MEDICAL SURVEILLANCE AND THE UNDERGRADUATE THESIS

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The Department of Chemical Engineering at the University of Sydney has a thesis as a core unit of study in the final year of the chemical engineering curriculum. Students are required to complete fifty credit units in their final year, and the undergraduate thesis is worth eight of them. It normally takes place in Semester 1 and may overflow into the vacation break before the second semester begins.

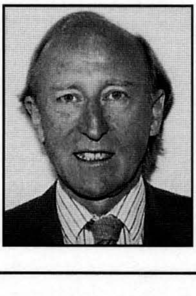
The thesis discussed in this article is an experimental thesis concerned with the operation of a distillation column to collect composition data on the trays for a ternary mixture of ethyl acetate-ethanol-water. The same thesis, however, can incorporate a significant new component that is designed to make students more aware of occupational exposure to hazardous substances.

This insight can also be valuable in other chemical engineering courses, including risk engineering, hazards and hazops, environmental pollution, and chemical engineering design. The awareness of the dangers of human exposure to hazardous substances is becoming evermore important due to the long-term health effects on workers in the oil, chemical, and biotechnology industries, as well as on the general public. Chemical engineering students need to be aware of alternative process flowsheets that avoid hazardous substances and a general chemical reduction-use program. Several popular books have brought the effect of chemicals on human health into the public consciousness.[1]

MEDICAL SURVEILLANCE

The World Health Organization has a medical surveillance program for the early detection of occupational diseases. It is a prevention program that should be brought to the attention of chemical engineering students. The information from such program can help students reduce the risk of exposure to hazardous substances. While medical treatment procedures are still not well developed for exposure that leads to cancer several decades ahead, numerous medical treatment procedures are outlined on Internet web sites, including osha.gov in the USA and worksafe.gov.au in Australia. There is also a CD-ROM[2] that contains outlines of medical treatment and surveillance programs for a wide range of hazardous substances.

Another CD-ROM search for ethyl acetate provides a wide range of information, including an eight-hour time-weighted average (TWA) exposure of 200 ppm in many countries and an outline of the proper medical treatment for it. This information confirms the low risk to students of exposure to ethyl acetate during a series of distillation experiments conducted for their undergraduate thesis. But chemical engineering students should be made aware of important and relevant sections of the subject's toxicology and epidemiology. Benzene is a substance that has undergone a reduced TWA over the years and is now recognized as being carcinogenic to humans. Details on background levels of benzene, a series of epidemiological studies, and cancer mortalities can be found in reference 3. The environ-



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mental effects of benzene[4] in wastewater and aircraft engine exhausts and their connective pathways to humans need to be carefully considered by chemical engineering students in the design of plants that produce benzene or fuels which produce benzene upon combustion. Can we expect a reduction in the TWA value for ethyl acetate in the future if there is medical evidence of an adverse health effect?

In New South Wales, 1966 legislation on Occupational Health and Safety (Hazardous Substances) Regulation has a separate division on an employer's duties relating to health surveillance. The employer must provide workplace health surveillance if any exposure to a hazardous substance results in a reasonable likelihood of a disease or other effect on health. This health surveillance must be under the supervision of an approved medical practitioner. The type of surveillance is listed in some detail for eleven hazardous substances, including acrylonitrile, asbestos, isocyanates, organophosphate pesticides, polycyclic aromatics, and vinyl chloride. The medical tests include the standard respiratory function tests such as FEV1 and FVC.

OCCUPATIONAL HEALTH AND EXPOSURE IN THE LABORATORY

The distillation column for the undergraduate thesis experiment involves medium quantities of solvent. The choice of solvents to be distilled by students should be based on occupational health, safety, ease of analysis, shape of the x-y diagram for binary systems, and the ability to extract knowledge on separation systems. Alcohol-and-water is a commonly used system. The occupational health risks to students of exposure to ethanol, by inhalation, need to be considered. How often are laboratory demonstrators advising students of the need to minimize the inhalation of ethanol?

For an undergraduate thesis or special project, it is useful to consider the ternary mixture of ethyl acetate, ethanol, and water. This mixture provides a good working environment to extract knowledge on ternary and binary azeotropes, distillation paths, and the appearance of a two-liquid-phase region in the distillation column. The following method has been used to actively reduce the exposure to ethyl acetate and ethanol over the students' extended period of work for the undergraduate thesis.

The most important aspect of occupational health is to introduce the subject to the students who will be involved, to notify them of the low hazard of ethyl acetate and ethanol, and to discuss with them the methods of reducing the mass inhaled. This introduces to them the psychological component of occupational health, leading each student to develop his or her own concern about the toxic nature of the inhaled substances. This component will play an important part in assessing their own exposure estimates. An approach to primary prevention of exposure is to increase ventilation in the laboratory, thus diluting the inhaled air and reducing the composition of the solvent in the air. The mass of inhaled solvent per breath can be reduced and the risk factor in occupational health could also be expected to be reduced. This involves starting exhaust fans and opening doors and windows to increase air circulation.

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The next aspect of occupational health is associated with safety and is concerned with the release of solvent vapors due to a laboratory fire. Students should be advised on the safety procedures to be used in the event of a fire. They should be told to evacuate the laboratory immediately and not to attempt putting out the fire, but to notify the safety officer instead. This is extremely important for minimizing the risk of exposure.

Good laboratory practice is important for occupational health. There is a direct association between hazard identification, hazard analysis, and good occupational health. When release of solvent vapors is the hazard to be minimized, a hazard identification program must be carefully conducted on the distillation equipment, identifying all possibilities of vapor release and listing all actions needed to prevent such a release.

For example, vapor could be released by a failure of the cooling water, a mechanical failure of a glass column piece, a gasket failure, or a low level in the reboiler. Special attention should also be given to the cooling water supply. Safety labels on the cooling water supply switches are essential to prevent an insufficient supply of cooling water and to minimize the release of solvent vapor.

Also associated with good laboratory practice is the need for the student to be present in the laboratory while the distillation equipment is operating. Students should be well trained in emergency procedures such as turning off the steam supply to the reboiler in the event of a solvent release.

STUDENT EXPOSURE TO ETHYL ACETATE

Students can be exposed to ethyl acetate in a number of the laboratory experiment phases. The first is concerned with calibration of the gas-chromatograph (GC) equipment for analysis of the ethanol-water-ethyl acetate mixture. This can involve exposure while transferring ethyl acetate from a 20-L drum to smaller glass vessels, the preparation of standards, and during the running of the GC. Student exposure to ethyl acetate during this phase in generally low. An internal standard is used in the GC calibration. In this case it was 1-propanol, and students should be aware of its occupational health characteristics.

Filling the distillation column with the ternary mixture involves transferring and measuring about 20 L of the mixture and often involves mild exposure to ethyl acetate. The distillation column, which had been tested for leaks with water, will now be found to have a smell of ethyl acetate, but no visible liquid leaks. The laboratory is equipped with a gas alarm system with a sensor adjacent to the distillation column. This alarm is continuously on but is not activated by this mild smell of ethyl acetate.

Running the distillation column with good ventilation until steady state is reached may require one hour and result in mild exposure to ethyl acetate. Additional exposure could occur when liquid samples are withdrawn from the nine column trays. Further mild exposure would take place for each distillation run.

BLOOD TESTS AND STUDENT PRIVACY

Students may be exposed to ethyl acetate before entering the unit operations laboratory. Ethyl acetate is a well-known solvent and is often used in the cosmetic industry as a nail polish remover, so female students who use this substance might be expected to have a higher ethyl acetate content in their blood. The body may also generate ethyl acetate from the complex biochemical pathways in the body.

The initial ethyl acetate content of students' blood is important before they enter the solvent environment of the unit operations laboratory, but this can pose some problems with privacy. Students have a right to privacy concerning analysis of their blood. Voluntary agreement must be obtained from the student for a blood test for ethyl acetate. Students are advised to contact the student medical center for this blood test.

The background level of ethyl acetate in the blood should be around 0.5 mg/L. One female student, however, had an initial level of 1.4 mg/L of ethyl acetate. This highlights the importance

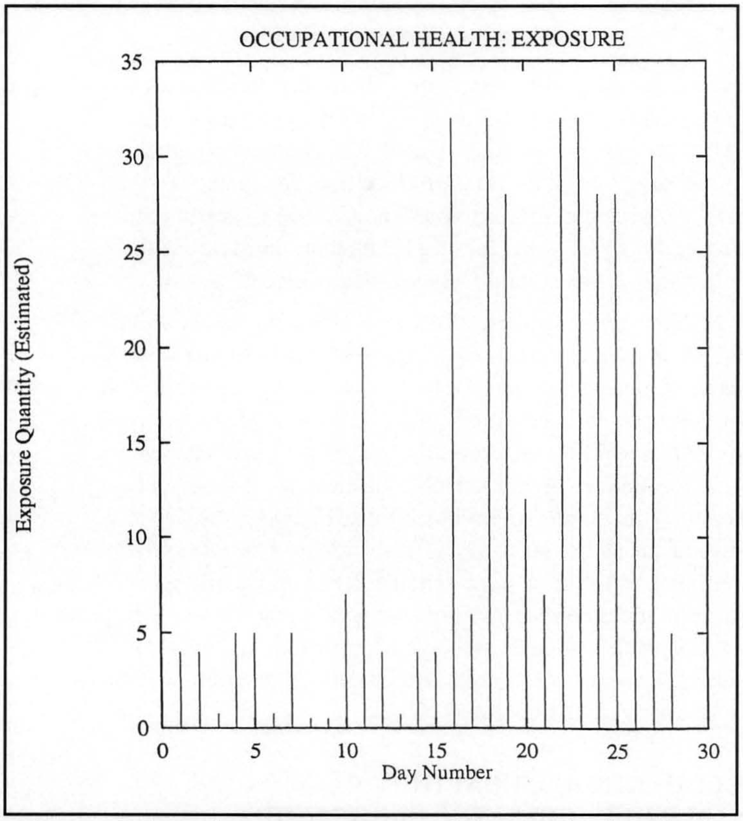

Figure 1. Estimated impulse exposure to ethyl acetate (male student).

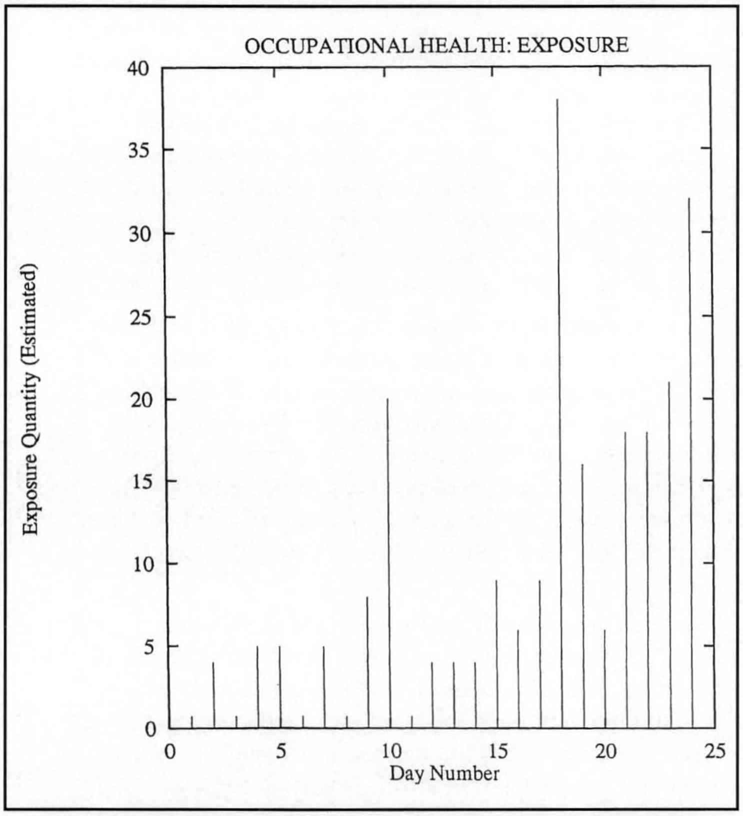

Figure 2. Estimated impulse exposure to ethyl acetate (female student).

of a blood test *before* conducting the distillation experiment.

Students were then asked to estimate their exposure to ethyl acetate in the qualitative terms of low, medium, and high and to estimate the number of hours at these exposure levels on each exposure day. This raw data represents a series of impulses of exposure to ethyl acetate, the height of the impulse being a measure of the perceived intensity of exposure.

The body reacts to these impulses by exhaling ethyl acetate, by generating enzymes to convert ethyl acetate to other substances for rejection, or by storing ethyl acetate in fatty tissue. The complex response is similar to the simple impulse response taught in chemical engineering mathematics and process control.

The process could be made more quantitative if the inhaled dose of ethyl acetate per impulse could be measured. This would require personal monitoring devices attached to the student and subsequent analysis of the sample tubes. These devices are useful in providing an integration of the impulse of ethyl acetate. Other methods, which are not practical in a unit operations laboratory, would involve a composition measurement of ethyl acetate in the air and a profile of the rate of inhalation of air.

The unit operations laboratory environment treated as a local workplace can be valuable in introducing students to exposure, occupational health, and perceived impressions of exposure.

TABLE 1
Blood Analyses
Ethyl Acetate (mg/L)

	Before	*After*
Male	0.5	0.5
Female	1.4	0.5

Medical surveillance is introduced to the students through blood tests both before and after the full laboratory period covering the undergraduate thesis. Students conducted a calibration, distillation runs, and analyses over a period of four months, with the number of exposure days limited to about thirty days. The period of zero exposure to ethyl acetate between exposure days may have provided time for the body dynamics to remove excess ethyl acetate from the blood.

Figures 1 and 2 show the estimated impulse exposure to ethyl acetate on the exposure days for a male and a female student, respectively. The data for these figures were obtained from the student's own impression of the level of exposure as low, medium, or high, and the hours of exposure. The differences in the two figures is due mainly to the different perceived exposure by each student. The two figures provide important qualitative information on the problem of estimating exposure without a personal monitor. The chemical engineering student will meet this type of occupational health problem when employed in the workplace. The unit operations laboratory environment treated as a local workplace can be valuable in introducing students to exposure, occupational health, and perceived impressions of exposure.

The end of the laboratory experiments, with the column drained and the solvents returned to the solvent store, marks the end of the occupational health exposure period. Students are then advised to have a second blood test for ethyl acetate. Table 1 shows the ethyl acetate content of the blood before and after the distillation experiments.

The blood results are most encouraging, with both students having background levels of ethyl acetate at 0.5 mg/L. One might conclude that student awareness of the occupational health study reduced their exposure, or that the ventilation of the laboratory was adequate, or that the interval between exposures was sufficient for the body to remove any excess ethyl acetate.

OCCUPATIONAL HEALTH GOALS

- To use the undergraduate thesis experiment on distillation to introduce students to the concept of medical surveillance.
- To introduce students to the psychological response of exposure limits to inhaled chemicals when introduced to the Material Safety Data Sheets (MSDS).
- To obtain essential information on the previous history of exposure to a chemical through a voluntary blood test *before* the experiment begins.
- To monitor the daily exposure to a chemical in a qualitative manner, thus introducing perceived exposures to a chemical and an improved awareness of occupational health.
- To introduce ventilation as a key measure in reducing exposure to a chemical.
- To have a repeat blood test *after* the laboratory experiment to ensure that preventive methods for reducing occupation health exposure have been successful.
- To expect students to perform better in the occupational health area of chemical engineering design and that they have an improved concept of occupational health, both in the workplace and in general.

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