

## **AC 2007-812: SOLID AND HAZARDOUS WASTE COURSES TARGETED TO THE DEVELOPING WORLD**

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# **Solid and Hazardous Waste Course targeted to the Developing World**

## **Abstract**

This paper compares and contrasts three courses related to Solid and Hazardous Waste Management: one new course module on Hazardous Waste that was taught at the UNESCO Institute for Water Education to 21 students from around the world in Summer 2006, and the traditional Solid and Hazardous Waste courses taught in the U.S. as part of the B.S. and M.S. programs. The UNESCO course module was geared to emphasize hazardous waste problems and approaches that are appropriate in the developing world. Traditionally, the U.S. courses focus on issues common in industrialized countries. However, some of the UNESCO course content can be added to U.S. courses to broaden the students' perspective and prepare them for work in a more global setting. Student attitudes about hazardous waste upon entering the course are contrasted for American vs. international students.

## **Introduction**

Hazardous waste is an issue of global importance. However, there are some notable differences in the most critical challenges facing the developing world and the developed world, specifically the U.S. After teaching a course on Hazardous Waste Management to graduate and undergraduate students at the University of Colorado - Boulder for eight years and a Solid Waste Management course for four years, in summer 2006 I had the opportunity to teach a module on Hazardous Waste in a Solid Waste course at UNESCO's Institute for Water Education (<http://www.unesco-ihe.org/>) in Delft, The Netherlands. The opportunity to refocus my traditional lectures on issues that are most pressing in the developing world was of interest, and the experience indicated content that might be useful to include in courses at my home university in the future. Key readings for the UNESCO course were recently-published journal articles rather than a traditional textbook, as most of the texts on hazardous waste focus on issues that are primarily of concern in industrialized countries. The student attitudes about hazardous wastes were also different when entering the courses, and these attitudes are contrasted.

One key area of concern is the export of hazardous and industrial wastes from industrialized countries into developing countries.<sup>1,2</sup> This continues to occur in spite of the Basel Convention. Much of this waste transport is electronic materials (E-waste) that are shipped from the U.S. and Europe into Asian countries under the guise of recycling.<sup>3,4</sup> However, unsafe working conditions and the lack of environmentally sound disposal practices after extraction of high value materials is cause for concern. For example, Guiyu, China, is a community whose economy is almost entirely driven by the extraction of materials from computers and monitors for recycling. This activity has resulted in significant environmental degradation.<sup>3</sup> Another concern is the use of pesticides in developing countries that have been banned in other places; for example, DDT and lindane.<sup>5</sup> The public is generally unaware or unconcerned that pesticides may pose unwanted side-effects, noting primarily the short-term benefits that are gained by their use. Beyond this, many of the hazardous wastes are generated by small and medium scale industries, such as automobile service shops and gas stations, lead-acid battery manufacturing/recycling, and paint

shops. Although less hazardous waste per capita is typically produced in developing countries, there is often poor general control of pollution and waste disposal in these countries. These countries also typically lack the financial resources to adequately treat or dispose hazardous materials.<sup>1,2,6</sup>

### Student Enrollment

One of the first key differences in the U.S. versus UNESCO courses are the students that enroll in the courses. Specifically, 38% of the students in the UNESCO course were practicing engineers who were taking the course specifically as a short course for professional development. The remainder of the UNESCO students were taking the course as an elective to fulfill requirements for their Master of Science (MSc) graduate degree. In comparison, few of the students participating in the U.S. courses had significant work experience. The hazardous waste course was required for students earning a B.S. degree in Civil Engineering with a water and environment focus. The hazardous waste course is an elective for Environmental Engineering B.S. students and M.S. students. The U.S. solid waste course is a graduate course that can be used as a technical elective for undergraduate or graduate students. Most of the UNESCO course students were from Africa (62%), Asia (24%), South America, and Eastern Europe. The majority of the students in the U.S. courses are from the U.S. An overview of the student demographics in the 2006 UNESCO course vs. the US courses from 1997 to 2007 are presented in Table 1. Student interest, background, and motivation varied widely. In general, the UNESCO students were very engaged and actively participated in class discussions with specific questions about solving problems they knew about in their home country. The students in the U.S. courses generally seem more passive.

Table 1. Students enrolled in UNESCO vs. U.S. Courses

Course	# graduate students	# undergraduate students	# students with significant experience in practice	# nonUS students	% women
UNESCO Solid Waste	21	0	8	21	29
U.S. Solid Waste	5 – 11	3 - 10	1 - 2	0 - 5	33 – 75
U.S. Haz Waste	1 – 14	9 - 39	0 – 4	0 - 3	32 - 56

### Student Attitudes

A short survey was given to the students at the beginning of the first lecture in the 2006 UNESCO module or U.S. Hazardous Waste course (January 2007) to gauge their initial attitudes toward hazardous wastes. Responses are summarized in Table 2. The student attitudes toward hazardous waste in their own country was similar: UNESCO students from developing countries (many from Africa) were split about 50:50 in rating the problem as significant or moderate; U.S. students also rated the U.S. problem at about 50:50 significant:moderate. Somewhat surprisingly, the U.S. students overwhelmingly (82%) rated the problem of hazardous waste in developing countries as significant.

Table 2. Student responses on the first day of Hazardous Waste module or class to the question: How important do you think the problem of hazardous waste is in:

Question	Students	number of students selecting ratings below			
		Significant	Moderate	Minimal	Not a problem
your country	UNESCO	7	7	1	0
the U.S.	U.S.	9	8	0	0
developing countries	U.S.	14	3	0	0
Africa	U.S.	10	5	2	0

The majority of the students in both the UNESCO and U.S. courses stated that they felt that the general population underestimates the problem of hazardous waste: 67% and 71%, respectively. Among the UNESCO students, they believed that the areas of the world generating the most hazardous waste were of North America (10 students), Europe (7 students), and Asia (5 students), primarily due to industrialization and consumerism (note: some students listed more than one response). In contrast, U.S. students believed that the most hazardous waste is generated in Asia (9 students), North America (8 students), and Africa (3 students). Reasons cited were industry, with large population and poor regulations in Asia; 3 students specifically mentioned China.

### International Course

Both the UNESCO course and my U.S. solid waste courses are taught on a block plan – an intensive three week course with ~3 hours of class each day. Students only take 1 course at a time. A summary of key topics covered in the various courses is presented in Table 3. In the first two-thirds of the UNESCO course the details of regulations, waste generation, waste characteristics, etc. were international in scope. From a solid waste perspective, per capita waste generation is significantly lower and organic composition much higher in low income countries.<sup>7</sup> This has significant implications for appropriate waste management strategies. The lectures on hazardous waste characteristics, toxicology, risk assessment, fate and transport, and solidification/stabilization technologies were nearly identical in the U.S. hazardous waste course and UNESCO module. The UNESCO course focused more on currently generated wastes, with lectures on battery waste and electronic wastes. In addition, some time was devoted to wastes associated with mining activities; particularly important since mining activities are being increasingly located in developing countries without strong environmental regulations. Battery waste and e-waste receive a relatively small amount of attention in the U.S. solid waste course, under the topic of household hazardous wastes. These topics have historically not been included to any significant degree in the U.S. hazardous waste course.

The hazardous waste arena in the U.S. is strictly regulated, so enabling students to gain familiarity with those requirements seems important. However, since each country will have its own regulations related to solid and hazardous wastes that may vary significantly (or in some cases, almost no regulations), devoting class time to this topic in the UNESCO setting seemed less beneficial to students.

As shown in Table 3, the topics that received the most emphasis in the UNESCO course were biotreatment and landfills. This reflects the technologies that are most sustainable given the

highly organic nature of the wastes in many developing countries, and the technologies that are appropriate and most widely used.

Table 3. Approximate number of contact hours spent on Topics Covered in the various Courses

Topic	UNESCO	U.S. Hazardous Waste	U.S. Solid Waste
Regulations	1	3	1
Characteristics	5	4	3
Collection	1.5		3
Fate & Transport	2	3	
Toxicology & risk assessment	7	10.5	
Reduce & recycling	5		10
Design		4	
Biological treatment	<b>9</b>	4.5	6
Incineration	3	0.5	4
Landfills, land disposal	<b>10</b>	1.5	3
Solidification, stabilization, other treatment, containment		12	

Another important point of contrast is the various activities in the courses, as summarized in Table 4. While the content in the US courses was well-supported by available textbooks, much of the material covered in the UNESCO course hasn't been gathered together and geared to developing world settings. For the hazardous waste module specifically, there were a number of articles published in peer reviewed journals that provided a good overview of topics from the perspective of developing countries.<sup>2, 4, 6, 8</sup>

Table 4. Comparison of Activities in Courses

	UNESCO	U.S. Hazardous Waste	U.S. Solid Waste
Readings	reader = journal articles, chapters, etc	80% text; 20% supplemental	90% text; 10% supplemental (EPA)
Lectures, hrs	45	33	~30
Homeworks	5 (exercises; largely in class)	6	8
Team Projects	1	2	0
Tours	3	0	~ 4
Exams	1	2	2

### Changes in U.S. Hazardous Waste Course

Some changes were made in the content taught in the Spring 2007 Hazardous Waste Management course in the U.S. to reflect issues of more global importance. These changes help the course fit into the "Engineering for Developing Communities" emphasis that has recently been developed in the graduate environmental and undergraduate civil engineering curricula. For the most part, these changes are fairly minor and fit within pre-existing topics covered in the course. For example, the regulations lectures were expanded to include the Basel Convention. The key contaminants lecture was expanded to describe the Persistent Organic Pollutants (POPs)

on the Stockholm Convention list. The toxicology lectures were expanded to present a world map indicating the global distribution of cancer incidence. The risk assessment lecture was modified to address the issue of “relative risk” and the fact that while in under-developed countries the greatest health risks are related to water and infectious diseases, as countries develop these risks transition to problems involving industry and toxic substances.<sup>9</sup>

## Summary

This paper suggests ways that an international perspective on solid and hazardous wastes can broaden the perspective of students and help prepare those who have an interest in working in the developing world. Despite the lack of a textbook that has an emphasis on the hazardous waste problems in developing countries, a number of good summary articles and publications are available that can provide adequate resources for students. The challenges in the developing world present an excellent opportunity to discuss life cycle analysis and sustainability issues.

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