctrine of development consisting in managing economic processes through the environment (Environmental Management Systems).

Agenda 21 was divided into four sections:

Section 1 – Social and Economic Dimensions,

Section 2 – Conservation and Management of Resources for Development,

Section 3 – Strengthening the Role of Major Groups,

Section 4 – Means of Implementation.

Agenda 21 comprises in total 40 chapters. Each chapter contains the basis for action, goals, recommendations and possibilities of carrying out the tasks. From the point of view of this paper's subject, which is the application of IT tools in environmental management, section 3 chapters concerning nature resources management and section 4 chapters seem to be particularly interesting:

33. Financial resources and mechanisms,

34. Transfer of environmentally sound technology, cooperation and capacity-building,

35. Science for sustainable development,

37. National mechanisms and international cooperation capacity – building in developing countries,

38.International institutions and arrangements,

39. International legal instruments and mechanisms,

40. Information for decision-making.

The fundamental international legal acts based on Agenda 21 are:

1. The United Nations Framework Convention on Climate Change,

2. The UN European Economic Commission Convention on Access to Information, Public Participation in Decision-Making and Justice in Environmental Issues,

3. The Convention on Environmental Impact Assessment in a Transboundary Context (Espoo),

4. The Vienna Convention on the Protection of the Ozone Layer.

In the European Union the EU-V Environment and Sustainable Development Programme and the EMAS (Environmental Management and Auditing System) Directive were developed and implemented as the basis for planning and the World Standardization Organization proposed a series of environmental management standards ISO 14000.

The first national-level document of this kind in Poland is the Resolution of the Sejm of the Polish Republic, of 02.03.1999 which obliges the government to submit by 30.06.1999 a document setting directions for the country's development by 2025, accordant with the principles of Sustainable Development, taking into account the social, economic and environmental aspects. But the most important regulation for Poland is the citing of the principles in the Constitution of the Polish Republic, of 1977 in articles:

Article 5.

„The Polish Republic guards the independence and integrity of its territory, ensures human and citizen freedoms and rights and public safety, protects the national heritage and ensures environmental protection, being guided by the principle of sustainable development".

Article 74.

1. Public authorities conduct a policy ensuring ecological security for the present and future generations.

2. Protection of the environment is the duty of public authorities.

3. Everybody has the right to information about the state and protection of the environment.

5. Public authorities support actions for the protection and improvement of the environment.

The notion of Sustainable Development was defined in Poland in the Environment Protection and Shaping Act of 31.01.1980 (Law Gazette 94.49.196) in article 3.3a.

Poland, fulfilling the obligations adopted at the summit in Rio de Janeiro has drawn up a document entitled: The Strategy of Sustainable Development of Poland by 2025, guidelines for government departments developing sector strategies[2]. This document consists of 6 parts. They contain the principles adopted at Agenda 21. Important in the context of this paper are articles: 5.7 Information about decision processes, 5.8. Management through the environment and integrated system of permits and 5.10 Sustainable development indicators, planning and monitoring of implementation.

Article 5.8 says that all decisions should be taken on the basis of a thorough analysis of initial states, a trend analysis and a forecast of short-, medium- and long-term economic results and ecological and social consequences. „Scientific communities should actively join in the development of proper methods of acquiring and processing information into the form of forecasts and optimization algorithms or decision options".

Article 5.8 concerns the doctrine of environmental management at the level of production and service companies and at the level of each workstation. As a result, the principle of liquidating pollution at the source and that everybody pays for his/her emissions, can be effectively applied.

Article 5.10 Indices for decision models are being developed by the UN Commission on Sustainable Development, the OECD Environmental Committee and the European Commission. But as yet they have not been applied in decision models. According to the recommendations such indices should be quantitative: inventory status, changes in production and consumption, revenues, vital statistics, inflation rate, currency rates, GDP, etc. and qualitative: energy, water and resource consumption, national income, purchasing power, non-renewable resources, development of technology, environmental degradation, external conditions, etc. The quantitative indices define the initial state and the local conditions while the qualitative indices define the interdependencies between the economy, the environment and the society. The indices allow one to evaluate and predict results.

RESPONSIBLE CARE

Responsible Care is an environment management programme whose participants (entrepreneurs) voluntarily and publicly undertake to carry out measures aimed at improving their performance in environmental protection, process safety and employee health protection[2, 3].

The currently promoted Responsible Care management model is based on Deming's spiral approach: Plan-Do-Check-Act. It is also proposed to adopt the Sustainable Development principles formulated in the Declaration, according to which economic effectiveness is oriented at profit for the community but it takes into account the social and environmental costs. In its present form the Programme includes measures aimed at improving product handling (product life cycle analysis), product management, transport safety, cooperation and logistics.

According to the RC Programme, when constructing indices for measuring the achievement of the environmental improvement goals adopted by a company, one should include the following data:

1. the number of fatalities,
2. the rate of accidents leading to temporary job loss,
3. the energy consumption and efficiency,
4. the carbon dioxide (CO_2) emission,
5. the sulphur dioxide (SO_2) emission,
6. the nitrogen oxide (NO_x) emission,
7. the phosphorous compound charge in the disposed sewage,
8. the total nitrogen charge in the disposed sewage,
9. the chemical oxygen demand (COD),
10. the accidents during distribution,
11. the emission of volatile organic compounds,
12. the heavy metal dump,
13. the rate of occupational diseases,
14. the removal of hazardous and non-hazardous wastes.

In Poland the Polish Chemical Industry Chamber – the Association of Employers exercises direct supervision over the Responsible Care Programme. The RC Programme Chapter, which includes the representatives of, among others, the Ministry of Environmental Protection and the Ministry of the Economy, sets the directions of action, does promotion and exercises specialized supervision. The RC Programme Secretariat is headquartered in Włocławek on the premises of the Chemeco Company (a member of the Anwil group). In Europe the Programme is supervised by the Responsible Care Committee CEFIC (European Chemical Industry Council).

The Responsible Care Programme includes tasks which can be supported by information technology. Considering that an increasing number of companies have a more advanced ISO 14000 conformant environmental management system certified it seems that IT solutions should be developed for the more advanced systems.

CLEANER PRODUCTION (CP)

The Cleaner Production environmental management system's requirements are more complex and formalized than those of Responsible Care. According to the International Cleaner Production Declaration, Cleaner Production is understood „to be the continuous application of an integrated, preventive strategy applied to processes, products and services in pursuit of economic, social, health, safety and environmental benefits".

The CP Programme was introduced in 1990 by the United Nations Environment Programme (UNEP) and the CP Declaration was issued by UNEP in 1998. In Poland the CP Programme is being implemented by the Polish CP Movement Association within the Polish Federation of Engineering Associations.

The process approach, in which the production process is divided into input-cycle-output, is recommended for the analysis, quantification and balancing of the production cycle for the purposes of developing projects based on the CP principles[4]. The tools for implementing such CP strategies are:

1. An environmental assessment (ecoaudit) covering an assessment of the environmental policy and its social acceptance, an evaluation of the principal environmental management functions and an evaluation of the readiness for the application of modern solutions.
2. A description and an assessment of the waste economy, covering an inventory of waste generation sites and a waste balance.
3. An evaluation of chemical substance harmfulness, including working out principles of selecting and storing chemicals and a risk assessment.
4. An energy audit covering an energy balance, an evaluation of the facilities' efficiency and an evaluation of the effectiveness of energy utilization in unit processes.
5. An environmental impact assessment covering an assessment of the environmental costs and benefits of the planned activity, a specification of the environmental problems and a prediction of the consequences of abandoning environmental protection measures.
6. The choice of the Best Available Technology (BAT).

Besides a technical and environmental analysis, an economic analysis of the project should be carried out4. Such indicators as: the Net Present Value (NPV), the Internal Rate of Return (IRR) and the payback period are taken into account in the analysis.

For a comprehensive assessment of project impact minimization a final report is drafted. The report includes:

– an informative part - a general profile of the enterprise;
– an environment impact self-assessment;
– a CP design covering a description of the project and the installations, design versions, a technical and economic feasibility study, a statement of effects, an implementation plan and a progress report;
– documentation.

The CP Programme is widespread in Poland. It has been adopted by numerous companies and it is an object of interest of many research centres investigating the product life cycle, the environmental impact of technologies, BATs and so on[4 – 7].

ENVIRONMENTAL MANAGEMENT IN ACCORDANCE WITH ISO 14000

In order to formalize and standardize the problems contained in the Sustainable Development idea and Agenda 21, the International Organization for Standardization (ISO) has developed an integrated system covering ISO 9000 Quality Management, ISO 14000 Environmental Management and ISO 1800 Occupational Safety and Industrial Hygiene. Currently industry specific standards, e.g. ISO 22000 concerning Food Safety Management, are added to the above standards. Certification for the standards can be obtained in an arbitrary order but for organizational and interconnectivity reasons it is advisable to obtain ISO 9001 certification first. The basic requirements concerning the description (indices) of management processes, improvement tools, system improvement techniques and models, monitoring, communication and the environment are similar. Taking the above into account, the International Organization for Standardization (ISO) set up a Strategic Advisory Group on the Environment (SAGE). The aim was to evaluate the international environmental management systems and to integrate them with the general management systems. In 1993 SAGE was replaced by the ISO Technical Committee on Environmental Management ISO/TC 207 with the aim to standardize the world environmental management systems.

Currently the environmental management standards can be divided into 7 major groups: environmental management systems, ecological reviews, ecolabelling, environmental analysis, life cycle assessment, terminology and definitions, environmental aspects in product standards. The certification standard is PN EN ISO 14001:2005 – Environmental management systems – Requirements with guidance for use[8]. It is one of the most important standards which systematize the whole system. The extension of PN ISO 14001 is the PN ISO 14004:2005 standard[9]. Considering this paper's subject – the application of computing techniques to environmental management – one should mention here the following standards:

PN ISO 14015:2004 – Environmental management – Environmental assessment of sites and organizations (EASO)[10],

PN ISO 14031:2002 – Environmental management – Environmental performance evaluation - Guidelines[11],

ISO/TR 14032:1999 – Environmental management – Environmental performance evaluation (EPE)[12],

PN ISO 14040:2000 – Environmental management – Life cycle assessment – Principles and framework (under revision)[13],

PN ISO 14041:2002 – Environmental management – Life cycle assessment – goal and scope definition and inventory analysis (under revision)[14],

PN ISO 14042:2002 – Environmental management – Life cycle assessment – Life cycle impact assessment (under revision)[15],

PN ISO 14043:2002 – Environmental management-Life cycle assessment – Life cycle interpretation (under revision)[16],

ISO/TR 14047:2003 – Environmental management – Life cycle impact assessment – Examples of application of ISO 14042[17],

ISO/TS 14048:2002 – Environmental management – Life cycle assessment – Data documentation format[18],

ISO/TS 14049:2000 – Environmental management – Life cycle assessment – Examples of application of ISO 14041 to goal and scope definition and inventory analysis[19].

And standards which have not been published yet in Poland:

ISO 14040 – Environmental management – Life cycle assessment – Principles and framework,

ISO 14044 – Environmental management – Life cycle assessment – Requirements and guidelines,

ISO 14064-1 – Greenhouse gases – Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals,

ISO 14064-2 – Greenhouse gases – Part 2: Specification with guidance at the project level for quantification and reporting of greenhouse gas emissions reductions of removal enhancements,

ISO 14064-3 – Greenhouse gases – Part 3: Specification with guidance for the validation and verification of greenhouse gas assertions,

ISO 14065 – Greenhouse gases – Requirements for greenhouse gas validation bodies for use accreditation or forms of recognition.

EMAS – ECO-MANAGEMENT AND AUDIT SCHEME – STRUCTURE AND REQUIREMENTS

The current directive of the European Parliament and Council allowing for voluntary participation of organizations in the Eco-Management Scheme in the European Union was issued on 19.03.2001. It consists of an introduction which gives reasons for creating and updating EMAS, 18 articles describing the eco-management and audit system, its goals, definitions, the accreditation system, the proper authorities, the registration of organizations, a list of the registered organizations and EMAS environmental verifiers, the logo, links with European and international standards, links with other legal environmental protection acts in the Community, the support of organization (particularly small- and medium-sized companies) participation, information, breaches, the committee, the review, costs and charges, the repeal of EEC directive no. 1836/93 and coming into force. Eight annexes were attached to the directive:

Annex. 1. Environmental management system requirements

Annex 2. Internal environmental audit requirements

Annex 3. Environmental declaration

Annex 4. Logo

Annex 5. Accreditation, supervision and functions of environmental verifiers

Annex 6. Environmental aspects

Annex 7. Environmental review

Annex 8. Information for registration purposes

Membership in EMAS is voluntary but on the strength of the directive, available only to companies from the European Union. However, due to, among other things, globalization trends, including all the countries of the world, are currently observed. The first version of EMAS (1836/93/EEC) permitted only industrial and public utilities companies to become members. Now EMAS has been extended to all private and public sector companies and integrated with the ISO 14000 standards. The administrative structure of EMAS in Poland is related to the country's administrative structure. The accrediting body in Poland is the Polish Accreditation Centre (PAC) located in Warsaw which exercises direct supervision over the accredited verifiers and the latter oversee the registration of organizations in EMAS. PAC informs the Minister of the Environment's verifiers about accreditations. Within EMAS the Minister collaborates with the provincial governors (voivodes) who also oversee the registration of organizations in the system. The National Ecomanagement Council – an opinion-forming body – collaborates with the Minister of the Environment. At the provincial governor level the opinion-forming function is performed by: the Provincial Environmental Inspector, the county starosts, the commune heads, the mayors and the provincial marshals.

For companies, membership in EMAS means their greater credibility, confirmed not only by ISO 14001 certificates but also by accreditation performed by independent verifiers in accordance with the 761/2001 order concerning EMAS.

METHODS AND TOOLS USED – POTENTIAL IT APPLICATIONS

In order to achieve the above objectives proper resources are needed for the analysis and shaping of environmental activities.

The quality management, and particularly environmental management, tools and methods are used mainly as the instruments for acquiring and processing the data. They aid such company activities as analysis, decision taking, supervision, design, diagnosis, control and also activities affecting the environment, allowing companies to take appropriate preventive and corrective measures.

In the literature on the subject one can find many methods according to which the above functions can be performed[4, 7, 20, 21]. The data analysis tools such as: block diagrams, the Ishikawa diagram, SWOT analysis, the Pareto-Lorenz curve, histograms, control charts, decision trees and data correlation and regression investigation methods are mainly used. Among the methods the most valuable are the ones which enable the selection and optimization of environmental parameters and processes and preventive methods. Adaptative statistical methods such as statistical process control, statistical process controlling and statistical analysis of results, i.e. a complex of statistical SPC techniques designed to improve a process by reducing its deviations, are employed here.

In practice, quantitative statistical process control techniques are used also in combination with qualitative techniques. As an example the methods of determining the causes and taking remedial measures aimed at eliminating undesirable process characteristics, such as Failure Mode and Effects Analysis (FMEA) and Six-Sigma, can serve [20, 21]. In order to design quality management systems, including environmental systems, based on the latest concepts one can use such techniques as the Taguchi method or the highly successful Quality Function Deployment (QFD) method (also called the quality house method)[20, 21] which greatly contributed to the development of the quality-oriented approach. QFD was first applied in Japan in 1966. It quickly gained popularity and today it is commonly used in Japan, the USA and for several years now in the countries of Western Europe.

In addition, tools which cover the economic aspects in environmental protection have been developed. They are used in the socioeconomic account of the method of evaluating environmental effects, in the economic-environmental evaluation of project effectiveness, in the estimation of environmental losses and for the need of waste recycling[4].

The application of the above methods can be expedited through the implementation of innovative IT solutions. The introduction of information technology facilitates complex operations involved in the analysis and decision taking under the conditions when the number of processes and interrelations continuously increases as new requirements stemming from changes in the environmental management concept are laid down. Thanks to its potential, tools and dynamic growth, information technology can also cause revolutionary changes in techniques and technologies in many fields. Information technology offers effective data analysis and processing tools, enables the building of decision-taking support systems which facilitate optimization and prediction, including the systems based on Knowledge Bases and Data Mining and expert systems. Although the qualitative approach to environmental management is relatively new, first successful attempts at introducing IT into it, using not only database methods but also artificial intelligence (AI), have already been made. An example here is the design of an expert system for SWD Eutro-Woda (concerning the quality of water in rivers) created in collaboration with the Milan Polytechnic - the Eutro-WODA system[22]. There are also examples of the application of IT to linear programming aimed at optimizing water supply and sewage disposal in industrial plants[24]. Artificial neural networks have been successfully employed to predict wind velocity and in the regressive modelling of air pollution concentrations[23, 25].

CONCLUSION

The progress in environmental management entails the development of relevant techniques and methods. Consequently, tools which would allow one to process large amounts of data, perform complex calculations, investigate the dependencies between key parameters and processes and predict the results of actions, are needed. The presented overview indicates the need for an integrated environmental management computer system based on the assumptions of the ISO 14001 standards since the latter are the most comprehensive and detailed and incorporate elements of the other concepts.

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