INTEGRATING ENVIRONMENTAL MANAGEMENT
By Introducing an Environmental Management System in the Student Laboratory

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The most efficient way to achieve an environmental and sustainable development culture and prevent pollution from industrial processes is to educate students by our own example. For this reason, the university must be a reference for future professionals who are to lead the industrial processes. These leaders will be chemical engineering students who, in the near future, will perform engineering tasks. Therefore knowledge, principles, and basics related to sustainable development should be introduced within the curriculum.[1, 2] These principles could be easily introduced in subjects related to Environmental Science and Technology, which constitutes a very important aspect of chemical engineering education. Engineering educators are responsible for achieving this goal, but in order to do so, the scientific and technological fundamentals of Environmental Science should be explained on the basis of sustainable development. These explanations can be applied using a tool that is now more common in industry and a subject in the chemical engineering studies curricula:[3] the environmental management system.

An environmental management system is defined by the International Organization for Standardization (ISO) as "the part of the overall management system that includes organizational structure, planning activities, responsibilities, practices, procedures, processes, and resources for developing, implementing, achieving, reviewing, and maintaining the environmental policy." Environmental policy is defined as the "statement by the organization of its intentions and principles in relation to its overall environmental performance, which provides a framework for action and for the setting of environmental objectives and targets."

There are a number of standards upon which one can model different environmental management systems. The ISO 14001 environmental management system standard is the most widely recognized framework, and many entities have their environmental management systems certified as conforming to ISO 14001.[4] The main features of these systems are:

- *A voluntary approach oriented to developing positive long-term objectives and progressing toward achieving them, rather than applying stiff penalties for failing to comply with many itemized requirements.*
- *A continual step-by-step improvement in the environmental performance of enterprises and industries.*
- *A complete integration of the principle of sustainable development.*
- *An easy and natural integration with other standards such as ISO 9000, the Quality Management System.*

The first objective of these systems is the same as that of chemical engineering educators: To enhance a positive attitude about environmental protection and management. Achieving this objective will result, on a long-term scale, in more sustainable development within society.[5, 6] The second objective is to design elements and implementation steps. Both of these objectives involve orientation and working familiarity with environmental management system guidelines. This is not always easy to achieve for workers and/or students because they do not usually feel involved.

Further, the selected objectives should be achieved within the more abstract concept of sustainable development. This concept demands that the three main aspects of development —economic, social, and environmental—be considered as

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a whole.[7-9] Attempting to do so often produces conflicting interests, and the solution—a successful integration—implies an essential change from commonly held views on progress and growth in human society. This integration is not explicitly included in ISO 14001 systems. For this reason, educators must provide the knowledge, concepts, and approaches of sustainable development to students—who will soon contribute to society's material progress and growth.

Using the environmental management system as a tool, we introduced the concept of sustainable development in chemical engineering education within the unit operations laboratory, which is the facility most similar to an industrial facility. In this way students become conscious in every session of the fact that they are participating in an environmental management system and trying to achieve further objectives related to environment that will contribute to the sustainable development of society. Students must be aware of generated hazardous waste and how adequate management of it is fundamental to avoiding problems in basic utilities such as drinking water, wastewater, or solid waste treatment. Students must learn to try to minimize waste production and the use of reagents while considering the social, economic, and environmental importance of this minimization. Students must work according to environmental and security regulations not only because it is their obligation legally but because they are conscious of its importance for society. To do so, students must be supplied with the necessary procedures and instructions. In this paper we show how the system has been developed and implemented in the laboratory, what role students have played, the main problems identified, and how those problems have been solved.

CONTEXT

Academic context

This work was undertaken in the Chemical and Nuclear Engineering Department of the Technical University of Valencia. This department teaches many subjects within engineering studies such as industrial engineering, chemical engineering, and materials engineering. Many of these subjects are related to environmental science, including environmental science and technology, environmental technology, water pollution, air pollution, solid wastes, environmental analytical techniques, environmental management, environmental impacts, radioactive pollution, and drinking water treatments. These subjects are scheduled for the later years of a student's studies as they build upon earlier knowledge to introduce concepts and techniques related to water pollution, air pollution, and hazardous wastes, the management of these concepts, and the main preventive tools used in industry.

The plethora of subjects related to the environment taught by our department was the basis for our objective of introducing sustainable-development principles and objectives throughout the students' academic tasks.

PREVIOUS EXPERIENCE

Among the various engineering studies, the Chemical and Nuclear Engineering Department mainly works with the Industrial Engineering School. This higher education center has been certified under the ISO 14001 Environmental Management System.[10]

The principal objective of this system is to improve the center's activities from an environmental point of view, to properly treat its wastes (paper, plastics, hazardous wastes, etc.), to reduce its consumption of raw materials, to create a positive attitude toward the environment, and to integrate the principles of sustainable development.

As in all environmental management systems, the people affected should be integrally involved, including not only the staff of the center but also the students. Although the students are the largest part of the Industrial Engineering School, it has been demonstrated that they do not know what the environmental management system is, what it implies, or what their role is within it. Usually their only contribution to the environmental management system consists of putting waste in the appropriate container as a rote action, without being conscious that they are part of a global management system trying to achieve broader objectives. For this reason, and because we are responsible for environmental subjects in engineering studies, it is our duty to involve students in the environmental management system and to use it to introduce the principles of sustainable development.

APPLICATION TO THE DEPARTMENT

In Spain, the docent responsibilities and student laboratories depend on the various departments within the university. Based on the implementation of an environmental management system in the Industrial Engineering School, the Chemi-

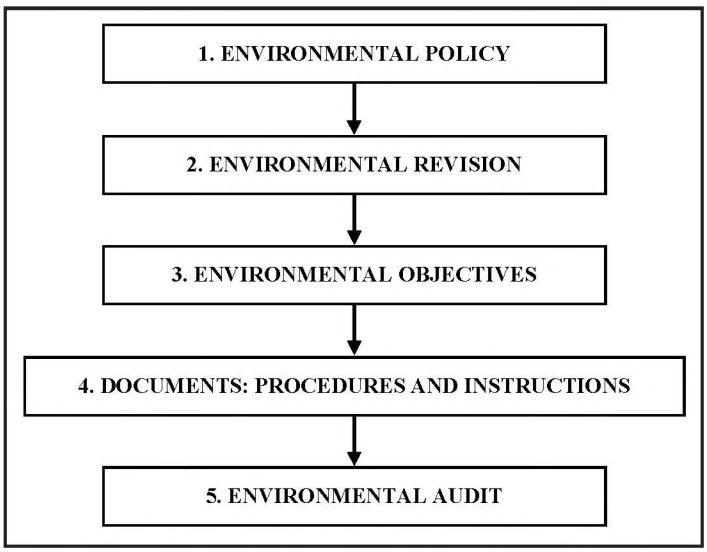

Figure 1. *Steps to implement an environmental management system.[11]*

cal and Nuclear Engineering Department is implementing an environmental management system in accordance with the ISO 14001 specifications. The steps toward implementation are contained in Figure 1. Referring these steps to the student's laboratory, we have:

1. Environmental Policy

The first step was approving the department's environmental policy. This environmental policy is presented in Figure 2. Many points of the environmental policy are directly related to students, and according to it our duty as engineering educa-

ENVIRONMENTAL POLICY

The Chemical and Nuclear Engineering Department is aware of the need to incorporate the environmental ethics to all its activities and, in accordance with the Environmental Policy of the Polytechnic University of Valencia, it has decided to assume that responsibility. The University, and by extension its Departments, have, as a main target, the creation, development and transmission of Science, Technology and Culture. They are an instrument for the advance of our society and for intellectual development, as well as for the promotion of the freedom of thought. Through all this, it is possible to influence society by introducing improvements in the relation of the human activity with nature and in the management of the natural resources.

The Department assumes the contents of the Agenda 21 document from the United Nations. It assumes the responsibility to generate science, technology and culture, according to solidarity principles with all the contemporary world and under sustainability criteria in order to extend it towards the future generations.

As part of a Higher Education Institution, the Department tries to raise awareness in all its members, as well as in the students, for the preservation and improvement of the Environment. It is conscious that through instruction and research it plays an exceptional role in the transformation of society.

As an instrument to reach these aims, the Chemical and Nuclear Engineering Department is committed to implement an Environmental Management System: UNE-EN-ISO 14001 and consequently to try to maintain the continuous improvement of its environmental practices. In particular:

1. Analyzing and evaluating the activities developed in the Department, according to the Environmental Management System, and trying to determine and to diminish the environmental impacts that can be derived from them.
2. Providing an environmental instruction adapted to all the students and workers.
3. Providing to the members of the Department appropriate training and environmental information related to their activity.
4. Fulfilling all the environmental legal requirements, trying to go beyond the prescribed minimums.
5. Rationalizing the consumption of raw materials, resources and energy.
6. Preventing the possible pollution and avoiding, as far as possible, the spills, the emissions and the wastes generated in the different activities.
7. Managing the wastes generated according to laws.
8. Informing of its objectives to the university community, favoring its participation in the environmental instruction of the students.
9. Working with the companies, institutions, and people that develop their activity with the department, to help them and to commend them for improving environmental performances.

To carry out these commitments, challenging environmental objectives will be established. They will be public and, as far as possible, quantifiable, evaluating continuously the goals.

Annual reviews will be made that will contain a revision of the environmental performances of the department and these will become public, spreading the expected objectives to all the university community

The Chemical and Nuclear Engineering Department Director

Figure 2. *Environmental Policy of the Chemical and Nuclear Engineering Department of the Technical University of Valencia.*

tors is to provide and foment environmental instruction on the basis of the sustainable development principles adapted to all students (points two and eight). In the laboratory, students are the main consumers of raw materials, resources, and energy. Therefore, according to point five, they must rationalize the consumption of these resources. They have to prevent possible pollution and avoid, as best as possible, the spills, emissions, and wastes generated in different activities (point six). Finally, according to point seven, they must manage the wastes properly in accordance with environmental laws. As faculty, we have to supervise and stimulate them to achieve these objectives, as well as to not only be cognizant of the Environmental Policy but also to develop new attitudes and aptitudes more consistent with the principles of sustainable development.

2. Environmental Revision

The second step was to analyze the department's environmental situation, including how it manages wastes, the consumption of raw materials, energy, etc. This analysis unveiled environmentally strong and weak points used to establish environmental goals to be achieved. In-lab discussion was used to alert students to these goals and how they relate to sustainable-development objectives, thereby encouraging student participation in the continuous improvement process required by ISO 14001.

3. Environmental Objectives

The third step was to establish objectives to be achieved. These objectives were related to different activities, but one of the most important objectives was to involve the students in the environmental management system in order to develop the principles of sustainable development.

4, Documents: Procedures and Instructions

The last step was the preparation of a manual with the necessary procedures and instructions. The most important in the student's laboratory are the following:

Procedures

- IQN-P-001: Procedure for the identification of significant impacts. This procedure aims to identify and quantify the impact of laboratory management on the environment, society, and the economy.
- IQN-P-002: Procedure for the identification and updating of the legal requirements.
- IQN-P-003: Procedure for environmental instruction. This procedure shows how to develop informative tasks in the laboratory. This information given to the students will not only be related to environmental issues, but also to cooperation and sustainable development.
- IQN-P-004: Procedure for writing and controlling environmental management system documents.
- IQN-P-005: Procedure for control of the wastes. This procedure includes classification of the waste indicating its hazard, the possible risks of inadequate control of it, and recommendations to reduce expenses derived from its management.
- IQN-P-006: Procedure for management of raw materials and natural resources. This procedure includes recommendations for reducing consumption of raw materials and natural resources, and for reducing expenses derived from their use.
- IQN-P-007: Procedure for environmental control of dealers. This procedure encourages dealing with companies that perform their activities according to the principles of sustainable development.
- IQN-P-008: Procedure for emergency situations.
- IQN-P-009: Procedure for detecting and correcting inadequate environmental management system performance and implementing future preventive actions.
- IQN-P-010: Procedure for internal and external environmental communication.
- IQN-P-011: Procedure for internal audits of the environmental management system.
- IQN-P-012: Procedure for revision of the environmental management system.

Instructions

- IQN-I-001: Instructions for proper hazardous wastes management.
- IQN-I-002: Instructions for management of waste paper.
- IQN-I-003: Instructions for management of waste glass.
- IQN-I-004: Instructions for management of used electronic equipment.
- IQN-I-005: Instructions for hazardous substances identification in the shopping process.
- IQN-I-006: Instructions for work in the laboratory according to environmental and sustainable principles.
- IQN-I-007: Instructions for the development of new, practical, laboratory classes according to environmental and sustainable principles.

For the students, the most important instructions and procedures presented in the first class are: IQN-P-001, IQN-P-003, IQN-P-005, IQN-P-006, IQN-P-008, IQN-P-009, IQN-I-001, IQN-I-002, IQN-I-003, and IQN-I-006. All allow students to actively participate in the environmental management system because they mainly relate to: the proper management and minimization of wastes and reagents; the critical analysis of the system in relation to sustainable-development principles; and carrying out adequate sustainable development and environmental work.

APPLICATION TO THE STUDENTS' LABORATORY

The most active student participation is developed in the laboratory. For this reason we emphasize applying the environmental management system to the teaching laboratory. In this way students are more conscious in every session that they are participating in an environmental management system. They learn that the principles that guide this system can be applied afterward in industry and that these principles are the same as those from sustainable development. Among other things, students must try to minimize waste production and reagent consumption, and be sure to work according to environmental regulations and the sustainable-development principles. To achieve these goals, we supply students with adequate explanations, concrete examples, and the necessary procedures and instructions.

Two problems identified with applying the environmental management system to the student laboratory were: 1) the proper management of varied wastes generated in the chemistry laboratory due to the great diversity, and 2) the sequence of courses. Subjects related to environmental science are upper-level courses. Experimental subjects, however, are pursued in the student's laboratory from the first year of the student's studies. At this level, they only have a general sense of what an environmental management system is and what the principles of sustainable development are.

To solve these problems, the following actions were taken:

- *The first day in the laboratory, students receive a theoretical explanation of the department's environmental management system. The explanation includes how the objectives of this system are related to the principles of sustainable development, and how students themselves could apply these principles in society after finishing their studies. The most important procedures and instructions used in the laboratory are also explained to the students.*
- *In each laboratory class, students have to write a report of their results that includes an environmental and sustainable evaluation of their work. This evaluation addresses the identification of the reactants used and the wastes generated. They must evaluate the cost of the experiment as well as determine the composition of the wastes and characterize them according to environmental laws. Then, they have to decide if the waste can be recycled, disposed of down the drain or in the general garbage, or if it must be collected in specific containers. To make this work easier, students receive a handout (shown in Table 1, next page) with an example from a chemistry laboratory exercise. They also use this page to gain awareness of the type and quantity of reagents used and the waste produced. In this way, it is easier for them to evaluate the work from an environmental and economic point of view. Additionally, they reference the bylaws pertaining to water pollutants and proper hazardous-waste management.*
- *In each session, students must propose alternatives to improve the practical laboratory class from the perspective of sustainable development. Concretely, they have to propose alternatives, when it is possible, for the used reactants by looking for other chemicals with a lower environmental, economical, and social impact. They also have to propose alternatives for proper waste management, and they can even make suggestions about the entire process. Initially these suggestions are more focused on the minimization of wastes, but later they consider the entire process from an environmental, social, and economical point of view.*
- *The last day in the laboratory, students have to discuss the different alternatives. This is probably the most active participation from students in the environmental management system because they usually find new environmental solutions and make new environmental suggestions related not only to the generated wastes but also to the development of the environmental policy, the inclusion of new facts in the environmental revision, and the criticism and development of the procedures and instructions to be more adequate for the practical laboratory classes. As an example of these proposals, students have suggested completing Statement 7 of the environment policy by adding the necessity of going beyond the legal obligations. These suggestions are made according to procedure IQN-P-012.*

The last two points are the most difficult for students—particularly for students in the first year of their studies—as it is much easier for last-year students who have already taken numerous classes related to Environmental Science and Technology. In addition, students in last year of their studies are more interested and active in the practical laboratory classes. They become more conscious that they are a part of the environmental management system and that the application of this system can contribute to sustainable development.

Nevertheless, the results obtained are very encouraging. In fact, we have approximately quantified the consumption of reagents per student and the production of wastes per student in some experiments carried out in the laboratory, and we have compared them between the first and the last years of study. Table 2 (next page) shows an example for the titration of hydrochloric acid (a typical titration necessary for various laboratory classes). The results show that, excluding accidents, there is a clear decrease in the consumption of reagents and the production of wastes in a student's last academic year. This decrease can be attributed not only to students' greater experience, but also to their greater awareness.

Therefore, the environmental management system is a tool that can easily be applied to introduce the principles of sustainable development in all the aspects of the future process that will be controlled by the students when they join the work force.

TABLE 1
Illustrative Form to Be Filled in By Students After Each Practical Laboratory Class

LABORATORY		VE16010			
SUBJECT		Chemistry laboratory			
STUDIES		Chemical Engineering		**YEAR**	2nd
CLASS No.	5	Redox titration			
OBJECTIVES:		Determination of the iron concentration present in a problem solution by means of a redox titration, using MnO_4^- and $Cr_2O_7^=$ as oxidant agents.			
REAGENTS USED					
Reagent		**Mass (g) or Volume (ml)**	**Concentration**	**Comments**	
$Na_2C_2O_4$		0.22 g/100 ml	2.201 g/l		
H_2SO_4		10 ml			
$KMnO_4$		70 ml	0.1 N		
Problem solution (Fe^{+2}, Fe^{+3})		20 ml			
$SnCl_2$		-		In excess	
$HgCl_2$		10 ml	0.25 M		
Zimmerman solution		25 ml		(Mn^{+2}, H_2SO_4, H_3PO_4)	
H_3PO_4		5 ml			
$Cr_2O_7^=$		50 ml			
WASTE PRODUCED					
LIQUIDS		**Mass (g) or Volume (ml)**	**Concentration (ppm)**	**Type**	
CO_2+Mn^{+2}+ H_2SO_4		140 ml	[Mn^{+2}]= 257.9	Hazardous waste	
Fe^{+3}+Sn^{+4}+Cl^- +Hg_2Cl_2+ Zimm.+Mn^{+2}		85 ml	[Fe^{+2}]=10259.3; [Cl^-]= 1044.12; [Mn^{+2}]=475.2	Hazardous waste	
Fe^{+3}+Sn^{+4}+Cl^- +Hg_2Cl_2+H_3PO_4 +H_2SO_4+$Cr_2O_7^=$		80 ml	[Fe^{+2}]=10970; [Cl^-]= 1044.12; [Cr^{+3}]=866.6	Hazardous waste	
GASES		**Mass (g) or Volume (ml)**	**Concentration (ppm)**	**Type**	
SOLIDS		**Mass (g) or Volume (ml)**	**Concentration (ppm)**	**Type**	

TABLE 2
Evolution of the Consumption of Reagents Per Student and the Production of Wastes Per Student in the Titration of Hydrochloric Acid

Reagent	**Mass (g) or Volume (ml)**	
	2nd academic year	**5th academic year**
Na_2CO_3	~0.85 g	~0.45 g
HCl ~ 0.1N	~100 ml	~30 ml
Phenolphthalein	~6 droplets	~4 droplets
Distilled water	~500 ml	~300 ml
PRODUCTION OF WASTES		
Waste	**Mass (g) or Volume (ml)**	
	2nd academic year	**5th academic year**
Na_2CO_3 ~ 4.5 g/l	~150 ml	~75 ml
HCl	~80 ml	~20 ml
$NaHCO_3$ + NaCl + phenolphthalein	~70 ml	~60 ml

CONCLUSIONS

It is possible to introduce the concept of sustainable development in engineering education by implementing an environmental management system in the students' laboratory.

In the laboratory, students learn to reduce the consumption of raw materials, resources, and energy; to prevent pollution; to reduce the generation of wastes; and to manage the wastes generated according to environmental laws.

Also in the laboratory, students learn to propose alternatives for its management to improve the laboratory work from an environmental, economical, and social point of view.

Finally, through all these aspects, students are more conscious of the fact that they are participating in an environmental management system and that its objectives and methods can easily be applied to their future jobs with respect for the principles of sustainable development.

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