DOCUMENT RESUME

ED 118 400 SE 020 214

AUTHOR Clum, James A.; Loper, Carl R., Jr.
TITLE Recycling Technology: Can It Be Taught?
PUB DATE Jun 75
NOTE 20p.; Paper presented at the Annual Meeting of the American Society for Engineering Education (Colorado State University, Ft. Collins, Colorado, June 16-19, 1975)

EDRS PRICE MF-$0.83 HC-$1.67 Plus Postage
DESCRIPTORS *College Science; Curriculum Development; Engineering Education; *Engineering Technology; Higher Education; Instruction; *Metals; Natural Resources; *Program Descriptions; *Recycling

ABSTRACT

This paper describes the content of a seminar-type engineering course dealing with materials reutilization (recycling). The course, consisting of lecture and discussion by various faculty and outside experts as well as student presentations of research papers on recycling topics, is intended to investigate current areas in which recycling of materials appears feasible. Subjects chosen to be investigated are examined as to the chemistry and physics involved in the recycling process, through a materials science and process engineering viewpoint, and concerning the economics of the situation. It is indicated that this slight modification of the curriculum in metallurgy to recognize future concerns in the area of materials reutilization will allay the need for entirely new programs to deal with the problem. (CP)

Event Number 2665

American Society for Engineering Education
Annual Conference, June 16-19, 1975
Colorado State University
Ft. Collins, CO 80521

Title of Paper

RECYCLING TECHNOLOGY: CAN IT BE TAUGHT?

Name of Authors

James A. Clum and Carl R. Loper, Jr.

Title and Address of Authors

Assistant Professor and Professor

Department of Metallurgical and Mineral Engineering
1509 University Avenue
Madison, Wisconsin 53706

RECYCLING TECHNOLOGY: CAN IT BE TAUGHT?

I. Introduction

An engineer should be concerned with the economic application of scientific principles in the creation of goods and in the delivery of services. In no case is the engineer's expertise more needed than in the problems related to the utilization of the mineral and energy resources available in the world. Although it has been argued that mineral resources are not at a crisis stage[1] (Figure 1) another viewpoint indicates the situation is grim[2] (Figure 2). That bleak outlook is especially foreboding for the United States with its well known capacity for mineral and energy consumption.[3] As the oil embargo of late 1973 has shown, the lessening of resource availability can cause serious economic dislocation in a country like the United States. This paper is not a discourse on the economy nor on mineral and energy resources per se. Rather our aim is to emphasize the role that engineering education can play in the area of materials reutilization (recycling).

There are, no doubt, many avenues by which engineering students can be involved in recycling. One popular approach has been to conduct seminar type courses utilizing the case study approach.[4] Another method that has been used successfully is that of a team study[5,6,7,8] on a specific topic.

Considering the entire network of materials supply and demand as set forth by Swan[9] (Figure 3) many of the team studies have dealt with the possibilities and problems of feedback from the component or materials system, e.g., glass[5,7] containers, automobile tires,[6] whole automobiles.[8] It is recognized that the industries involved in the earlier stages of the supply-demand framework have generally been seeking high process yields. In that regard recycling or reclamation of valuable materials from process wastes is well established on an industrial scale, e.g., the recovery of metallic value from metallurgical slags. The seminar type courses are not as easy to characterize but they can readily include studies of all portions of the supply-demand framework.

A seminar type course dealing with recycling has been given since 1971 in the Metallurgical and Mineral Engineering (M&ME) Department at the University of Wisconsin-Madison. That course has had the following format:

(1) one two-hour meeting per week for fifteen weeks;

(2) lecture and discussion by various faculty and outside experts;

(3) student presentations of research papers on recycling topics.

A list of the topics which have been the subjects of the student presentations is given in Table I.

The course was open to any qualified student, with the consent of the instructor, and actual enrollment included some non-M&ME students.

II. Principles of Recycling

A. Subject Areas

An examination of the research papers by the seminar students in that course as well as an evaluation of some of the team studies in recycling at other schools has led to the recognition of a core of subject matter which permeates the recycling concept. We have identified those subjects and note them in Table II. The importance of those subjects to any educational scheme aimed at recycling is that they provide a background that transcends the entire resources supply-demand network. It is such a background that we feel is essential to effective recycling education. The reason being that recycling schemes, methods, or processes which are developed out of the context of the entire supply-demand network may not be truly effective.

Some examples of "good ideas" for recycling that become less attractive with a more thorough study are noted in the following paragraphs. It can be seen from those examples that a more extensive understanding of the processes and materials involved was needed to fully recognize the implications of recycling.

Our point is that recycling or reutilization can be taught if a broad context is used as a basis of such an educational program. This does not mean that specific skills, e.g., process design, or materials handling, cannot be used to advantage in developing a Recycling Technology. Rather we mean that the interdependence of processes, resources and social utility of product or service is significant. So significant, in fact, that to consider one aspect without regard to the others may have negative consequences.

B. Examples of Recycling Oversights

The following three examples are all citations of technical problems related to recycling schemes in which a lack of consideration or understanding of the entire scheme could have caused long term difficulties.

1. Dust from the basic oxygen steelmaking furnace (BOF) can have a high iron oxide content which makes it potentially suited to recycling (in agglomerated form) as a feed for ironmaking blast furnaces. In some cases, however, the scrap fed to the BOF can contain zinc in the form of galvanized steel. That zinc can end up in the BOF dust and if it enters the blast furnace can lead to refractory attack and subsequent irregular blast furnace operation. Thus, the BOF dust must be treated to remove zinc before being reused in the blast furnace.

2. The recycling of aluminum beverage containers should be conceptually simple if a magnetic method is used to separate the iron bearing portions of the refuse. However, certain containers have decorative coatings with deleterious elements in them which contaminate the aluminum melt. Thus, a further separation of aluminum cans by product is necessary if the contaminating element is to be kept out of the aluminum melts.

3. The problems associated with production and recycling of tin coated containers has resulted in the development of tin-free tin cans. These containers have coatings of chromium overlayed with a lacquer. Unfortunately, there are two questions raised by this mixed container scheme. Firstly, there is the sorting problem of the tin and tin-free cans. Secondly, in remelting, the chromium coated cans represent a potentially permanent loss of the chromium value due to oxidation into the slag. Thus, the concern for one material, tin, creates a problem with another valuable resource, chromium, which could be alleviated by a rationalized approach to container use.

C. Role of the Principal Subject Areas

The role of the subject areas in Table II in education for recycling can be stated as follows:

(a) Process Principles (including chemistry, physics, thermodynamics, statistics, materials characterization and behavior and processing methods): This category includes the engineering and science background that provides a detailed knowledge of the processing steps related to a recycling scheme. It may be desirable, for example, to revise the conventional processes or products in the supply-demand network so that reutilization can be more easily achieved. In the case of electric motors some difficulty occurs in separating copper windings from the ferrous materials. If the copper is replaced by aluminum (and some motors have that design) then the motor is a more suitable piece of ferrous scrap since the aluminum is readily oxidized in the steel remelting furnace. At the same time an understanding of the related processes and their interdependence must be obtained such that the important overall view of the reuse pattern can be established. For example, it is extremely important that any recycling scheme include a detailed energy balance similar in scope to an environmental impact statement. Such a balance is currently implied in the design of a recycling process by the dollar costs of operations. However, expression of the energy units required is a more rational approach and one by which comparisons can be more easily made. The formulation of wide ranging process schemes involves all the elements of engineering and science as well as economic and social considerations.

(b) Economics: It is quite obvious that the techniques of any recycling scheme must be cost effective in order to compete with other materials sources. In the development of such schemes a clear understanding of economic factors, e.g., market potential of the various forms of the recycled material, is sometimes difficult to obtain especially if the recycled product has no established market. The economic factors in recycling may be difficult to assess for other reasons which involve social costs. For example, it is not easy to quantify the benefits associated with removing containers from refuse although some companies have at times artificially established a price for such material as a matter of social concern.

(c) Social effects: The pressure by groups of society to develop recycling methods has been generally directed at materials contained in consumer goods. Industry has always been aware of recycling as an alternative source of materials (and energy) but until the social costs of raw materials became translated into real costs industry found it necessary to continue to rely on the raw materials sources. Those imposed social costs have developed from several concerns. In some cases (mostly in this country) concerns with the environment, including land use and more recently energy use, have made development of new mineral extractive and refining capacity increasingly expensive. The raw materials supplying nations have, at the same time, developed a greater concern for their own resources as a matter of national policy. That type of social effect has also raised the effective attractiveness of reutilization of available materials (along with, of course, the more efficient utilization of raw materials).

Recycling technology can also induce negative social effects. For example, the environmental concern with sulfurous emissions from industrial and fossil fuel power plants have led to more efficient collection of sulfur containing materials. Subsequent treatment of those materials has provided a new source of sulfur which in turn has caused a reduction in operation of the conventional sulfur sources. That, of course, contributes to an increase in social cost for the persons underemployed in the sulfur industry.

III. Identifying Appropriate Curricula

If one examines Table II and then asks what sort of curriculum could be devised that would provide such background it becomes apparent that a number of similar curricula already exist. Those existing curricula are in departments of Metallurgical, Ceramic or Chemical Engineering. As Table III shows by a sampling of departments of Metallurgical Engineering, most of the sample provide as a requirement or an option the subject areas we feel are common to problems in recycling technology. That table was developed by looking only at catalog statements of courses and curricula. In that sense it is inadequate since course descriptions are usually somewhat vague. However, it is generally the case that those departments which offer a full range of courses provide the desired background. Some departments, even of Metallurgical Engineering, do not provide a suitable background in Chemical Metallurgy, e.g., column D in Table III. Other schools provide a heavy dose of not only chemical (extractive) metallurgy but also minerals and materials processing--

fields of study complementing each end of the chemical metallurgy spectrum. Departments of Ceramic Engineering are also mostly oriented towards teaching the principles common to the entire spectrum of ceramics from geological origin to ceramic (or glass) consumer product. In the case of Chemical Engineering departments the chief strengths are in process analysis and design with a disadvantage perhaps being the lack of materials characterization and behavior. The remaining discussion will focus on metallurgical engineering with the understanding that those more familiar with ceramic or chemical engineering curricula could make similar statements.

IV. Three Major Problems of Recycling/Raw Materials Utilization

In order to show how the subject areas we have chosen relate to recycling we have identified three technical problems of recycling which are also typical problem areas in utilization of raw materials. The technical problems of recycling which we have identified match very closely with the training that a student receives in chemical or extractive metallurgy and materials processing. For either resource utilization, or reutilization, those major problems are:

(1) Collection--The useful waste product or mineral is dispersed either geographically or in the case of some wastes dispersed in time, i.e., low volumes are generated. For example, in a given locality it may be unwise to construct a permanent facility for crushing automobile tires since after the initial build-up is processed the actual discard rate is too small for regular operations to continue. The same sort of problem (actually one of materials handling) can be found in mineral

deposits, e.g., the native copper deposits of Upper Peninsula Michigan can be very rich but on a very localized scale which makes processing facilities too expensive to construct or operate.

(2) <u>Contamination</u>--This is really separate from the dispersal problem common to lean ores or small waste disposal sites. It is a matter of the inclusion of residual materials often at a low level of concentration which deleteriously affect the processing and/or the product. In the case of recycled materials a good example is leaded steel. The remelting of that material can cause a deterioration of refractory life due to attack by liquid lead. Additionally the melting shop atmosphere can be contaminated with lead-bearing effluent. Finally, carryover of the lead into the new material may adversely affect properties. There are numerous analogies in raw material utilization but one that is especially pertinent is the sulfur impurity level in coal. In that case the environmental regulations against high sulfur fuels make it necessary for electric generating plants to attempt to utilize such sources of fuel as: natural gas, low sulfur oil, low sulfur coal such as metallurgical coal or the as yet unmined Western coals. The ramifications of such requirements have serious side effects on: western lands, our balance of payments, our metallurgical industries. The latter situation, e.g., in terms of cokemaking for ferrous process metallurgy uses, in turn creates demands for other raw materials such as fluorspar, magnesium, calcium carbide and other materials used to control sulfur levels in ferrous metallurgical products.

In either the recycling of lead-bearing scrap or the use of higher sulfur level fossil fuels a narrow approach to problem solving is not likely to be successful.

(3) Cost--This problem area of recycling and of raw materials utilization is most simply expressed as: the least expensive material, available in suitable quantity, with the necessary characteristics will be utilized. Those items constitute an "effective cost" for a given use of a material.

When viewed from the end use portion of the supply-demand network there are many alternatives for components, and the materials that such components are made of, which will perform a function. In other words, a given material whether obtained from natural or recycled resources has no guaranteed position in function except as its ability to satisfy the above "effective cost" criteria can be shown to be superior to other materials.

V. Summary

Through the methods of special topics courses either as seminars or group projects, students can become involved in recycling technology.

The teaching of recycling technology as a quasi-discipline implies that a set of principles are underlying in which background instruction is required. The question of identifying those principles is central to whether such a subject as Recycling Technology can be taught.

Our experience with recycling processes and special topics courses in recycling has led us to believe that there are some principles common throughout recycling technologies. Moreover, we see that those principles are common to a number of engineering disciplines. They are, however, especially pertinent to a broad curriculum in metallurgy or metallurgical engineering. In that sense the concepts and problems of mineral (materials) utilization and <u>re</u>utilization (recycling) are analogous.

Our conclusion then is that Recycling Technology can be taught and, in fact, is being taught but with an emphasis on the earlier portions of the supply-demand network. The shift to greater emphasis on <u>re</u>utilization should not require a major transition period, nor the development of altogether new programs, if the analogies are recognized.

References

1. McKelvey, V. E., "Mineral Position of the United States," in The Mineral Position of the United States, 1975-2000, University of Wisconsin Press, Madison, 1973.

2. Cameron, E. N., "The Contribution of the United States to National and World Mineral Supplies," in The Mineral Position of the United States, 1975-2000, University of Wisconsin Press, Madison, 1973.

3. "Status of the Mineral Industries," Bureau of Mines, U.S. Department of Interior, 1975.

4. Rosauer, E. A., "Junk: Who Needs It," 83rd ASEE Annual Conference, Colorado State University, Ft. Collins, 1975.

5. Bosscher, J. P., "Recycling As An Exercise in Engineering Education," 83rd ASEE Annual Conference, Colorado State University, Ft. Collins, 1975.

6. Braton, N. R., "Fragmentation of Polymers by the Reduced Temperature Technique," Rpt. No. II, Engineering Experiment Station, University of Wisconsin-Madison, April, 1972.

7. Samtur, H. R., "Glass Recycling and Reuse," Rpt. No. 17, Institute for Environmental Studies, University of Wisconsin-Madison, March, 1974.

8. Berry, R. S. and Fels, M. F., "The Production and Consumption of Automobiles" (An Energy Analysis), Rpt. to Illinois Institute for Environmental Quality, by Dept. of Chemistry, University of Chicago, July, 1972.

9. Swan, D., "Science and Technology: Aid and Hindrance," in The Mineral Position of the United States, 1975-2000, University of Wisconsin Press, Madison, 1973.

Table I

M&ME 806--Materials Recycling Seminar

Sample of Topics Presented

"Recycling the Automobile," presented by an Inst. Environ. Studies graduate students, considered the various factors which made the junked automobile an undesirable problem.

"Recovery of Metals from the Automobile," presented by an MME undergraduate, discussed the recoverable metals and unrecoverable metals in the auto.

"Sn and Cu in Recycled Municipal Refuse," presented by an MME graduate students, considered the source and problems of contaminants in recycling of metals.

"Disposal of Municipal Refuse," presented by a Civil Engineering faculty member, reviewed the disposal problems--concentrating on metallics.

"Madison Refuse Mill," presented by a Civil Engineering faculty member, reviewed the city refuse mill and landfill operation and studied the flow of metallic materials through this system, included tour of the mill and landfill site.

"Recovery of Metals from Urban Refuse," presented by an MME faculty member, summarized Bureau of Mines work on incinerated and raw refuse.

"Cryogenic Recovery of Automobile Tires," presented by a Mechanical Engineering faculty member, summarized UW and other approaches to cryogenic recycling of rubber tires.

"Cryogenic Recovery of Copper Wires," presented by an MME undergraduate, reviewed his independent study research in the use of cryogenics to strip insulation from wires and to recover motors, etc.

"Separation of Refuse," presented by an MME undergraduate, reviewed US Bureau of Mines separation system.

"Recycling Problems of the Automobile," presented by a Mechanical Engineering undergraduate, reviewed the physical problems of clean separation of materials in the auto.

"Flow Chart of Metals Recycling," presented by an MME faculty member, reviewed the steps involved in the process of handling secondary metals.

"Scrap Dealer Operations," presented by a Milwaukee "scrap dealer", reviewed the nature and incentives of this industry.

"Secondary Aluminum," presented by an MME undergraduate, reviewed the production of secondary aluminum ingot and the source of materials considered.

Table I (cont'd.)

"Recycling Aluminum Cans," presented by a representative of ALCOA, reviewed the pros and cons of recycling aluminum cans.

"Re-use of Sand," presented by an MME undergraduate student, reviewed the pros and cons of reuse of foundry sands.

"Scrap and the Metals Industry," presented by an MME faculty member, reviewed the use of scrap by the ferrous foundry and steelmaking industries.

"Glass: A Solid Waste Problem and Its Recycled Uses," presented by an MME undergraduate, reviewed the nature of glass collection, remelting or other reuse methods.

"The Reclamation of Lead from Used Battery Scrap," presented by an MME undergraduate, discussed his independent survey of the lead-acid battery industry.

Table II

Principal Subjects Common to Recycling Technologies

1. Chemistry (including physical chemistry)
2. Physics (through modern physics)
3. Materials Science (including behavior, characterization and properties)
4. Principles of Process Engineering (including transport phenomena, unit operations, process analysis, process design)
5. Thermodynamics (including thermochemistry)
6. Economics (including methods of cost benefit analysis)
7. Statistics (including sampling methods, regression analysis, experimental design)

Table III

Offerings by Metallurgical Engineering Departments of Principal Subjects Common to Recycling Technologies

Subject	Credits offered by Department						
	A	B	C*	D	E	F*	G
1. Chemistry	16	10	21	8	12	8	14
2. Physics	7	12	14	12	8	12	11
3. Materials Science	**	3	8	**	3	4	3
4. Process Principles	15	12	20	N.A.	10	12	10
5. Thermodynamics	3	3	3	3	3	**	3
6. Economics	6	opt.	6	opt.	4	3	3
7. Statistics	opt.	opt.	opt.	opt.	opt.	opt.	opt.

Notes:

*: Quarter system, others are semester system

**: Available in another form, e.g., Materials Science = Physical Metallurgy or Thermodynamics = Process Principles

N.A.: Not Available

opt.: Available as elective

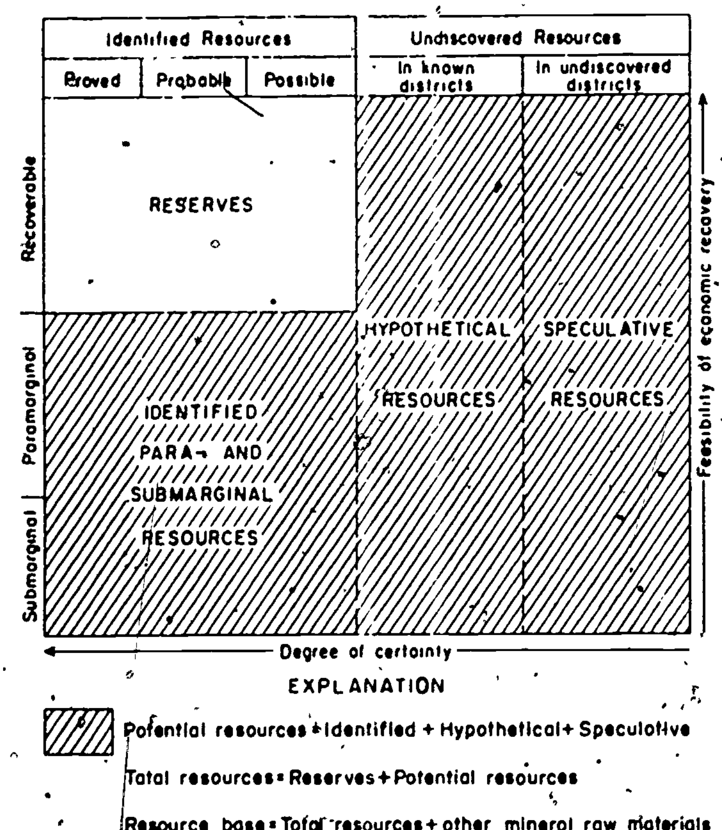

Figure 1. Classification of mineral resources being used by the U.S. Geological Survey in assessing total mineral resources in the United States.[1]

1	MINERALS	(iron ore)
2	BASIC MATERIALS	(iron/steel)
3	PRIMARY FABRICATION	(steel sheet)
4	COMPONENT FABRICATION	(auto body)
5	SUBSYSTEM ASSEMBLY	(automobile)
6	SYSTEM	(surface transport)
7	FUNCTION	(transportation)

Figure 3. A Frame of Reference for Minerals Use[9]. The Supply - Demand network from natural raw materials to societal function.