Distribution Category:
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International Exchange
(UC-2080)

ANL-97/20

ARGONNE NATIONAL LABORATORY
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WASTE MINIMIZATION AND POLLUTION PREVENTION TECHNOLOGY TRANSFER: THE AIRLIE HOUSE PROJECTS

by

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Environmental Management Operations

November 1997

Work sponsored by U.S. Department of Energy
Assistant Secretary for Environmental Management

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ACKNOWLEDGMENTS

The authors would like to acknowledge the contributions of several people who helped make these projects successful.

The Microscale Chemistry in Education Project was headed by Harold Myron of Argonne National Laboratory s Department of Educational Programs. The project was assisted by Randy Landsberg and Rosemary Pausma. Dave Green, Mitch Erickson, James McCreary, and James R. Thuot formed an advisory group with Dr. Myron for this project.

The Microchemistry Cost Benefit Study Project was led by Ralph Gatrone, former Chairman of the Wilkes University Chemistry Department and formerly a member of the Argonne National Laboratory staff. Dr. Gatrone is currently Chairman of the Troy State University Department of Physical Sciences and Chemistry.

The Bethel New Life Recycling Trainee Project was headed by Jennifer McHenry of Argonne National Laboratory s Environmental Management Operations and Cedric Melton and Jarvis Butler of the Bethel New Life organization.

Valuable assistance, guidance, and support were received from the U.S. Department of Energy, Chicago Operations Office and the Argonne Group.

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ABSTRACT

The Airlie House Pollution Prevention Technology Transfer Projects were a series of pilot projects developed for the U.S. Department of Energy with the intention of transferring pollution prevention technology to the private sector. The concept was to develop small technology transfer initiatives in partnership with the private sector. Argonne National Laboratory developed three projects: the microscale chemistry in education project, the microscale cost benefit study project, and the Bethel New Life recycling trainee project. The two microscale chemistry projects focused on introducing microscale chemistry technologies to secondary and college education. These programs were inexpensive to develop and received excellent evaluations from participants and regulators. The Bethel New Life recycling trainee project provided training for two participants who helped identify recycling and source reduction opportunities in Argonne National Laboratory s solid waste stream.

The pilot projects demonstrated that technology transfer initiatives can be developed and implemented with a small budget and within a short period of time. The essential components of the pilot projects were identifying target technologies that were already available, identifying target audiences, and focusing on achieving a limited but defined objective.

SUMMARY

The U.S. Department of Energy (DOE) Airlie House Pollution Prevention Technology Transfer Projects constituted a pilot-scale program developed for DOE Chicago Operations Office (DOE-CH) by Argonne National Laboratory (Argonne). The program was intended to transfer current or developing DOE pollution prevention technologies and techniques to the private sector. The ultimate goal of the pilot study was to identify and define a program that other DOE facilities could use as a model pollution prevention tool.

The nature of the pilot program dictated development of project ideas that were readily available and that had an identified market. The projects needed to focus on a specific audience in order to be successful. Throughout, the program was constrained by time and funding. Argonne selected three projects to develop as part of the Airlie House program: one in microscale chemistry in education, one in microscale cost benefits, and one in recycling and training.

The microscale chemistry in education project focused on high school science teachers. The desired outcome was to develop an interest in microscale chemistry programs that would lead to a change in curricula and reduce the amount of hazardous waste produced in schools. Although only one workshop was originally planned, the subscription was outstanding, and two additional workshops were held. Results were very positive. Several of the schools are currently developing curriculum changes as a result of the information received in the workshops. Both the Illinois Environmental Protection Agency and the Illinois State Board of Education are actively interested in the program.

The microscale cost benefit study project focused on the cost benefit of changing a traditional organic chemistry macroscale educational program to a microscale program. During the first year of the project, macroscale cost data were collected and microscale experiments were developed. Cost benefit data on microscale courses were collected the second year. This program will be used in conjunction with the microscale chemistry education project to encourage schools to change to a microscale chemistry curriculum.

The Bethel New Life recycling trainee project trained two individuals in waste stream analysis and development of recycling programs. The project had two objectives: (1) to provide practical training and (2) to analyze Argonne waste streams and identify opportunities for Argonne recycling efforts. Placed in the Argonne Waste Prevention Program, the trainees worked with regular staff members. After six months of training at Argonne, the two participants were hired by environmental firms.

1 INTRODUCTION

The U.S. Department of Energy s (DOE s) Strategic Plan identifies the transfer of technology developed by DOE facilities to the private sector as a major objective. An important part of the Strategic Plan involves promotion of economic growth by helping industry to become more competitive and cost effective by shifting to resource efficiency and pollution prevention. The DOE sites are constantly developing, testing, and implementing new waste minimization and pollution prevention technologies for use at their facilities. Many of these technologies have application in the private sector. The basic objective of this effort is to develop mechanisms to transfer key areas of this technology to the private sector. Another key element in the DOE Strategic Plan is to help reform science education. This report addresses a program to foster this effort by introducing microscale chemistry education into high school and postsecondary classrooms, thereby reducing both costs and waste generation.

Senior DOE managers held a meeting in April 1994 at the Airlie House in Virginia to identify methods to implement the transfer of technology to the private sector. One of the specific objectives was to implement several small technology transfer activities in the waste minimization and pollution prevention area. The pilot projects needed to operate within a strict framework. They needed to (1) have specifically defined objectives and deliverables, (2) be started almost immediately, (3) be completed in a short period of time, and (4) be inexpensive to implement. The DOE Chicago Operations Office (DOE-CH) took the lead role in implementing small technology transfers in the private sector.

The Airlie House projects were simple in scope. The DOE-CH was to transfer to the private sector waste minimization and pollution prevention technologies that DOE facilities were currently developing or implementing. Because the pilot projects needed to start quickly with minimal funding and be completed in a short period, the specific projects needed to involve activities that were ongoing, near completion, and marketable in the private sector.

DOE-CH selected Argonne National Laboratory (Argonne) as one of the DOE facilities to develop programs and implement the technology transfer initiatives. Argonne was identified as one of the laboratories particularly suited for this type of project because it is a large multidisciplinary facility, has very strong working relationships with the private and educational sectors locally and nationally, is in a large urban area, and has excellent waste minimization and pollution prevention programs.

As part of the Airlie House initiatives, Argonne undertook three pilot projects at a cost of about $60,000 each: (1) microscale chemistry in education, (2) microchemistry cost benefit study, and (3) Bethel New Life recycling trainee. The criteria used in selecting the projects are described in Chapter 2. The projects are described in Chapters 3, 4, and 5. Conclusions drawn from these three projects are summarized in Chapter 6.

2 PROJECT SELECTION CRITERIA

2.1 PRINCIPAL FACTORS

The following factors influenced project selection, but time and available funding were dominant.

C The time frame to start the process dictated that the technology needed to be past the research or development stage. If a project posed unanswered questions, they would have to be resolved before a private sector partner could be identified. What was needed were projects that were ready to go.

C Customers for the technology needed to be readily available. Argonne did not have time to search for a market or negotiate Cooperative Research and Development Agreements. Results for the proposed projects were needed in less than one year.

C Funding for the projects was limited; therefore, overall project budgets needed to be low. This criterion also favored selection of local projects to avoid travel costs and provide for maximum interaction among parties. Local or regional customers therefore took precedence over national customers.

C Personnel needed to be identified quickly who had sufficient time available to conduct the program, implement the individual initiatives, and shepherd the program to completion.

C The projects selected needed to provide tangible benefits to the participants. To do something just for the sake of meeting a commitment did not address the intent of the program. The projects needed to be relevant and meet participant needs.

It was envisioned that a future full-scale program could be built on the foundation of the pilot program. A full-scale effort would begin with a detailed list of available technologies and emerging technologies in the late stages of development. The next step would be to identify potential customers, who would then be contacted by operators of the full-scale project regarding developing partnerships to transfer and implement the technology. This process would be implemented by Argonne s Industrial Technology Development Center.

2.2 FOCUS

Project funding restricted the number of activities that could be conducted, so to achieve maximum benefit, each program required a limited scope, audience, and objectives. The intent was to ensure that the target audience could reap the maximum benefit in a short period. In addition, the limited scope helped focus staff attention on the specific objectives and helped keep the projects on track.

Although they could begin with a broader customer base, full-scale projects ultimately would also have to focus on very specific activities, audiences, and objectives. Focus is important for the success of any technology transfer effort, pilot or full scale. The customer needs to see an advantage to implementing the technology. Targeting too broad an audience or using too many ideas will cause individual customers to lose interest. Ultimately, the customer needs to make a decision on implementation, choosing from the many different technologies available. If a potential customer cannot link a specific technology with a specific need, that customer will not be willing to commit the company resources necessary to achieve success.

2.3 FINDING PARTNERS

Time requirements for the pilot projects dictated that the necessary partnerships needed to be readily available. Argonne could not negotiate new agreements with new partners. The microscale chemistry in education project used teacher networks and sources that had been well established by Argonne s Division of Educational Programs (DEP). The microchemistry cost benefit study involved a university faculty member and former Argonne employee who had participated in the development of Argonne s microchemistry programs. The Bethel New Life recycling trainee project made use of an established link between Argonne and a local community development corporation.

Although the specific pilot projects discussed here focused on limited partnerships using established relationships, this need not always be the case. Partnerships can come from very diverse groups, including community development organizations, state and local governments, federal agencies, and private industry. National and international partnerships are also feasible. In practice, Argonne s microchemistry program also generated additional interest among international groups, junior colleges, Native Americans, and state governments.

After the projects were developed and implemented, Argonne personnel began discussing the initiatives with the Illinois Environmental Protection Agency (Illinois EPA). The state agency had attempted to develop a microchemistry program for several years but had not yet succeeded. Argonne and Illinois EPA have now begun developing plans for a joint effort in this area.

It is envisioned that in the future, laboratories and other industrial partners will use the guidelines developed by these pilot proposals to implement full-scale programs using the pollution prevention technology.

2.4 IMPLEMENTATION

The final steps of the Airlie House pilot program are follow-through and publishing of the results. Technology that is made available to an organization but for some reason has not been implemented has, in effect, not been transferred. Project implementation often requires fine tuning of the technology to fit the precise needs of the user. This step is critical to effective technology transfer.

An example of implementation difficulties is found in Argonne s microchemistry projects. High school teachers were favorably impressed with the microchemistry technologies. However, they have several needs that must be addressed as the process is implemented, namely: (1) the school administration must support the changes to curricula, (2) funds must be made available for supplies, and (3) additional experiments must be identified that will complete the full year s program. Conducting the initial program but leaving the potential users without the assistance or resources to meet these needs will not result in effective technology transfer. Argonne is assisting teachers as they request help with these issues. Some of the teachers returned to Argonne in December 1995 to discuss the microscale chemistry in education workshops and other opportunities.

Finally, once a project is successfully completed, the results must be documented and published. The DOE and the general public cannot know a process has occurred, or that it has been successful, unless they hear or read about the results. In addition, the results of the implementation process need to be published and documented so that program sponsors and others can identify and pursue successful efforts. Technology that is not documented and published is stillborn. It can have no germinal effect on the future.

3 MICROSCALE CHEMISTRY IN EDUCATION PROJECT

3.1 BACKGROUND

The purpose of the microscale chemistry in education pilot project was to develop the interest of secondary education teachers in practicing and teaching the techniques of microscale chemistry. The secondary education system is having difficulty continuing its historic practice of offering large-scale science and chemistry programs because these programs use large quantities of raw materials, generate large amounts of waste, and require large inventories of materials that pose safety risks. This situation has pressured some school administrations to curtail these science and chemistry education programs. The results are twofold: (1) fewer students are exposed to the enriching features of a good science or chemistry background, resulting in fewer chemistry students in college and an overall lack of appreciation of science on the part of the general public; and (2) students who decide to go into the field of chemistry will not have a background in the latest technology and will be behind when they go to college or enter the job market.

The focus of this pilot project was to expose science teachers to microscale techniques, develop their enthusiasm for such techniques, and assist them in implementing microscale technologies in their programs. The project was started by Argonne s Division of Educational Programs in cooperation with Argonne s Environmental Management Operations, Waste Prevention, to introduce microscale chemistry techniques (and related waste minimization and prevention practices) to faculty at the middle (junior high) school, high school, college, and university levels. This effort could alter the perception of the chemistry laboratory in the next century and have a sweeping effect on all scientific and engineering disciplines that use chemical techniques. The overall goal of the program is to reduce the volume of chemical waste generated in teaching and research laboratories throughout the country. Without this initiative, the teaching of chemistry at all levels of education will become difficult or impossible because of the increasing costs for disposal of the wastes generated. This consequence will quickly be felt by industrial and government research organizations that depend on the training of a technical work force at all levels of the educational system.

3.2 SITUATION ANALYSIS

Microexperimentation is a process currently used in graduate schools and in some research and development programs. The use of these techniques has reduced waste generation, increased safety, and reduced experimental costs (Pike et al. 1993). The present predominant use of macro techniques is primarily due to the lack of resources and training opportunities for teaching microchemistry to faculty at both the precollege and postsecondary levels. At present, the potential cost savings and safety benefits of implementing a microscale program in the teaching laboratory have not yet achieved widespread recognition among school administrators. The perceived usefulness of microchemistry in technology training in the high school is detailed in Appendix A.

3.3 STRATEGIES

Several related programs are being developed as a two-phased effort geared to the differing needs of precollege and college chemistry laboratories and their teachers. Pilot-scale training programs currently in an implementation and development phase in the Chicago area will be expanded to meet regional and national needs. User needs have been identified through an extensive evaluation tool developed for the high school teacher workshops conducted by Argonne as part of the Airlie House program. Needs that have been identified include (1) continued training of teachers, (2) augmentation of instructional material, and (3) development of experiments suitable for pre-college general physical chemistry curriculum and advanced placement classes. A significant number of teachers felt that school administrators should be informed about the cost and safety benefits of microscale techniques. The teachers indicated that most school administrators thought that big is better. Teachers wanted to learn about correct storage and disposal of chemicals, as well as reuse of the chemical waste products for their teaching laboratories.

3.4 TACTICS AND APPROACH

For the Airlie House pilot project, a group of Argonne scientists and experts in the field of microexperimentation developed a series of training sessions for high school faculty. More than 90 teachers from the Chicago area learned the techniques of microchemical experiments through workshops offered by the Argonne DEP. The experiments that teachers performed to learn about the benefits of microchemistry included the following:

C *Charles Law I and II*: Two different techniques are used to measure the volume-temperature relationship of a gas and extrapolating that data to predict absolute zero.

C *Acids-Bases I*: A microwell plate is used to examine the properties of acids, bases, and indicators.

C *Acids-Bases II*: A simple exploration of the effects of acids on everyday items.

C *Stoichiometry*: Moles, conversion of mass, and balanced equations are combined to identify an unknown salt.

C *Redox/Electrochemistry I*: A simple, low-cost electrolytic cell is constructed.

C *Redox/Electrochemistry II*: The potentials of different ion combinations are measured.

C *Precipitation Reactions*: An exercise is conducted to determine the products in a double replacement reaction.

C *Kinetics*: A simple experiment is carried out to determine the rate law for a reaction.

C *Fractional Distillation of Natural Products*: A simple distillation is conducted to introduce use of microscale glassware.

Appendix B gives literature references for these laboratory activities.

The original pilot project was designed for one workshop. However, because of widespread interest and oversubscription, the project was expanded into three workshops. As a result of the success of the initial pilot project, the microchemistry in education workshops will be expanded to a larger audience in the full-scale phase of this program. Simultaneously, the experiments and laboratory training books developed for the workshops will be evaluated and expanded. New teachers will be trained, and microscale techniques will be implemented in the classroom.

The Illinois EPA and the Illinois Board of Education have developed an interest in the program. They worked with Argonne to present one workshop in 1996 and are planning to expand the workshops with other industrial partners and to reach more educational institutions. In addition, a microchemistry section will be developed on the World Wide Web home page of Argonne s DEP to disseminate information on laboratory activities throughout the country.

3.5 BENEFITS FROM SUCCESSFUL IMPLEMENTATION

Microscale chemistry offers educational institutions a tool for realizing source reduction opportunities in their teaching laboratories. This program also has a considerable public relations potential for reducing the concern of administrators regarding chemistry programs and for informing a public increasingly skeptical of the costs and value of educational programs.

A key benefit of microscale chemistry for high school and college teachers and students is increased experimental capabilities. Benefits for administrators include reduced costs of chemicals and reduced waste disposal. Benefits for the general public include better trained chemists and an enormous reduction of chemical waste.

3.6 EVALUATION

Participant evaluations of the high school teacher workshops held during the spring of 1995 indicate that the precollege chemistry teachers were very receptive to this initiative and requested more technical support through DOE-CH and Argonne. Figure 3.1 shows participant teachers involved in the microchemistry experiments. The high school workshop participants responded to an extensive evaluation survey (see Appendix A) that will be used to determine future plans for this initiative. The overall results of the participant evaluation of the usefulness of microscale chemistry in high school education are presented in Table 3.1. Table 3.2 summarizes the workshop participants evaluations of interaction with the Argonne staff. After the workshops, the participants reported a much higher expectation of future interaction with Argonne, with 66.6% reporting high expectation (5 and 4 scales) of future interaction.

The workshop participants were shown a video describing the glassware used in the microchemistry experiments. Table 3.3 details the participant evaluation of the usefulness and understandability of the video.

FIGURE 3.1 Participant Teachers Conduct Microchemistry Experiments

TABLE 3.1 Workshop Participant Evaluation of Microscale Chemistry in High School Education[a]

Category	Not At All (1)	Some Extent (2)	Little Extent (3)	Large Extent (4)	Great Extent (5)	Total Responses	Average Evaluation[b]
	Evaluation Rating (1 to 5)						
Increase Theoretical Knowledge							3.59
Number of Responses	1	11	16	28	13	69	
Percentage	1.4%	15.9%	23.2%	40.6%	18.8%		
Increase Practical Experience							4.41
Number of Responses	0	1	3	30	32	66	
Percentage	0.0%	1.5%	4.5%	45.5%	48.5%		
Incorporate Workshop into Classroom							4.31
Number of Responses	0	1	7	30	30	68	
Percentage	0.0%	1.5%	10.3%	44.1%	44.1%		

[a] Dates of Workshops: March 17, May 5, and May 8, 1995.

[b] Average evaluation based on 1 to 5 rating.

TABLE 3.2 Workshop Participant Evaluation of Interaction with Argonne[a]

Category	Not At All (1)	Some Extent (2)	Little Extent (3)	Large Extent (4)	Great Extent (5)	Total Responses	Average Evaluation[b]
	Evaluation Rating (1 to 5)						
Prior Interaction with Argonne							2.77
Number of Responses	26	14	5	9	20	74	
Percentage	35.0%	19.0%	6.8%	12.2%	27.0%		
Expected Future Interaction with Argonne							3.62
Number of Responses	2	4	17	23	23	74	
Percentage	2.9%	5.8%	24.6%	33.3%	33.3%		

[a] Dates of Workshops: March 17, May 5, and May 8, 1995.

[b] Average evaluation based on 1 to 5 rating.

TABLE 3.3 Workshop Participant Evaluation of Glassware Video

	Evaluation Rating (1 to 5)						
Category	Not At All (1)	Some Extent (2)	Little Extent (3)	Large Extent (4)	Great Extent (5)	Total Responses	Average Evaluation[a]
Useful							3.54
Response	2	4	15	10	10	41	
Percentage	4.5%	9.7%	36.9%	24.3%	24.3%		
Understandable							4.07
Response	1	2	5	18	15	41	
Percentage	2.4%	4.8%	12.2%	43.8%	36.7%		

[a] Average evaluation based on 1 to 5 rating.

The original workshops developed considerable enthusiasm among the participants. The workshop participants were contacted during the fall school term FY 1995 to determine if they are implementing the program and find out what assistance they might need in doing so.

3.7 NEXT STEPS

Following the first successful workshops, a short Argonne video, The Message is Clear, was prepared describing the microexperimentation program and the Airlie House Pollution Prevention Technology Transfer Pilot Projects concept. The audience for this video was primarily DOE management.

As an outgrowth of the successful pilot project, the next steps involve expanding the audience for microscale education. Contacts were made with the Illinois EPA Office of Pollution Prevention, and a forum was conducted by the National Science Teachers Association on implementing microscale chemistry in education. The major events in support of this initiative are as follows:

C Junior High and High School Teacher Workshops on *Forensics-Utilization of Microscale Techniques*, June 26 August 18, 1995. (Eight follow-ups were scheduled for academic year 1995-1996.)

C Illinois Science Teachers Association: *Demonstration of Instructional Van Facilities*, Springfield, September 29 30, 1995.

C College Faculty Conference on Microscale (Central States Universities, Inc.), November 2 3, 1995.

C Regional High School Microscale Chemistry Workshop (Chem West), December 6, 1995.

C College Faculty Hands-on Workshops (Chemistry in Context), academic year 1995 1996.

C Microscale Chemistry Short Course, National Science Teachers Association, St. Louis, March 1995.

C Midwest Regional Workshops for Middle and High School Teachers, academic year 1995 1996.

C National Workshops for High School Teachers, spring and summer 1996.

C Microscale Home Page, spring 1995 fall 1996.

4 MICROCHEMISTRY COST BENEFIT STUDY PROJECT

4.1 BACKGROUND

The focus of microscale chemistry programs is on reducing material purchases and waste generation and improving safety by reducing chemical inventories. The objectives of the microchemistry cost benefit study project were to evaluate the monetary savings, reduced waste generation, and decreased safety risks that can be realized at educational institutions that adopt microscale programs to replace current macroscale programs.

The microchemistry cost benefits study pilot project focused on the cost of a macro-organic university chemistry program for one year, measuring the quantities of materials used and the waste generated. In the second year, the program switched to micro-organic chemistry, and the same parameters were measured. Significant safety events were to be noted. The results of this project are documentation and direct cost comparison between the two techniques (macrochemistry and microchemistry). The published documentation of this effort can be used by other educational institutions to justify changes in curricula.

4.2 SITUATION ANALYSIS

The organic chemistry (CHM231 and CHM232) courses offered at Wilkes University in Wilkes-Barre, Pennsylvania, provided a typical program that could be studied to evaluate needs for the microchemistry cost benefit study project. These two one-semester (14-week) courses provide an introduction to the chemistry of carbon compounds through the theoretical principles of mechanism and functional group manipulation developed over the last century. The Wilkes University organic chemistry laboratory integrates isolation, purification, analysis, instrumentation, and synthesis with the material discussed in lecture. The organic course and associated laboratory are required for students majoring in chemistry, biochemistry, biology, pharmacy, and materials engineering. In addition, students majoring in a variety of other disciplines, such as psychology and physics, with the intent of attending a professional school (medical, dental, etc.), also take the course. During the 1994-1995 semesters, the course was taken by 70-80 students per semester in five laboratory sections. However, the addition of a Pharm D (Doctor of Pharmacy) degree program at Wilkes University necessitated that the organic chemistry laboratory increase the student population from 16 students per laboratory to 24 in six laboratory sections.

Waste generation is a serious problem in all academic macrochemistry departments (university and secondary levels), as well as in industry and national laboratories. Since the cost of disposing of a single toxic chemical (e.g., methanol) reportedly can be 10 to 36 times greater than the original purchase price, it is not surprising that a number of institutions have decided to make microscale laboratories a major part of their curriculum. However, prior to 1994, despite ever-increasing budgetary restrictions and spiraling waste disposal costs, the chemistry department at Wilkes University had only begun to implement waste reduction at the source through microexperimentation. In addition, while a number of organic chemistry laboratories have introduced microchemical techniques, and the general consensus is that these departments are experiencing a reduction in operating costs primarily due to waste reduction, no laboratory has quantified the actual cost savings of introducing a microexperimental laboratory.

4.3 STRATEGIES

The microscale chemistry project at Wilkes University project was conducted over a two-year period. The first year (FY 1995) concentrated on collecting data on cost and waste generation from the then-current macrochemistry-based organic chemistry curricula. The data are representative of typical macro-organic chemistry curricula. This information was used to evaluate per student cost and effort. Also during the first year, safety and health practices were monitored, with emphasis on spills, broken glassware, and any other actions or opportunities for concern.

During FY 1995, experiments were identified that required replacement or modification to be amenable to microscale techniques. Examples of microchemistry replacement experiments were either identified in the literature or were developed. Experiments were developed and tested by a group of four students to determine their effectiveness and to familiarize the staff with actual implementation. Modifications in procedure and glassware utilization were noted. (Figure 4.1 shows students looking over equipment used in micro experiments.)

During the second year of the project (FY 1996), the microchemistry experiments developed during the first year were applied and studied. Again, detailed notes were taken to evaluate any changes in safety and health practices. The most important feature of the second year was the documentation of material purchased, glassware replaced due to breakage, reduced waste volumes, and the costs associated with these modifications.

4.4 TACTICS AND APPROACH

Five organic laboratory sections at Wilkes University conducted experiments during the 1994 1995 academic year that had previously been performed in the chemistry department.

FIGURE 4.1 Wilkes University Students Examine Microscale Equipment for Reducing Waste at the Source

Fourteen macroscale or semi-microscale experiments were performed by 65 students, and the wastes were collected in separate containers. The following experiments were included:

C Isolation of cholesterol from bile stones,

C Isolation of eugenol from cloves,

C Simple distillation of a two-component organic mixture,

C Fractional distillation of a two-component organic mixture,

C Bromination of hydrocarbons,

- C Isolation and resolution of carvone,
- C Resolution of phenylethylamine,
- C Nucleophilic substitution reaction,
- C Aromatic substitution chemistry,
- C Diels-Alder reaction,
- C Oxidation of alcohols,
- C Grignard reaction,
- C Synthesis of an ester, and
- C Synthesis of benzalacetone.

Upon examination of the experimental procedures used in the above macroscale experiments, the following 10 waste categories were identified:

- C Water miscible organics,
- C Hydrocarbons,
- C Chlorinated hydrocarbons,
- C Aqueous soluble acids,
- C Aqueous soluble bases,
- C Solid acids,
- C Solid bases,
- C Solid waste,
- C Sharps (glass, needles, etc.), and
- C Inorganic waste.

During the 1994-1995 academic year, approximately 85 gallons of waste (1.3 gallons per student) was generated from all 10 waste categories, with the largest volumes being water-miscible organics, hydrocarbons, chlorinated hydrocarbons, and solid waste. Several generalizations can be made. For example, the single largest component of the water-miscible waste was acetone. The single largest category in the solid waste fraction was represented by paper towels contaminated with traces of organic material. As expected, the inorganic category generated several small quantities of waste that had to be segregated because of reactivity considerations. The total cost to dispose of the waste generated by the five organic laboratory sections was approximately $8,245, or nearly $125 per student.

During the summer, four students investigated the conversion of the 14 macroscale experiments (as performed at Wilkes) to a suitable microscale form. The two experiments that proved the most difficult were the isolation of cholesterol from bile stones and fractional distillation. Isolation of cholesterol from bile stones as a microexperiment required the development of a number of laboratory skills not previously needed for the experiment. One example is the filtration of very small volumes of liquid through normal-sized filter paper. The sheer act of pouring one milliliter becomes a relatively difficult procedure when nearly half of the liquid phase is absorbed by the filter paper.

Fractional distillation required the purchase of specialized glassware columns. It is very difficult to remove high-boiling fractions using microscale glassware, principally because of the rapid cooling of the fractionating column in a high-air-flow hood. These difficulties were eventually overcome.

The experiments that were finally settled upon for the organic chemistry course are:

- Isolation of cholesterol from bile stones
- Isolation of eugenol from cloves
- Simple distillation
- Fractional distillation
- Thin-layer chromatography
- Extraction of caffeine from tea
- Bromination of alkanes

C Isolation of chlorophyll

C Preparation of cyclohexene

C Preparation of 1-bromobutane

C Diels-Alder reaction

C Aromatic substitution

C Preparation of ethyl laurate

C Grignard reaction

C Oxidation of alcohols

C Preparation of ethers

C Von Konstanecki reaction

Because of the implementation of the microscale program, the Wilkes University curriculum experienced an unanticipated benefit in the form of an increase from 14 to 17 in the number of experiments that can be conducted in a two-semester sequence. While not anticipated, this benefit is certainly not unexpected, because one of the primary observations made was the decreased time required for average students to complete laboratory procedures. During the first year of the program, average students were taking approximately 2.5 hours to complete a laboratory experiment. The implementation of the microscale techniques into the curriculum allowed the students to complete an experiment in approximately 1.5 hours. This time reduction resulted in increased student efficiency, as well as an increase in their desire to learn the techniques being taught without rushing to complete the experiment. A significant improvement in safety and glass breakage was also observed.

The second year of the program generated 46 gallons (a reduction of about 40 gallons from 1994-1995) of total waste (0.36 gallon per student), roughly distributed as indicated earlier, and the total cost of disposal was reduced to $4,462. However, even more significant was the reduction in the per student cost of waste disposal from $125 per student in 1994-1995 to $32 per student in 1995-1996. The difference between the macroscale and microscale approaches represents a savings greater than the actual cost of implementation. The major expense in the conversion to microscale techniques is the cost of the glassware. This cost can be reduced significantly if students work in groups of two or three, each experiment is required to be done in duplicate, and glassware is shared. The actual cost of implementation was not significant, because the Wilkes University Chemistry Department possessed a sufficient number of microscale glass kits to equip the organic laboratory with 24 kits for the 24 students assigned to the section. Laboratory sections shared glassware kits. Interestingly, glassware breakage, which is normally a very serious concern in an organic laboratory, was significantly reduced, primarily because of the sturdy nature of microscale glassware.

4.5 BENEFITS FROM SUCCESSFUL IMPLEMENTATION

Our analysis of the program results concludes that a university or college chemistry curriculum would save enough money in the first year of conversion to cover the expense of converting from macroscale to microscale techniques. In addition, several other advantages have been observed. From an empirical vantage, it appears that students working with microscale glassware are less concerned with breakage and, therefore, are less apprehensive and more results oriented. The students have ample time to perform several experimental runs, which gives them greater confidence in the technique that they have learned. In addition, despite an increase in the student population in the organic laboratory sections of 50% (16 to 24 students), no significant safety events were noted during the two years that the microscale experimental approach has been utilized. We believe that because of the smaller quantities used by the students, they were more relaxed and less likely to have an accident.

4.6 EVALUATION

In the past, college and university chemistry programs have been negatively impacted by the cost of operation and waste generation. Several universities have given serious consideration to eliminating or at least drastically curtailing the chemistry laboratory curricula as a direct result of these impacts. This program has clearly demonstrated that microchemistry is a cost-effective method that should allow the continuation of the presentation of the modern chemistry laboratory in science education.

A second benefit from this program is that the cost analysis can be indirectly applied to DOE facilities and other laboratories that do chemical work. The cost and logistical impact of shifting from macro to micro programs has always been slow to develop within DOE because of unfamiliarity, presumed cost, presumed ineffectiveness, and applicability problems. The information generated by this program can be used to overcome these concerns and to convince other organizations that there are options available to reduce cost and increase safety.

5 BETHEL NEW LIFE RECYCLING TRAINEE PROJECT

5.1 BACKGROUND

The final pilot project developed by Argonne was a recycling trainee program conducted in cooperation with the Bethel New Life organization in Chicago. The purpose of this project was to train two community residents in recycling practices and techniques that Argonne is developing to reduce its own waste streams. The trainees were to become temporary Argonne employees for a period of six months, working primarily in the nonhazardous material recycling area.

Argonne had previously entered into a partnership to provide technical assistance to the Bethel New Life organization in Chicago. Bethel is a church-based, low-income, community development corporation dedicated to sustainable community development. Bethel is located in the West Garfield Park area of Chicago. It operates a job training center, develops community housing, and works to return industry to the community and to develop jobs for sustainable community growth. Bethel also has experience operating a recycle center in the community. Argonne has worked with Bethel in the past to develop affordable housing; to provide advanced technology for rehabbing, environmental characterization, and restoration techniques; and to develop techniques for reclaiming the urban environment. The third Argonne pilot project for the Airlie House program was a continuation of this relationship and was especially appropriate in light of the recycling efforts of Bethel New Life, the City of Chicago, and Argonne.

The City of Chicago initiated two recycling ordinances in 1994. The first initiated curbside recycling for family dwellings. More significantly, beginning in January 1995, the city implemented recycling requirements for multifamily housing, small and large business, and industry.

Argonne, like many large research and development facilities, generates significant quantities of solid nonhazardous waste. The material comes from normal facility garbage collection, construction, facility modification, maintenance, and general operations. Waste material is collected and shipped to recycle facilities, transfer stations, and landfills. The material is similar, but not identical, to municipal garbage. Argonne did not understand the makeup of this material until preliminary characterization studies were begun in 1993 and detailed studies were completed in 1994 (McHenry and Thuot 1995). The studies indicated that significant portions of the waste could be recycled. Grass-roots efforts were initiated to begin the recycling effort.

Argonne had identified a need to continue source separation and characterization activities to evaluate recycling progress as new initiatives were implemented. In addition, Argonne was very interested in evaluating construction and modification wastes for recycling. Therefore, Argonne decided to develop a program to use two Bethel personnel in the recycling and source characterization area to provide on-the-job training and to benefit the Argonne recycling effort.

The trainees could then use this experience to develop jobs and community-based solutions to Chicago s recycling efforts. The trainees were selected from the inner-city community served by Bethel and had been previously screened by the Bethel Employment Service Center.

5.2 SITUATION ANALYSIS

Argonne generates significant quantities of nonregulated wastes, ranging from paper to construction debris, and is interested in minimizing the amount of material being landfilled and in maximizing the recycling of resources. At the same time, the City of Chicago is interested in reducing the amount and cost of landfill waste. The City of Chicago has recently mandated recycling requirements that cover virtually the entire spectrum of the city. The Bethel recycling trainee project offered the opportunity to meet the following needs:

- Argonne would benefit by having two trainees working in its recycling program, characterizing waste and identifying opportunities for recycling.

- The two trainees would benefit by having jobs and learning the process of waste characterization and recycling.

- The West Garfield Park community would benefit because the trained individuals would know how to establish effective recycling programs and would be able to assist community development by identifying opportunities.

- The City of Chicago would benefit because the trainees would aid businesses in establishing their own recycling efforts.

5.3 STRATEGIES

The plan was to hire the two individuals into Argonne trainee positions. They would receive some benefits, including vacation and medical. Requirements included a high school education, good employment record, and a recommendation by Bethel. The two individuals would receive a broad spectrum of training at Argonne, including basic worker training, introductory hazardous material and radiation worker training, computer training, and other site-basic, required courses.

The on-the-job training was conducted by staff from the Argonne Waste Prevention Program. The training began by characterizing waste streams from several buildings, including offices and laboratories. The initial characterization was followed by implementing recycling efforts and following up on initial characterization.

The next training effort reviewed construction waste generation. The trainees worked with Argonne construction field representatives to identify material entering construction dumpsters. The objective was to identify opportunities for recycling construction materials. The trainees were also introduced to time studies to determine if low-radioactive materials could be recycled, under what conditions could they be recycled, and what risks were associated with the recycling.

5.4 TACTICS AND APPROACH

The recycling trainee project involved a blend of on-the-job training and classroom instruction. The trainees received instructions in hazardous material handling and basic radiation protection and took computer courses in word processing and spreadsheet development. The trainees worked with the materials and assisted people in recycling efforts to identify opportunities and barriers to recycling. (Figure 5.1 shows the trainees working with Argonne staff to segregate different types of waste.)

The training project identified several opportunities and problems with recycling programs. For example, pallets are often discarded by one group and purchased by another. They are inconsistently recycled. The program identified an opportunity to recycle all of the pallets delivered on-site and to divert good pallets to replace direct purchases. Another opportunity for recycling exists with construction dumpsters, which are frequently filled with such materials as wood, metal, wire, brick, and mortar. The co-mingled material has little potential for recycle because it must be sorted out of the dumpster. An opportunity exists to increase recycling by sorting and segregating the material as it is put into different dumpsters. Figure 5.2 shows trainees identifying and demonstrating waste segregation for dumpsters.

Another problem area identified is the discard of material in conjunction with movement of Argonne personnel. Individuals moving or leaving the laboratory often clean out their offices by discarding large amounts of material. Frequently, this material is recyclable paper that only needs a cover or binder removed. Cleanup efforts in general have similar problems; frequently, opportunities for recycle were ignored in the name of expediency. Cleanup represents another opportunity for recycling.

5.5 BENEFITS FROM SUCCESSFUL IMPLEMENTATION

This type of program offers several benefits for the DOE facility, the community, and the individual trainees. Argonne benefits because the training efforts identified recycle opportunities in the low-level waste area that may not have been otherwise noticed. This discovery led to new Argonne programs that reduced waste generation and operating cost. In addition, data

FIGURE 5.1 Trainees Work with Argonne Staff in Waste Segregation Operations

were collected for the DOE Recycle 2000 initiative, which is designed to promote the recycling of low-level contaminated metal.

The trainees benefited because they developed a skill and obtained jobs. The skill development was virtually all hands-on practice and was readily translated into an employment opportunity. The two trainees completed the program in September 1995 and were immediately hired by a Chicago environmental firm engaged in remediation programs. The community will benefit as the trainees work within their community to improve recycling efforts.

5.6 EVALUATION

This type of training program seems simple to develop and implement. The employment benefits and recycling opportunities are easily identified. Successfully identifying an opportunity and realizing the benefits of implementation are important. The trainees identified several opportunities to expand recycling efforts, but they could not see the direct benefit of implementation because of time constraints. The implementation cycle for most projects is from

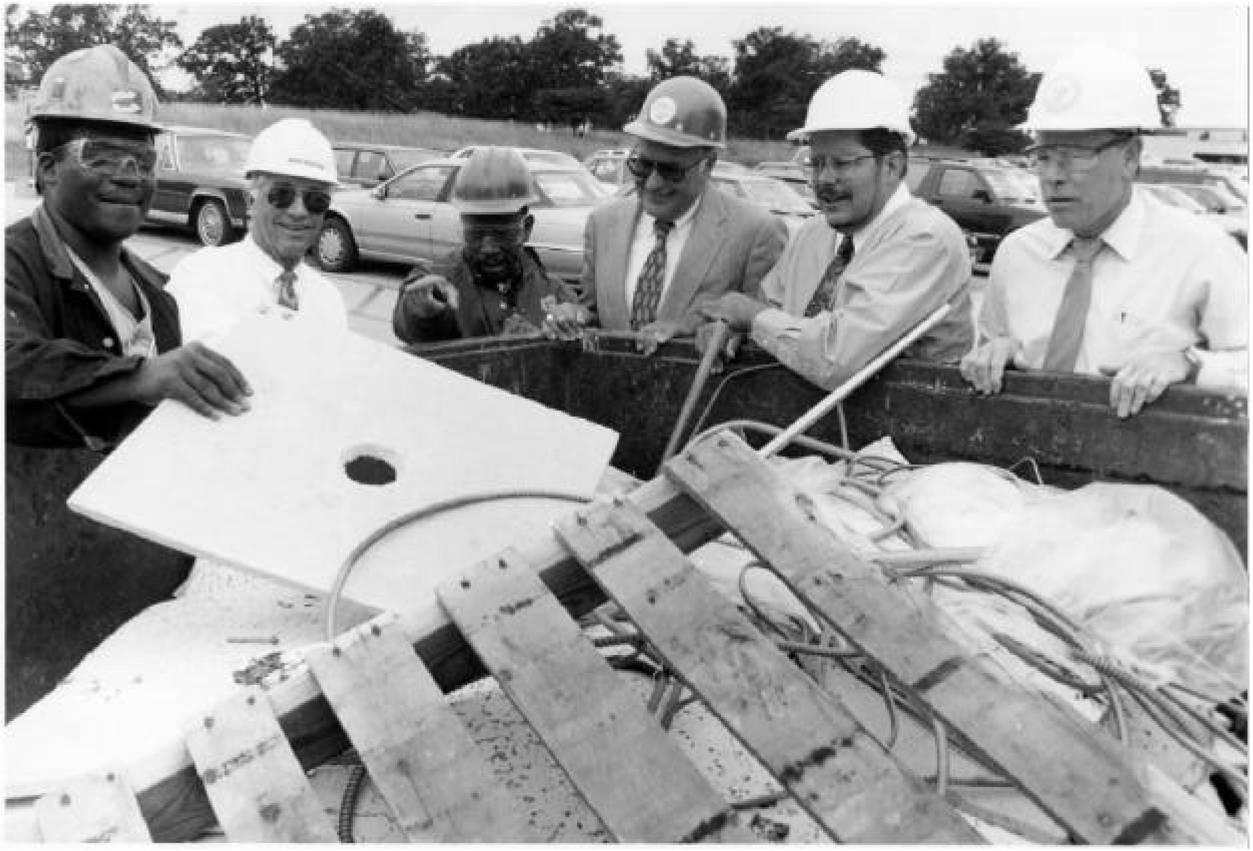

FIGURE 5.2 Trainees Demonstrate Waste Segregation for Dumpsters

several weeks to several months. Concrete results may follow this period by an additional several weeks. In this case, the trainees were not able to see the results of their work.

Programs of this nature are important because mutual objectives are accomplished. In addition, the trainees learn job skills associated with the technical work. Finally, they gain the skills associated with actually being employed. The community relations benefits of this type of project are also very significant. People can see that the government (through DOE) is making positive contributions in a program that has tangible benefits to those involved and to the community.

6 CONCLUSIONS

The Airlie House Pollution Prevention Technology Transfer Pilot Projects successfully demonstrated DOE s ability to interact and cooperate with the industrial and educational sectors to develop mutually beneficial programs. The pilot program identified several specific objectives: (1) the technology needed to be in a development or an implementation stage that was suitable for transfer to the private sector, (2) the process could not be expensive, (3) the pilot projects needed to be completed within a short period, and (4) the process needed to be transferrable. Ultimately, the pilot projects could serve as examples to other DOE facilities for developing positive relationships with local communities.

The funding and schedule requirements restricted the technologies that could be used to microchemistry and recycling projects that were very near completion or, preferably, in an implementation stage. It was felt that the participating teachers and New Bethel Life trainees would be receptive to the new technology.

Argonne chose two related projects in the microchemistry area and one in the recycling area for the pilot projects. The first two were chosen because they were mutually supportive. The microchemistry education workshops identified technology that could be implemented in a school curriculum. The microchemistry cost benefit study developed cost information demonstrating the benefits of the transformation. The education project was intended to be a one-day workshop, but it was immediately oversubscribed. Three workshops were held, and additional follow-up activities were developed for FY 1996. The microchemistry pilot programs were a significant success. The following positive results were identified:

C Significantly more interest for microchemistry education was discovered than was originally anticipated.

C Several schools began implementing curricula changes immediately after the workshops.

C The education workshops were relatively easy to develop and run.

C Future education workshops can be run at a much lower cost.

C Initial costs of the education workshops were about $40,000, with the two subsequent workshops costing about $10,000 each, giving a total cost of $60,000.

- C The second and third education workshops were essentially duplicates of the first and could be repeated at the margined low price until the potential audience is satisfied.

- C The microchemistry cost benefit study project was easy to develop and will provide the justification for changing college and high school curricula. Lower costs are an important implementation factor. Certainly some individuals are skeptical and do not want to change; they must be shown positive evidence and be given cost-effective reasons for change. This project will provide that evidence.

- C The microchemistry cost benefit study project has identified hurdles that must be overcome for successful change. For instance, currently not all of the necessary glassware is available for some experiments.

- C Interaction with state regulators has helped to foster a positive and mutually beneficial relationship with the Illinois EPA.

The Bethel recycling trainee project served a dual purpose. The individuals received training in waste stream analysis, characterization, segregation, and recycling opportunity assessment and implementation; and Argonne was able to identify additional recycling opportunities. The trainees worked with Argonne personnel to become familiar with operations. The individuals also worked to identify recycle opportunities in the low-level waste area, collecting data for the DOE Recycle 2000 initiative. At the conclusion of the training period, the individuals obtained employment in the environmental sector.

The pilot demonstrations were successful because they focused on specific needs: the benefits of changing a chemistry curriculum; of implementing microchemistry experiments in a general chemistry curriculum, and of training individuals in specific recycling areas. The projects limited the participants to people who could implement the measures or who actually did the work. The audience was not expanded to people or groups that would not have a detailed interest in the subject. This factor was very important because no effort was lost due to lack of interest or attention.

Argonne had available individuals who knew the subject areas and who could put the necessary effort into achieving a successful outcome. It was important not to exceed individual capabilities because this would have destroy the credibility of the participants.

The efforts were cost-effective because the subject matter was focused. Attempting to cover too much information would cause confusion and degrade Argonne s ability to project enthusiasm for this type of environmental work.

Finally, all of the groups affected by this work have a positive impression of DOE and Argonne. The successful implementation of the Airlie House Projects has helped develop a positive working relationship between Argonne and the Illinois EPA.

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APPENDIX A:

MICROCHEMISTRY EVALUATIONS

Appendix A provides a tabular breakdown of microchemistry evaluations from microscale chemistry workshops held for high school teachers on March 17, May 5, and May 8, 1995. The average of that evaluation is given for each category.

TABLE A.1 Participant Evaluation of Specific Experiments for Overcoming Barriers[a]

	Evaluation Rating (1 to 5)						
Category	Not At All (1)	Some Extent (2)	Little Extent (3)	Large Extent (4)	Great Extent (5)	Total Responses	Average Evaluation[b]
Useful							3.54
Number of Responses	5	6	18	24	14	67	
Percentage	7.5%	9.0%	26.9%	35.8%	20.9%		
Understandable							4.29
Number of Responses	2	2	4	23	33	64	
Percentage	3.1%	3.1%	6.2%	35.9%	51.6%		

[a] Based on microscale chemistry workshops for high school teachers March 17, May 5, and May 8, 1995.

[b] Average evaluation based on 1 to 5 rating.

TABLE A.2 Participant Evaluation of Laboratory Modules[a]

Module/Category	Evaluation Rating (1 to 5) Not At All (1)	Some Extent (2)	Little Extent (3)	Large Extent (4)	Great Extent (5)	Total Response	Average Evaluation[b]
Microscopy[c]							
Useful							3.77
Number of Responses	1	7	14	28	16	66	
Percentage	1.6%	10.6%	21.2%	42.4%	24.2%		
Understandable							4.26
Number of Responses	1	0	9	25	29	64	
Percentage	1.6%	0.0%	14.1%	39.0%	45.3%		
Charles Law							
Useful							3.81
Number of Responses	1	0	10	27	28	66	
Percentage	1.5%	0.0%	15.2%	40.9%	42.4%		
Understandable							3.53
Number of Responses	1	0	7	19	27	54	
Percentage	1.8%	0.0%	13.0%	35.2%	50%		
Acids-Bases							
Useful							4.30
Number of Responses	0	1	9	25	31	66	
Percentage	0.0%	1.5%	13.6%	37.9%	47.0%		
Understandable							4.41
Number of Responses	0	2	2	17	28	49	
Percentage	0.0%	4.1%	4.1%	34.7%	57.1%		
Stoichiometry							
Useful							4.54
Number of Responses	1	2	6	20	30	59	
Percentage	1.7%	3.4%	10.2%	33.9%	50.8%		
Understandable							4.29
Number of Responses	0	3	0	16	35	54	
Percentage	0.0%	5.6%	0.0%	29.6%	64.8%		

TABLE A.2 (Cont.)

Module/Category	Evaluation Rating (1 to 5): Not At All (1)	Some Extent (2)	Little Extent (3)	Large Extent (4)	Great Extent (5)	Total Response	Average Evaluation[b]
Redox/Electrochemistry							
Useful							4.40
Number of Responses	0	1	3	18	32	54	
Percentage	0.0%	1.8%	5.6%	33.3%	59.2%		
Understandable							3.59
Number of Responses	0	2	1	15	43	61	
Percentage	0.0%	3.3%	1.6%	24.6%	70.5%		
Precipitation Reaction							
Useful							4.14
Number of Responses	0	1	7	13	38	59	
Percentage	0.0%	1.7%	11.9%	22.0%	64.4%		
Understandable							4.50
Number of Responses	0	2	7	11	42	62	
Percentage	0.0%	3.2%	11.3%	17.7%	67.7%		
Kinetics[d]							
Useful							3.96
Number of Responses	0	7	7	12	19	45	
Percentage	0.0%	15.6%	15.6%	26.7%	42.2%		
Understandable							4.41
Number of Responses	0	1	2	13	18	34	
Percentage	0.0%	2.9%	5.9%	38.2%	52.9%		
Fractional Distillation							
Useful							3.57
Number of Responses	3	6	17	13	15	54	
Percentage	5.6%	11.1%	31.5%	24.0%	27.8%		
Understandable							4.25
Number of Responses	1	1	7	9	23	41	
Percentage	2.4%	2.4%	17.1%	22.0%	56.1%		

[a] Based on microscale chemistry workshops for high school teachers March 17, May 5, and May 8, 1995.

[b] Average evaluation based on average of 1 to 5 rating.

[c] Microscopy module relates to use of the microscope.

[d] Only performed on May 5 and May 8, 1995.

APPENDIX B:

REFERENCES FOR MICROCHEMISTRY EXPERIMENTS

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