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ISO 14000 Environmental Management Systems for Engineering Students*

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Environmental sciences and technologies, together with principles and strategy of environmental management and sustainable development, constitute a vital aspect of engineering education nowadays. This paper describes why and how new courses in environmental management systems (EMS), based on the International Standardisation Organisation (ISO)14000 series of standards, were designed and implemented at Donetsk State Technical University (DonSTU). The benefits of the ISO approach to environmental management are discussed. In designing the EMS courses, the faculty in DonSTU were, to their benefit, able to use links with the international community of engineering educators. The paper presents the ideology, objectives and curriculum of the ISO 14000 EMS course introduced at DonSTU in the 1997/98 academic year. The arrangement of seminars and case studies, as well as the content of the developed study pack, are also outlined.

INTRODUCTION

The environmental challenges we face today tend to be more global in scope than in the past. It is becoming increasingly clear that what we do in the backyard of one country affects people and ecosystems throughout the world.

The Ukraine, as other countries of the former Soviet Union that are undergoing economic transition, has inherited a badly damaged environment, energy and material intensive economic production, and obsolete and polluting technologies. Economic transition aims to improve economic performance on a sustainable basis, and requires significant improvement in environmental planning and management, and the integration of environmental policy with other policies dealing with economic development, market reform, privatisation, legal reform, and total democratisation of society.

What engineering educators can and should do under these circumstances is to put into the heads of their students, those who will perform engineering tasks in the near future, the ideology, principles, the way of thinking of environmentally friendly engineering. The faculty at Donetsk State Technical University (DonSTU) has, for a long time, considered a good understanding of global and specific environmental issues, together with the principles and strategy of sustainable development, to be an important aspect of engineering education [1]. As well as environmental sciences [2][3] and engineering [4], environmental law and regulations, much attention has been paid to training engineering students in environmental management. The first special courses in environmental management were introduced at Donetsk Technical University for students of metallurgy in 1991. Now they are also provided to students of other specialities.

Recently, before the start of the 1997/98 academic year, these courses were restructured on the basis of the International Standardisation Organisation (ISO)

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14000 series of standards on environmental management systems (EMS). At that time the Ukraine was only officially intending to adopt ISO 14000 standards.

HOW THE IDEOLOGY OF EMS COURSES WAS DEVELOPED

The realisation of the necessity for the introduction of a new course in environmental management systems did not arise abruptly among DonSTU faculty. A major stimuli was provided by international academic links established by DonSTU after the Ukraine gained its independence.

In February 1995, six academics from DonSTU visited the University of Portsmouth in the United Kingdom and took part in a two-week seminar on environmental engineering. Much of the discussion during the seminar concerned the environmental management system and British experience in the field, in particular, British standard BS7750.

At the time of DonSTU's 75th anniversary, an international seminar on engineering education was arranged under the auspices of the UNESCO International Centre for Engineering Education (UICEE), between 31 May and 3 June 1996. The seminar included discussion of issues of environmental protection and environmental engineering and collected a wide audience of Donetsk academics. The keynote lectures were given by speakers from Australia, the United Kingdom, the United States, Slovakia and Germany.

In May 1997, Prof. Jean-Marie Gogue, President of Management Strategic, Paris, France, organised a two-week seminar at DonSTU on quality management systems. The idea of a total quality management system, a combined system of quality and environmental management, attracted much attention at that seminar.

By the end of the 1996/97 academic year there had already been many discussions among the faculty in Donetsk about possible approaches to, and principles of, teaching EMS to engineering students. It was recognised that the ISO principles of environmental management were attractive as a basis of contemporary environmental strategy for an enterprise, an industry, and a country. Those discussions were summarised in June 1997 at a three-day train-the-trainer workshop, *ISO 14000 Environmental Management Systems*.

The workshop was organised by the Donetsk Office of Environmental Protection and Technology (EPT) in the frame of the bilateral Ukrainian-American *Programme to Promote Sustainable Development in the Ukraine,* sponsored by the US Agency for International Development. The lectures, seminars and case studies at the workshop were provided by trainers from DonSTU and prepared previously at the Donetsk EPT office, which is under the directorship of Dr N.P. Cheremisinoff. One of the present authors (Vadim V. Prisedsky) headed the team of Ukrainian trainers. The primary aim was to provide a working knowledge of the ISO 14000 EMS standards and their design elements and implementation steps to representatives of Ukrainian industry.

A large group of leading academics from DonSTU were invited and took an active part in the workshop. Their main concern was with the adoption of general principles and of the structure and content of training in environmental management systems at higher school. They decided to take the course that had been designed for the workshop as a basis for the university course in EMS.

BENEFITS OF THE ISO APPROACH TO ENVIRONMENTAL MANAGEMENT

ISO 14000 standards on environmental management systems provide an example of applying entirely new principles to standardisation. They differ widely from rigid regulations on which many standardisation systems were previously based. The total success of the ISO approach to standardisation has already been demonstrated worldwide with the ISO 9000 quality management system.

The ISO 14000 standards on environmental management are attractive for the following features:

- A *voluntary approach* oriented to developing positive long-term tendencies, rather than applying stiff penalties for failing to comply with many itemised requirements.
- *A continual step-by-step improvement* in the environmental performance of enterprises and industries.
- A complete integration of *the principle of sustainable development* into ISO ideology, which is of vital importance for the Ukraine and other new independent states of the former Soviet Union undergoing a massive, but wavering economic transition.
- An easy and natural integration with ISO 9000 standards on *quality management systems* (QMS); and the possibility of developing total quality management systems (TQMS) combining quality and environmental management.

All these make ISO principles of environmental standardisation equally advantageous both to leading industrial powers and countries facing serious problems in their economic development.

THE COURSE OBJECTIVES

For the first time in the Ukraine, new courses on ISO

14000 EMS started at DonSTU in the 1997/98 academic year. Courses in EMS and ISO 14000 standards were also introduced for postgraduate students as a form of continuing engineering education.

The primary objective of the courses is to enhance a positive attitude about environmental protection and management, which corresponds to the strategic aim of continual environmental education at DonSTU.

The second objective is to provide the necessary working knowledge of the ISO 14000 environmental management system, its design elements and implementation steps. Much of this training involves orientation and a working familiarity with ISO EMS guidelines as they are presented in the ISO 14001 standard [5].

The third objective is to provide knowledge about EMS auditing and ISO 14000 certification (including combined ISO 9000 and ISO 14000 - total environmental quality management certification) and their role in business practice and economic development of the country as a whole.

The fourth objective is to develop in students the personal, professional and organisational skills necessary to implement the EMS systems within enterprises.

CURRICULUM

The course in EMS comprises lecture sessions, seminars and case studies. The programme includes:

- An introduction into the history of management systems, environmental management, standardisation and the International Standardisation Organisation.
- ISO 14000 guidelines and general principles; scope and structure of ISO 14000 series of standards; ISO 14001 standard as a specification document;
- Environmental Policy: how to formulate and publish it.
- Environmental Action Plan: how to develop it.
- ISO 14000 procedures and communication system: how to design an EMS data system.
- EMS auditing.
- ISO 14000 and total environmental quality management (combined ISO 9000 and ISO 14000) certification.
- The role of ISO certification in business practice and economic development of an enterprise and industry.

The course begins with an introduction to the history of standardisation, management systems and environmental management, which includes a short history of management, elements of the system approach, and the history of the International Standardisation Organisation since its creation following the Second World War. Attention is given to the change in the ISO ideology of standardisation in the 1970-80s when ISO 9000 Quality Management Systems were developed.

The key ideas of management systems are explained using the historic Deming model:

PLAN - DO - CHECK - IMPROVE

The difference in interpretation and implementation under the command economy and in a democracy is discussed as a characteristic distinction between the two systems.

The basic notions of EMS are introduced, incorporating the notion of the environment as:

> *surroundings in which an organisation operates, including air, water, land, natural resources, flora, fauna* [5],

as well as other notions, such as environmental aspects and impacts, environmental policy and management programmes, environmental monitoring and measurements, environmental performance and environmental audit.

The attention of students is drawn to the general ideology of ISO 14000 EMS as a voluntary system of continual improvement of environmental performance integrated into the strategy of sustainable development. The benefits of such ideology for large and small countries, strong and developing economies are reviewed.

The aims of an environmental management system are classified as:

- Identification and control of environmental aspects, impacts and risks.
- Establishing and achieving an environmental policy, objectives and targets, including compliance with legislation.
- Identifying environmental opportunities.
- Monitoring and continual improvement of environmental performance.

The introduction of EMS will affect practically all functions of an enterprise, from research and development, manufacturing, finance, planning and development, marketing, through to management and distribution (retail and wholesale).

Environmental policy is defined in the next section of the course as:

> *a public statement by the organisation of its intentions and principles in relation to its overall environmental performance* [5].

A statement by the organisation of its environmental policy provides a framework for action, helps to set its environmental objectives and targets, serves as a

foundation of the EMS, gives an overall sense of direction, and serves as a baseline for comparing strategies, plans and actions. It is usually a long-term document that provides the setting for environmental objectives and targets, and states commitment to environmental protection. Students are trained to use all necessary inputs to formulate policy statements: general values of the organisation; strategic business plans; values of the organisation; legislation, regulations, standards and codes to which the organisation subscribes; views of stakeholders; statements of other groups; and last, but not least, results and findings of an initial environmental review. The content of the environmental policy relates to the organisation's activities, products, services; defines the environmental areas to be addressed; appeals to broad as well as specific aspects; and may include occupational health and safety aspects. ISO 14001 Standard requires that an Environmental Policy Statement should:

- be defined by upper management;
- be appropriate for the nature and scale of the impacts of the organisation's activities, products and services;
- show commitment to continual improvement of environmental performance and prevention of pollution;
- demonstrate commitment to compliance with environmental legislation, regulations and other requirements;
- be documented, implemented, maintained, and communicated to all employees; and
- be available to the public.

Students then learn how to develop an Environmental Action Plan (EAP), which, they are taught, should meet environmental performance goals containing clear measurable objectives and targets [5]. The EAP should define priorities, identify the responsibilities of personnel, allocate resources, and set out measurable targets and goals. The main criteria for the development of EAP are environmental policy, legislation and regulations, business opportunities, technical, operational and economic requirements, and views of interested parties. Targets should be set at all appropriate levels and functions: research and development, manufacturing, finance, planning, marketing, management and distribution. They should be demanding, focus on major environmental aspects, show commitment to continual improvement, be quantified wherever possible, and be given specific deadlines. The EAP allocates staff, responsibilities and financial resources.

The success of implementation of an EMS depends greatly on how the Action Plan is divided into specific assignments, responsibilities and procedures. Students must therefore develop an organisational chart of responsibilities and an example of technological procedures relating, usually, to hazardous waste tracking or storage, spills and fire protection, sampling or sample presentation, laboratory analysis, etc.

The next part of the curriculum concentrates on an EMS reporting and communication system. Benefits of voluntary reporting are shown as:

- Enhanced investor and stakeholder confidence
- Easier access to capital and investment markets
- Trust of regulators
- Competitive advantage through customer approval
- Enhanced employee satisfaction and motivation
- Improved communication with interested parties

The external environmental report corresponds to good business practice supported by the International Commerce Chamber *Business Charter for Sustainable Development.* Students study the forms and content of environmental reports and communications.

Study of the ISO 14000 data system concentrates on data collection, interpretation, communication, record handling, document control and maintenance, hazardous waste tracking and storage, spills and fire protection. The principles and organisation of environmental monitoring and environmental computer nets are also considered here.

In the next section of the course, students are acquainted with EMS audit. The EMS audit is defined as:

> *a systematic, documented verification process of objectively obtaining and evaluating evidence to determine whether an organisation's EMS conforms with the EMS audit criteria, and communicating the results of this process.*

The issues of environmental audit instruments and criteria, audit process and its execution, preparation of the audit report are considered. In case studies, students may use examples taken from the study pack [6].

The final part of the EMS course orients the students in ISO 14000 and also ISO 9000 certification: how an organisation can obtain ISO certification and what benefits the certification gives to an enterprise and to an industry. The attractiveness of ISO certification to the Ukraine is specified.

SUSTAINABILITY PRINCIPLE IN THE EMS COURSE

Complete integration with the principle of sustainability is one of the prominent features of ISO 14000 standards on environmental management systems. The 1992

United Nations Conference on Environment and Development in Rio de Janeiro set a lasting and sustainable development as a priority goal for the international community. After that, courses in sustainable development were introduced at DonSTU in 1993-95 as obligatory for students in environmental engineering.

Some other students acquire knowledge on sustainability while studying the course on EMS. For these students, a section on sustainable development is introduced into the course.

The concept of sustainability demands that the three main aspects of development - economic, social and environmental - are considered as a whole [5]. These often produce conflicting interests and their pacification implies an essential change in common views on progress and growth in human society [7]. An important aim is, therefore, to provide the ideology, concepts and approaches of sustainable development to our students who will soon contribute to material progress and growth. They must be taught to avoid and overcome many crucial threats to sustainability, such as large-scale technical catastrophes, limited supplies of non-renewable fuels and mineral raw materials, increasing greenhouse effects, ozone holes, soil, water and air pollution.

The section on sustainable development in the course contains a history of the problem of sustainability; conflicts in the development of human societies and threats to sustainability; social, economic and environmental aspects of sustainable development; and the principles of low-waste technology.

SEMINARS AND CASE STUDIES

Much of the training in ISO 14000 EMS is undertaken as case studies. Students, divided into groups of two to four persons, undertake the following tasks:

- Study the business and technological performance history of *their own enterprise* (using handout material from the study pack)
- Conduct an initial environmental review
- Formulate environmental policy statements using all necessary inputs
- Determine how policy statements are documented, maintained, communicated and publicised
- Develop an Environmental Action Plan (EAP) for their enterprises
- Divide the EAP into specific assignments, responsibilities, and procedures
- Develop charts of environmental monitoring or environmental computer nets

The groups present their policy statements and environmental action plans at a seminar, where they receive and provide critiques of policy statements, impacts of EAP and impacts of EAP failures. They learn to assess how successfully an organisation acts using such criteria as:

- the provision of necessary resources;
- carrying out best procedures and work tasks;
- initiation of actions to prevent noncompliance with legal or policy requirements;
- identifying potential problems;
- providing solutions to problems and verifying implementation;
- control of fulfilment of quantified targets and tasks;
- control of activities until required changes are carried out; and
- readiness to act in emergencies.

The need for a system approach, which is the heart of ISO EMS, is emphasised in all studies throughout the course. For instance, at a seminar a teacher guides students to the conclusion that a successful industrial waste treatment programme for a particular industry or enterprise should be, in fact, a total environmental control programme. It should include not only traditional water pollution control, but also air pollution control, noise control, soil conservation, radiation protection, ground-water protection, hazardous waste management, solid waste disposal, and combined industrial-municipal waste treatment and management.

STUDY PACK

Under the auspices of the *Environmental Policy & Technology Project* the trainers in DonSTU have prepared a study package containing about 170 slides that cover all the topics of the EMS course [6]. The package comprises textual explanations, graphical illustrations and schemes, and questions and checklists to each chapter, worksheets to case studies for workgroups, model environmental policy statements, and procedures, etc. ISO 14001 standard and some other standards of the ISO 14000 series are attached as an appendix.

English and Russian versions of the study pack have been prepared. The English version was compiled first as it was based on international standards and other original sources written in English. Now it is used by those students at DonSTU who take their courses in English in the English Technical Faculty. Other students use the Russian version, which is a translation of the English one.

Figure 1 represents an example of a slide with an explanatory text. The slide helps to understand what

What is an environmental action plan?

- A process of narrowing down from broad, long-term goals through objectives and targets to a plan of action.
- Which leads to:
- A plan of action to meet environmental performance goals containing clear measurable objectives and targets…
- Based on:

The Environmental policy
Identified priorities
Environmental aspects of operations

Figure 1: An example of a slide from the study pack.

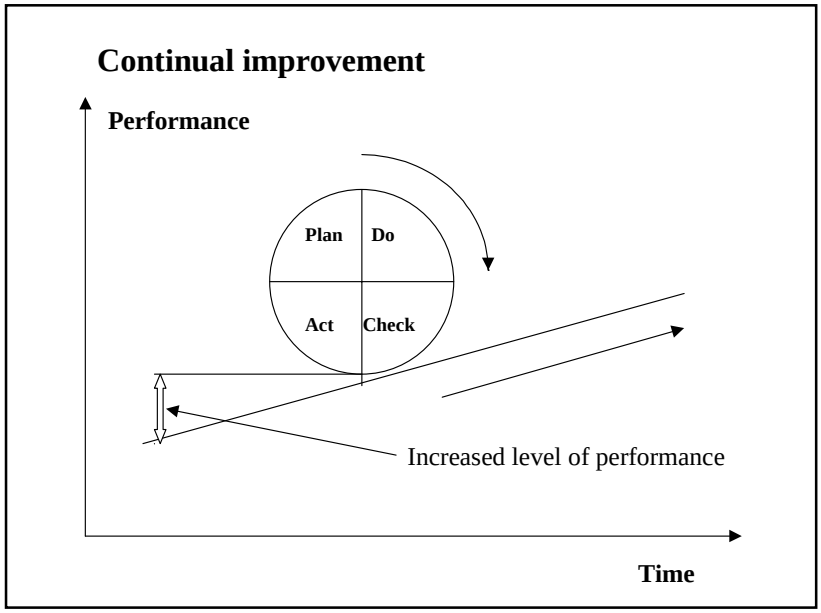

Figure 2: Graphical illustration explaining how Deming's model works.

the environmental action plan is. Textual slides refer to basic concepts and notions of environmental management standards, their structure and, especially, to practical implementation steps.

Figure 2 gives an example of a graphical illustration from the package, illustrating how the *Deming's model* works. Turning the wheel, repeating continually the cycle: *plan - do - check - act to improve*, we increase the level of environmental performance.

Checklists, such as that shown in Figure 3, orient students to appreciate each stage of EMS development critically. They may be used as a source of questions for teachers to ask in the discussion at seminars or, after the course, as a guide for implementing and developing EMS in an enterprise.

The pack also contains environmental documents of leading world firms. For example, *Kodak's Nine Guiding Principles,* the *US Department of Defence EHS Policy* and *Akzo Nobel Operating Policy* are included as model environmental policy statements.

CONCLUSIONS

A good understanding of scientific and engineering environmental issues together with strategy and principles of environmental management and sustainable development is a vital aspect of modern engineering education. It is of special importance for the Ukraine, especially as the country has inherited a badly damaged environment, obsolete and polluting industrial technologies.

The ISO 14000 series of standards on environmental

Checklist: The Environmental Action Plan	
1.	Is the action plan consistent with the enterprise's policy and strategy?
2.	Does it contain concrete objectives and targets
3.	Does the action plan contain: • quantified objectives to reduce environmental impacts and risks? • activities for the development of the EMS? • appropriate reviewing and reporting procedures?
4.	Does the action plan include for each activity: • a description of the purpose and intended results of the activity? • duration and date of completion? • resources required? • persons responsible for implementation and follow-up?
5.	Is there provision for a periodic review to identify whether: • implementation has achieved the intended results? • additional activities must be included in the action plan? • objectives, targets and activities require adjustment?

Figure 3: A check list from the study pack.

management systems is attractive due to the voluntary character oriented to continual step-by-step improvement in environmental performance of industries and enterprises and complete integration with the principle of sustainable development.

In developing the ideology of new courses in environmental management systems, the DonSTU faculty used links with the international community of engineering educators.

New courses on ISO 14000 environmental management system, the main ideas and topics of which are presented in this paper, started at DonSTU, the first in the Ukraine, in the 1997/98 academic year.

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BIOGRAPHIES

Alexander A. Minayev graduated from Donetsk State Technical University in 1964 as a metallurgical engineer. Since 1965 he has been with DonSTU as a researcher, associate professor, Head of the Division of *Processing of Metals by Pressure*, professor (from 1990), and rector.

He obtained a PhD from the same University in 1972 and DSc (DrTechnSci) in 1989. Professor Minayev is a distinguished specialist in metallurgy. He became widely known for his contribution to the theoretical basis for rolling carbonaceous and low-alloyed steels. In particular, he developed the classification for melting temperatures and deformation influences

on metal qualitative characteristics. He has published over 250 scientific works, including seven books and manuals, and eighty patents. Some of his work has been published in international journals and was written jointly with specialists and academics from Germany, England, Russia, Poland, and Slovakia.

Professor Minayev is a member of the Academy of Sciences of Ukrainian Higher School, the Academy of Engineering Sciences of Ukraine (from 1991), the European Association for Engineering Education (1994), the European Association for International Education (1995), and the International Academy of Exact Sciences, Industry, Education and Arts in California (1996).

Vadim V. Prisedsky was born on 29 April 1942 in the Donetsk region, Ukraine. He graduated with honours from Donetsk State Technical University in 1963 as a chemical engineer. He obtained a PhD (Cand ChemSci) in inorganic chemistry from Donetsk State University in 1971 and DSc (DrChemSci) in physical chemistry from Moscow State University in 1985.

He spent 25 years in industrial research with the Institute for Solid-State Electronic Materials and has been with the Donetsk State Technical University as Professor and Head of General Chemistry since 1989. His research interests include solid-state chemistry, nonstoichiometry and lattice defects in crystals, oxide functional materials: ferroelectrics, ferromagnetics, piezoelectrics, ionic conductors, superconductors, and engineering education. He has published over 250 scientific works on these subjects including five books, two manuals, and twelve patents.

Professor Prisedsky is a corresponding member of the Peter the Great Academy of Sciences and Arts (St Petersburg, Russia), and a member of the American Chemical Society (1995).

Gennady S. Klyagin graduated from Donetsk State Technical University as a mechanical engineer in 1959. In 1969 he obtained a PhD from the Research Institute for Metallurgical Machine-Building.

His sphere of scientific interest includes utilisation of waste of the metallurgical industry; recirculation of waste in industry; development of new technological schemes and equipment for low-waste and environmentally safe metallurgical processes; engineering education. He has published about 100 publications and obtained 32 patents.

He is currently Associate Professor, Head of Division and Dean of the French Technical Department at DonSTU.

Vyacheslav I. Ignatov graduated with a diploma of mechanical engineering from Donetsk State Technical University in 1973. In 1984 he was awarded Doctor of Philosophy from DonSTU in design of mining machines and systems. For 25 years he has been with DonSTU and is now lecturing in *Design and construction of mining machines and systems* and *Automated design*. He did a special course in the scientific subjects in the USA and Great Britain.

His research interests include computer modelling of working processes in mining machines and strength analysis and synthesis of spatial metalwork. He has a wide experience in strain measurement research of complex machines and mechanisms.

Since 1994 he has been Vice-Director of International Activity at DonSTU. He was DonSTU co-ordinator of the USAID project *Institutional Partnership* (1995-97), co-ordinator of the Ukrainian-American seminar *Workers' health in Donbass* under the guidance of the National Research Committee of the USA Academy of Science (1997), and co-ordinator of TACL project of British Council (1995-97).

Terence J. Oliver graduated in 1973 and after a career in railway engineering joined the University of Portsmouth, England. He is a principal lecturer specialising in engineering and product design. His interests include managing academic/industry programmes and developing international links. These have exceeded $US3 million over a ten year period.

He is currently manager of all undergraduate projects in mechanical engineering at the University of Portsmouth and is responsible for the Product Engineering Design Masters programme.