ENERGY & ENVIRONMENT IN ENGINEERING EDUCATION*

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INTRODUCTION

Awareness about environmental problems in Egypt has increased significantly during recent years. There is now widespread appreciation of the serious health risks, degradation of natural resources, climate change and need for preventive measures for environmental protection. Such measures will have many technical and economic consequences.

Solving pollution problems should be directed to Pollution Prevention, Reduction and Control. This philosophy, among several others, should be reflected in the teaching curricula of the Faculties of Engineering. Future engineers should be properly equipped with adequate environmental knowledge to understand and contribute to resolving the local, regional and global environmental challenges seen in our national plans for environmental protection, regional agreements and international conventions.

Specific courses on environmental pollution, protection, management should be preceded with the necessary courses on basic sciences, supporting sciences, etc. Part of these courses should be tailored to fit and suit the particular specialization of each Engineering Department.

In order to realize these objectives effectively, the staff members for each Department should be introduced to this evolving and fascinating field of Energy and Environment. This could be achieved through a well designed intensive program of training and capacity building.

The paper is an attempt to present an overview of the different courses and topics that could be proposed for the various departments in the Faculties of Engineering. Each Department could select the appropriate contents and the level of details that should be covered for each course.

MAIN ENVIRONMENTAL OBJECTIVES:

The main objectives of teaching environmental topics in all Departments of the Faculty of Engineering is to improve the awareness and understanding of the new generations of engineers about the main environmental issues relevant to each Department. These objectives could be summarized as follows:

- Development of an *Environmental Management System* (EMS)
- Compliance with *Environmental Legislation*
- Minimization of *Consumption*
- Management of *Waste*
- Conservation of *Energy and Raw Materials*
- Encouragement of *Environment-Friendly Technologies and Products*
- Reviewing *Transport Options*
- Promotion of *Environmental awareness*
- Monitoring and Evaluation of *Environmental Performance*

These topics represent a broad outline of the main objectives. Each one of these objectives could be easily subdivided into its main elements.

MAIN ENERGY AND ENVIRONMENT TOPICS FOR ENGINEERING EDUCATION

The main energy and environment topics required for engineering education are given below. These topics cover a very wide area of the subject. Each Engineering

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department, however, should select the most relevant topics most suitable to the field of specialization of the Department. The main topics to be taught are: Basic Sciences, Supporting sciences, Natural Resources & Materials, Environmental Subjects, Environmental Systems, Environmental Technology, Energy and Environment, Environmental Problems, Environmental Protection, Cleaner Production, Waste Management, Social & Human Dimension, Risk Analysis and Assessment, Environmental Management, Environmental Economics, Environmental Uncertainties, Environmental Models, Environmental knowledge Base, (data and statistics), Environmental Technology Assessment, Environmental Impact Assessment, Life Cycle Analysis.

A course on *Environmental Management* System may include: Rational land use planning, Water management, Energy management. (promotion of renewable energy sources, promotion of clean and energy efficient technologies), Waste Management (minimization, recovery, Reuse, Recycle, etc.). Environmental Impact Assessment, Environmental Monitoring, Life Cycle Analysis, Environmental Economy, etc.

A course on *Waste Management* may include: the environmental and economic benefits from Waste Minimization: at Source, Re-use, Recycle, Repair/Upgrade, Life Extension, Incineration, (with energy recovery /without energy recovery), Dumping/ Landfill, Composting. The economic and environmental benefits of Waste Management has been very well demonstrated in several industries all over the world and in certain industries in Egypt.

ENVIRONMENTAL PROBLEMS

A course on *Environmental Problems* should cover in-detail the following main topics: definitions, types, causes, scope, consequences, measures of reduction, prevention and control, (mitigation measures), etc. The main topics of environmental problems are: Air Pollution, (from Industry, from Transport, From Power Plants, etc.), Emissions, Water Pollution, (River Nile pollution, Coastal water pollution, Marine pollution, Ground water pollution, Lake water pollution), Coastal Erosion, Climate Change, Ozone Depletion, Noise pollution, Informal urbanization, Desertification, Deforestation, etc.

ENERGY AND ENVIRONMENT

A course on Energy and Environment should cover the main types of energy resources and should indicate clearly the following facts:
Energy and life are inseparable. The use of energy is essential to economic and social development. The quality and comfort of human life on our planet earth is closely connected with the exploitation and harnessing of energy available in nature.

- Energy use is a major source of emissions.
- The deleterious impact of human activities on nature in the energy field is significant.
- The world is fast running out of conventional energy resources due to the ever increasing demand. This necessitates cleaner and more efficient technologies to use the available energy resources

The main types of energy resources could be subdivided as follows:
Primary Energy Sources: The primary sources of energy include: Solid Fuels, Liquid Fuels, Gaseous Fuels, Hydropower, Nuclear Energy, Solar Energy, Biomass, Wind Energy, Ocean Energy, Geothermal Energy, (taping natural sources of steam, hot water, hot brine, etc.
Secondary Energy Sources, (Converted From Primary Energy). The secondary sources of energy include: Electric and Heat Energy.
Renewable Energy Sources: The renewable energy sources include: Solar Energy, Hydropower, Wind, (Blades, Generators, Masts, Towers), Biomass, Ocean, etc.
Non Renewable Energy Sources (depletable): These sources include: Oil, Natural Gas, Coal
Energy Saving Techniques:
Energy saving could be achieved through: Combined cycle generation, Raising overall energy efficiency, Changing the behavior of the user, Improving the control system, Improving the energy system, Changing the energy system

The environmental problems resulting from energy consumption may be controlled by:

improving efficiency in energy production, transmission, distribution and consumption
- creating environmentally sound energy systems.
- cleaner and more efficient technologies to use the available energy resources.
- minimization of total energy consumption
- minimization of wasted energy
- Using energy efficient products and systems
- modernize existing power systems to gain energy efficiency and develop new and renewable energy sources, such as solar, wind, hydro, biomass, geothermal, ocean, etc.
- help people learn how to develop and use more efficient and less-polluting forms of energy.
- Promote environmental impact assessment. and other ways of making decisions that integrate energy, environment and economic policies so as to foster sustainable industrial development.
- Use administrative and economic measures that encourage industry to develop safer, cleaner and more efficient technologies.

A major part of the environmental problems of energy consumption comes from the Transport Sector. The following issues of the Transport Sector should be clearly identified:

- Transportation is essential for economic and social development, and the travel demand will undoubtedly increase, however this activity is a serious source of atmospheric emissions.
- People mobility is increasing now at a high rate. Traffic causes 70-90% of urban air pollution.
- Millions of tons of different types of cargoes are moved from sources to consumption.
- The transport system should remain a positive factor in economic development, fulfilling the needs of mobility and at the same time preserving the environment. Exhaust from vehicles poses health risk, as the number of vehicles has increased rapidly in Egypt in the last few years.

MANAGING TRANSPORT SYSTEMS

The management of the transport sector may be achieved by:

- Simulating, planning and managing city transport networks
- Expansion and encouragement of the use of public transport
- Encouragement of vehicle sharing and Inter-city Passenger
- Promoting Cleaner Vehicles, (using CNG, Using Electric Vehicles, etc.)
- Developing an efficient, cost-effective, less polluting and safer rural and urban mass transport.
- Development of environmentally sound road networks.

The oil crises in the 1970's and the current energy situation have renewed interest in electric vehicles as a potential low pollution, energy efficient technology. Today electric vehicles are being developed for many applications, specially for delivery services in urban areas.

POLLUTION FROM INDUSTRY

- A course on *Industrial Pollution* should clearly indicate the impact of Industry on Climate Change and other Environmental Problems.
- Industry provides goods, services and jobs, but the industrial use of resource and materials cause atmospheric emissions.
- Our atmosphere is under increasing pressure from greenhouse gases that threaten to change the climate and from chemicals that reduce the ozone layer.
- Industry needs to make more efficient use of materials and resources, install pollution controls, replace chlorofluorocarbons (CFCs) and other ozone-depleting substances with safer substitutes, and reduce wastes.
- Most industries use large amounts of water for cooling purposes or as an integral part of the manufacturing process. Consequently industrial effluents may contain waste products, heat, leached material from heat exchanger, etc. The heat exchangers must constantly be cleaned to keep the heat exchange efficiency high. These cleaners may be toxic than process wastes.

Treating all industrial effluents can be very expensive. Modification of the entire process could be a more economical proposition. This often results in an increase of efficiency with a lower overall production cost, i.e. this is the cost-effective method of handling unwanted effluents.

- There are environmental and economic benefits from increasing efficiency and waste reduction.

ENVIRONMENTAL TECHNOLOGY ASSESSMENT

Environmental Technology Assessment is a tool that could promote the use, development and application of environmentally sound technologies. It encourages cleaner production and discourages the use of environmentally hazardous technologies, processes and products that encourage unsustainable consumption patterns. Decision makers in industry must be aware of the potential local, regional and global environmental impacts of the technology choices they make.

LIFE CYCLE ASSESSMENT, (LCA)

The public in Egypt should now be aware that the consumption of manufactured products and the daily services and activities of our society adversely affect supplies of natural resources and the quality of the environment. There is now a growing awareness of the need to radically decrease waste streams from production and consumption processes. This awareness has not only brought about the implementation of improvements in processes but has also led to improved and increased circulation of materials. Unfortunately, not all industries have been able to make use of all reusable and/or recycled materials available. Similarly, collection of materials for reuse/recycle has not been an efficient and successful process in some industries.

LCA is a tool to evaluate the environmental consequences of a product or activity holistically, across its entire life. LCA is sometimes called a "cradle-to-grave" assessment. LCA is a systematic way of examining the environmental Impacts from raw materials extraction through the processing, transport, use and disposal. LCA could be used to assist companies to quantify and assess their impacts to the environment, to identify opportunities to minimize that impact and significantly to realize cost savings by making more effective use of available resources. It can also be used to evaluate the effects of resource management options designed to create sustainable systems.

The Main Components of LCA are:

a) Identification and quantification of energy and resources used and environmental releases to air, water and land (*Inventory analysis*).
b) The technical qualitative and quantitative characterization and assessment of the consequences on the environment (*impact analysis*).
c) The impact analysis addresses ecological and human health consequences and resource depletion. The evaluation and implementation of opportunities to reduce environmental burdens (*improvement analysis*).

LCA adopts a holistic approach by analyzing the entire life cycle of a product, as follows:

- Raw materials extraction and acquisition
- Materials processing and manufacture
- Material transportation
- Product fabrication
- Product transportation, distribution, operation/consumption
- Product maintenance and repair
- Product disposal/scrapping

RISK ANALYSIS AND ASSESSMENT, (RA)

- Risk analysis is used for the assessment of the hazards and can be associated with the following three questions:
    - What can go wrong?
    - What are the effects and consequences?
    - How often will it happen?
- Risk assessment is the process of assigning magnitudes and probabilities to adverse effects resulting from human activities or natural catastrophes. Risk assessment has been recognized as a valuable tool to support decisions about actions that may have undesirable effects

(Environmental and otherwise). Conceptually, RA applies to the human health, ecological health, safety, environmental degradation, etc.

- Chemical risk and safety has been a worldwide concern especially after Bhopal. The Middle East region, and Egypt in particular, has a large concentration of petroleum extraction and processing facilities including highly hazardous facilities such as LNG terminals, petrochemical processing plants, gas, oil and product pipelines, oil and gas tankers and sea terminals, etc. Hazardous and toxic releases from such facilities due to either accidents or sabotage (for example, the deliberate incineration of Kuwait's oil fields by the Iraqi army in the aftermath of the Gulf war in 1991) pose a significant threat to health and the environment. Serious accidents and toxic releases could also occur when using dangerous substances in the production process, during transport of dangerous substances, within the industrial plant, etc. A comprehensive risk assessment of such facilities should involve regulatory authorities and the scientific and technical community and should be based on state-of-the-art codes and standards that greatly facilitates safety planning, builds confidence and enhances security.

Risk assessment is based on the following main items: I) Development of accidental scenarios which could potentially lead to release of hazardous or toxic material. ii) Specification of various pathways (air, water, ground) by which the hazardous material can lead to public exposure and the roots of such exposure (inhalation, skin absorption, etc.). iii) Estimation of consequences such as: human health effects, environmental contamination, economic loss, etc. iv) Calculation of risk taking into account the likelihood of the scenario and the release of the toxic materials.

Risk Reduction Actions

The procedure commonly used to reduce risk is based on : Identification of hazards, Location of hazards and Analysis of hazards. Actions that may be taken to reduce risk include: actions to eliminate hazards, actions to eliminate or reduce consequences, actions to reduce probabilities to acceptable levels. The methods commonly used to reduce risk include: changes in the design of the physical system, changes in the design of the control systems, changes in the process variables, such as temperature, pressure, stress, etc., changes in the process / plant materials, changes in the test and inspection procedures of key components, changes in the variabilities and uncertainties of the system.

DESIGN AS PART OF THE ENVIRON-MENTAL ENGINEERING SYSTEM

The Environmental Engineering System includes: Design, Construction, Operation, M/R, Decommissioning/Scraping. Each element of this system should include the main topics and issues as part of the engineering side of the subject.

Design is one of the main courses in Faculties of Engineering that has a close connection with the relevant issues of energy and environment.. The association of Design, directly and indirectly, with safety, economy, energy and environment could be clearly seen as follows:

- *Design:* Objectives, Concepts, Assumptions, Procedures
- *Material Selection,* Should be based on: Strength considerations, M/R considerations, Disposal considerations, Economic considerations, Environmental considerations
- *Mathematical model:* Assumptions & Validity
- *Analysis:* Methods, Accuracy and Degree of sophistication

Design Criteria, Could be based on one or more of the following items: *Safety* considerations, *Risk* assessment, *Economic* considerations,(Initial cost, Operational cost, M/R cost, Disposal cost), Life span, M/R, Environmental impacts: Pollution problems, (missions & waste), Energy efficiency.

Design Objectives

The main objectives of design could be the minimization of: building cost, M/R cost, cost of failure, cost of decommissioning (scraping), life cycle cost. Other design objectives are: performance, safety, environment, etc.

Design for Environment (DFE)

DFE is a new approach of design intended to make Safety, Health, Economy, and Environmental Protection an integral part of: Design, Manufacture, Distribution/ transport, Product use/operation, Maintenance/Repair, Recycling, Disposal/ scrapping

Design for Safety

Design for safety should not only include safety of the system but should also include risk to human life and risk to environment. In the maritime sector, tragic accidents with environmental disasters have focused world opinion on ship safety and operation. Unfortunately, design for safety and safe operational practices are only effectively appreciated after serious accidents have occurred. The Factor of Safety commonly used in Engineering Design should include, not only safety requirements, but also risk to human life and risk to environment, as follows:

$$\gamma = \gamma_X . \gamma_Y . \gamma_Z \quad (1)$$

where:

- γ = total Factor of Safety
- γ_X = factor taking account of the safety of the system
- γ_Y = factor taking account of the risk to human life
- γ_Z = factor taking account of the risk to Ecology

The higher the magnitude of the total Factor of Safety, the less the probability of failure, the less the cost of failure, the less the risk to ecology and the higher the irrational use of materials and resources. On the other hand, the lower the magnitude of the factor of safety, the higher the probability of failure, the higher the risk to human life and the higher the risk to ecology. This indicates clearly that the Magnitude of the Factor of Safety should be rationally selected so as to satisfy the requirements of safety, ecology and economy.

SHIP DESIGN FOR ENERGY SAVING (ECONOMIC OPERATION)

- Manpower saving, (through increased Mechanization & Automation).
- Reducing Unproductive time through improving quality and reliability
- Energy saving through: Reduced fuel consumption, Improved ship design, Proper selection of main ship dimensions, Proper selection of ship proportions, Using optimum ship shape
- Improving propulsion efficiency
- Raising efficiency of marine power plant
- Improving heat recovery system
- Improving ship routing
- Improving rudder design
- Reducing ship motions
- Using sail assisted ship propulsion, etc.

Therefore, the teaching of Design courses should be more comprehensive than that normally given in our Faculties of Engineering and should cover the main issues outlined above.

CONCLUSIONS

In order to ensure successful introduction of energy and environment courses in the different Departments in the Faculties of Engineering, it is necessary to "train the trainers". This could be achieved through a program of "Capacity Building" dedicated to the staff members of the Faculty of Engineering who have not yet been involved in this important discipline. One way of achieving this objective, is to conduct several specialized workshops and seminars, for each Department, to create incentives particularly for the young staff members, to encourage staff members to join research teams working on energy and environment problems in Egypt, etc.

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