Integrated Computer-Aided Instruction for Separation Technology in Pollution Prevention and Control

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Abstract: The separation and oxidation technologies for pollution control involve a large amount of technical information from many areas, such as science, engineering, economics and government regulations. The integrated computer-aided instruction can be of great help for students and professionals. The unit operations of separation technology include sedimentation, air flotation, neutralization, chemical precipitation, air stripping, stem stripping, solvent extraction, adsorption, ion exchange and membrane separation. Oxidation includes chemical, biological and enhanced oxidation processes. The instruction starts with government regulations and classification of wastes, followed by theories and empirical correlations needed for calculations in equipment sizing. The computer expert system will perform a large part of engineering computation. The last part of the instruction is the data bank and procedures for preliminary cost estimate for equipment.

Keywords: Computer-aided instruction, separation technology, oxidation, pollution control, cost estimate.

Introduction

The selections of process and design of equipment for pollution control require the knowledge and computational skills in many areas. To name a few, they are chemical engineering, environmental engineering, mechanical engineering, chemistry and environmental laws. It is neither possible nor necessary for one person to know every thing, but many issues involved in the selection and design of process are interconnecting a vast amount of technical information from many professions. With the help of computer, one may be able to overcome the barrier caused by the limit of time and professional training.

The speed and size of memory of desk-top and lap-top computer have reach the point that such computer-aided instruction and computation are possible. With the 650 MB CD and 250 MB Zip disk it is possible to have an instruction which cannot only include a large amount of technical information, but also can be revised easily and quickly.

Environmental laws and Regulations

Many countries, including Taiwan and the United States of America, have laws and regulations to protect the environment. In the U.S.A. these laws and regulations which have significant impacts on water and wastewater treatments are the Clean Air Act, the Clean Water Act, the Safe Drinking Water Act, the Toxic Substance Control Act, the National Environmental Policy Act, the Marine Protection, Research and Sanctuaries Act and the Resource Conservation and Recovery Act [1, 2].

The ISO 14000 is a series of voluntary standard developed by the International Organization for Standard (ISO). It is very likely to have an impact on industrial wastewater treatment in the industrialized countries [3].

The responsibility of enforcing these laws and regulations falls on the government agency. However, the

economic concerns and community reactions also play an important role in protecting the environment. As a result, many people from various walks of life and professions are involved in the environmental protection work. Communication among them is very important.

Substances of Concerns

The list of substances of concerns and hazardous substances in industrial wastes is long. According to the U.S. Environmental Protection Agency (EPA), the industrial wastes can be classified into four categories [4]:

Type F Wastes- Hazardous wastes from nonspecific sources, such as spent solvents.
Type K Wastes- Wastes from industrial-specific sources, such as distillation bottom of organic manufacturing processes.
Type P Wastes- Acutely hazardous discarded commercial products and off-specification products.
Type U Wastes- Other discarded commercial products.

This classification helps to show the physical and chemical properties of wastes. The chemical names of these hazardous substances are identified in the EPA's Priority Pollutants List, which included 129 chemicals. According to the EPA these chemicals can be divided to the following groups: (1) 11 volatile organic compounds (VOC=s), (2) 46 base/neutral extractable organic compounds, 11 acid extractable organic compounds, (3) pesticides and PCB=s, (4) 13 metals, and (5) total cyanides. Most wastes are in the form of wastewater or sludge. The identification of these chemicals is very helpful in selecting a treatment process.

Separation Technology

These chemicals, as well as oil and suspended solids in water which are not hazardous but environmentally undesirable, must be separated from industrial wastewater before the reuse or discharge to lakes, rivers or the ocean. The separation task can be accomplished by one or combination of unit operations shown in Table 1 [2, 4, 5, 6, 7].

The asterisk * indicates the young technology, which shows strong potential, but may still need more work in research and development. On the other hand, a number of very mature unit operations, such as air flotation, with minor modification may find new applications.

Table 1 Separation Technology for Wastewater Treatments

Sedimentation Air Flotation Neutralization Chemical Precipitation Air Stripping
Steam Stripping Solvent Extraction Adsorption (Activated Carbon, Non-carbon adsorbent *)
Ion Exchange
Membrane Separation
Reverse Osmosis (RO), Ultrafiltration (UF), Nanofiltration *
Dialysis, Electrodialysis

The application of these operations and equipment design require extensive knowledge and computational skill. A computer expert system will not replace a well-trained human specialist, but it can provide enough knowledge for process selection and reduce the time for preliminary design. It also can help one in understanding the limit of separation operations due to chemical equilibriums.

Oxidation of chemicals in wastewater to innocuous substances can be an alternate or additional approach to

treat wastewater containing organic compounds. Table 2 shows various levels of oxidation processes. It can be aeration operation, which is a simple chemical oxidation using the oxygen in air as its oxidant. To improve the reaction rate, wet air oxidation can be used. Biooxidation is very popular also. In the recent years, custom-made microorganisms for specific organic wastes are reportedly available in the market. Chemical oxidation using hydrogen peroxide or ozone is the next stronger approach. The even further stronger approach is reported for refractive chemicals that is the enhanced chemical oxidation, such as the ultraviolet-light enhanced ozonation. For a small amount of chemicals in high concentration, incineration is a possibility.

Table 2 Pollution Control by Oxidation

Aeration	Wet Air Oxidation	bio oxidation	Chemical Oxidation
Enhanced Chemical Oxidation (UV Enhanced Ozonation)		Incineration	

Sludge Treatment

Many separation processes produce sludge containing pollutants, which must be treated before disposal. The operations of sludge treatment can be divided into three groups:

(1) Volume reduction, such as dewatering and drying,
(2) Stabilization by chemical or biological oxidation, and
(3) Conditioning for final disposal, such as cement solidification.

Some of separation technologies for wastewater treatment shown in Tables 1 and 2 can also be used in treating sludge, making sludge innocuous. The final heavy weapon for the treating sludge containing organic wastes is incineration. The incineration is energy intensive. Either land or ocean incineration must be monitored closely. The pyrolysis is less energy intensive, but it has not yet fully studied.

Engineering Calculations and Cost Estimate

Engineering calculations are needed in developing (1) process diagrams, (2) equipment list, and (3) equipment sizing. The cost and maturity are important factors in the selection of technology to be used. The costs of these processes given in Tables 1 and 2 can be estimated, if a proper cost data bank is established. The cost estimate procedure is similar to that used in chemical process.

Knowing the properties, flow rate, and target concentrations of pollutants in wastewater or sludge, one can establishes a list of equipment, equipment sizing, and performs a preliminary cost estimate. Usually the objective of a preliminary cost estimate is to obtain a cost estimate within 30% accuracy. It is used in the selection of process and equipment, before committing to the purchase of equipment or a costly engineering design. The cost estimate procedure is given by [8, 9, 10].

Knowing the cost of a piece of equipment of size s_1 at the year t_1 is C_1, the same type of equipment of size s_2 at year t_2 is C_2, which is given by:

$$C_2 = C_1\left(\frac{t_2}{t_1}\right)\left(\frac{s_2}{s_1}\right)^m$$

where m is 0.7 for many types of equipment. The time index t_1 and t_2 are available in the literature, such as Chemical Engineering and Business Week.

If the process is technically and economically feasible, the final step is to search the vendor and request the quotations for equipment needed.

Chemistry, Equilibrium and Mass Transfer

Wastes are unavoidable byproducts of many processes which produced energy and materials to support the modern society. The balance of environmental concerns and economic development has become a contemporary social and political issue.

As illustrated above, the environmental protection through pollution control requires a broad background in science and engineering, including theoretical formulas and empirical correlations in many areas. The understanding of engineering and economic limitations of pollution control technology is also needed. This broad background at least includes the knowledge in the chemistry, phase equilibrium and mass transfer, as well as cost estimate procedures and environmental laws and regulations.

Vendors

It is a tradition that technical books do not include the list of equipment vendors, to avoid an appearance of making commercial promotion. However, it is helpful to the reader to know the vendor of the equipment they are considering. On the other hand, the list of vendors is long and changes frequently. Usually it takes three or four years to publish a technical book. It is not practical to include the list which changes frequently. This situation may be changed, if CD or Zip disk is used.

Example - Air Flotation

Air flotation is an old technology, but with minor modification it has found a number of new applications [11, 12, 13]. Originally air flotation is developed for removing suspended solids in water. Fine air bubbles delivered to water can attach to suspended fine solid particles and bring them to the surface of water for removal. Since 1970's it has been used to remove emulsified oil droplets. In 1980's, with enclosed shell, it is used to remove dissolved volatile organic compounds from wastewater. Recently another new application is found. In addition to air, diesel oil is injected to the flotation cells to remove non-volatile organic compounds in water. This new application is still in its research-and-development stage. Its first application is in oil spill control operation. Various chemical additives reportedly tested to improve the performance.

Conclusion

The personal computer with 650MB CD or 250MB Zip disk has enough speed and memory to provide multi-disciplinary instructions and assistance in design calculations and cost estimates for pollution control. It also can include the information which changes rapidly and frequently, such as the environmental regulations and the list of equipment vendors.

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