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A KNOWLEDGE-BASED SYSTEM FOR WASTE MINIMZATION IN METAL FINISHING AND ELECTROPLATING INDUSTRIES*

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Abstract: This paper introduces a knowledge-based system for waste minimization in metal finishing and electroplating industries - MEPPI (minimization of environmental problems in processing industries) waste minimization techniques, such as process modification, raw materials reduction and resource recycling and recovery, and suggests its implementation in industries rather than end-of-pipe treatment.

The data for process analysis, materials balance for each unit, and test data collection, should be inputted into MEPPI first. One can then obtain information on which unit will generate wastes, what kind waste will be produced, and the waste amount and content. Further analysis of this information can reveal if each unit is operating ideally and if the whole process is in the best state. MEPPI can indicate the possibility of waste minimization in every unit, provide all kinds of waste recovery and recycling methods for users to select from, and can reduce raw materials consumption so that the loading on the end-of-pipe treatment plant will be diminished. Realization of waste minimization will improve the economics of industries.

MEPPI is a rich-database, friendly-interactive system integrating waste minimization audit calculation and waste minimization technique in a computer package. It can help designers to estimate the waste of a new factory and also process management or operators to minimize the release of hazardous or toxic waste into the environment.

Key words: waste minimization, knowledge-based system, metal finishing, electroplating
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INTRODUCTION

The generation of wastes will be increased with the rapid development of technologies and industrial practices. A large amount of hazardous or toxic wastes is generated in the processing industry (Nathanson, 1986). Although conventional end-of-pipe waste treatment has proved to be one of the effective methods for protecting the environment against pollution, it still has drawbacks such as high-cost, resource-wasting, and transformation of waste from one kind of matter to another. Therefore, waste minimization has become a prime concern in our society(Higgins et al., 1989).

Waste minimization techniques include process modification, source reduction and alternation, recycling, resource recovery, waste exchange, and treatment/disposal, etc. Process modification includes technology and equipment changes, material substitutions, and operation optimization. Source reduction involves decreasing the quantity and toxicity of toxic material. Recycling and resource recovery includes reuse of waste with or without treatment. If some residues are still exited after all the methods have been used, end-of-pipe treatment should be considered and zero pollution can be realized(Nemerow, 1995). Waste minimization techniques can not only reduce hazardous waste generation, but also decrease the operation cost of the waste treatment plant and increase the profit of the factory(Steward, et al., 1993). MEPPI is an expert system, which assists processing engineers and management to minimize the discharge of harmful materials into the environment by the implementation of waste minimization strategy (Yue, 1996). Process modification rather than expensive end-of-pipe treatment method is advised by MEPPI.

In this paper, some further work based on MEPPI will be presented. We combine the experiences of environment audit and survey in factories, to design a knowledge-based computer system that can:

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1. Recognize the reasonability of processing operation

2. Identify recoverability of waste from each unit

3. Compare the total waste concentration with recovery method used or not

4. Calculate the factory profit in every situation

A friendly software, with interactive capability and multiple databases, is used.

HARDWARE AND SOFTWARE

1. Hardware

An IBM compatible PC with not less than 850 megabytes hard disk, not less than 16 megabytes rams.

486 CPU with built-in math compressor.

600 × 480 256 colors or higher monitor and 1.2 megabytes 5″ floppy disk.

2. Software

Window 3.1 or Unix operating system;

KAPPA-PC expert system shell with version 2.3.2 or later; Original MEPPI program.

CONCEPT OF MEPPI

Waste minimization from the viewpoints of environmental safety and economics, is aimed to reduce hazardous and toxic wastes and recover resource. Before implementing appropriate waste minimization measures in industries, waste minimization audit should be conducted first to identify which units are the potential sources of all wastes generated, and what measures should be employed to reduce wastes.

A waste minimization audit program can help management and engineers to identify waste sources and implement waste minimization strategies effectively. The input information for the program results, such as the waste release spots, types, and amount, etc., can be obtained by means of survey, data collection and analysis, and assessment. A successful waste minimization audit program not only requires management commitment and support, but also depends on correct information acquisition and analysis. Data analysis and calculation is complicated work that should be done repeatedly when the data change.

Hence, in order to decrease the complex work of data analysis and calculation in the waste minimization audit program and generate the new result as soon as possible, calculation rules for data analysis should be added to MEPPI. Different units produce different wastes, so data should be inputted separately based on the units' operation. For example, there are two units. One is plating copper, the other is rinse. Though both units use water, the consumption of water should be inputted into the computer separately to different unit. Inputted materials are of two kinds: raw materials used in each unit, and materials that come from an upstream unit in the processing program.

Waste minimization can be carried out after waste minimization audit. Waste minimization techniques in industries can be generally categorized into process modification, source reduction and alteration, resource recycling and recovery, end-of-pipe treatment.

Process operators can use the results of waste minimization audit calculation to analysis if each unit operation is below optimum, or if the whole process is optimized. MEPPI can also provide some suggestions on how they are commonly used to modify the process and minimize waste.

MEPPI also contains the database of recovery and treatment methods for users to select the suitable methods for their factories. These methods have been proved to be available in practice.

STRUCTURE OF MEPPI

MEPPI should be used for two purposes: 1. To calculate waste for designer of process production; 2. To identify the waste for the operator of production. Therefore, two situations should be considered when an MEPPI package is designed.

First, the package must contain a lot of databases that can be chosen for a scheme. A designer can obtain a lot of information for achieving process optimization and less waste generation, for waste recovery, and for treatment methods. The software must be flexible. For example, if a raw material is not suitable for the process, it should be easily replaced by inputting

another material. The profit in all kind of situations can be compared.

Second, the package must be user-friendly and have interactive capability; users can easily operate it and access other systems. A dialogue box must be included to teach the operators how to use the package simply and rapidly. The showing windows should display as much information as possible. Fig.1 shows the structure of the knowledge-based system in electroplating industry.

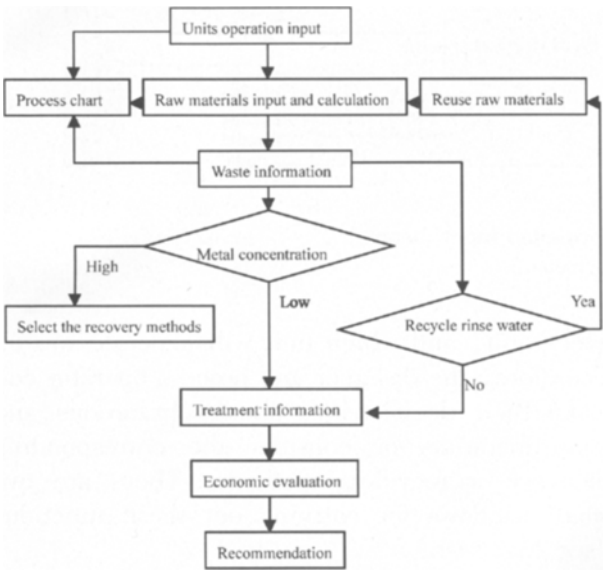


Fig.1 The structure of MEPPI package

INTERACTIVE CAPABILITY OF MEPPI

1. Installation and running MEPPI

After the KAPPA-PC has been installed and runs in the computer (Fig.2), MEPPI can run after the user clicks on "Open" in the function "File", and the main menu will be activated (shown in Fig.3). There are four data input levels including "Industry", "Inventory", "Waste Treatment", and "Economics". Three buttons, "Process Sketch"; "Recommendation"; and Final Report", are use to display the summary of data inputting with the four data inputting levels and database of MEPPI. Moreover, the user can delete all old data that inputted and begin a new program by clicking on the "New Session" button.

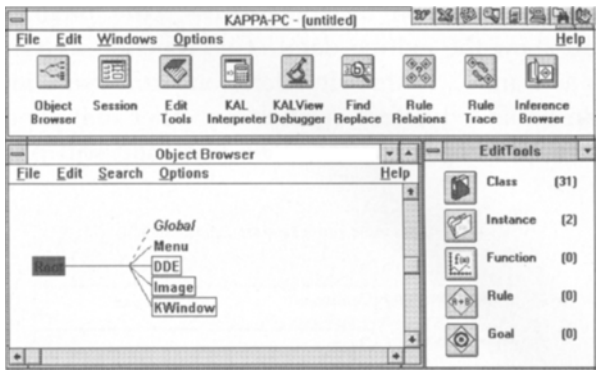


Fig.2 The interactive capability of KAPPA-PC

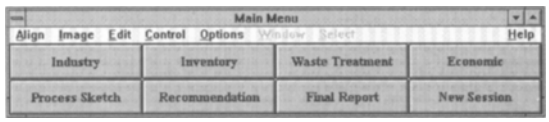


Fig.3 The main menu of MEPPIP

2. "Industry"

"Industry" is used to input one by one the information on every unit's operation in process. Clicking on the proper button, activates "Process _ Info" as shown in Fig.4.

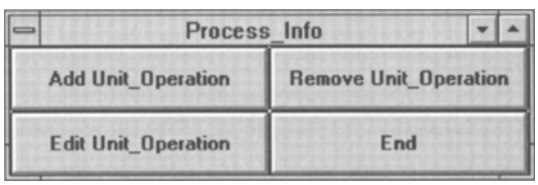
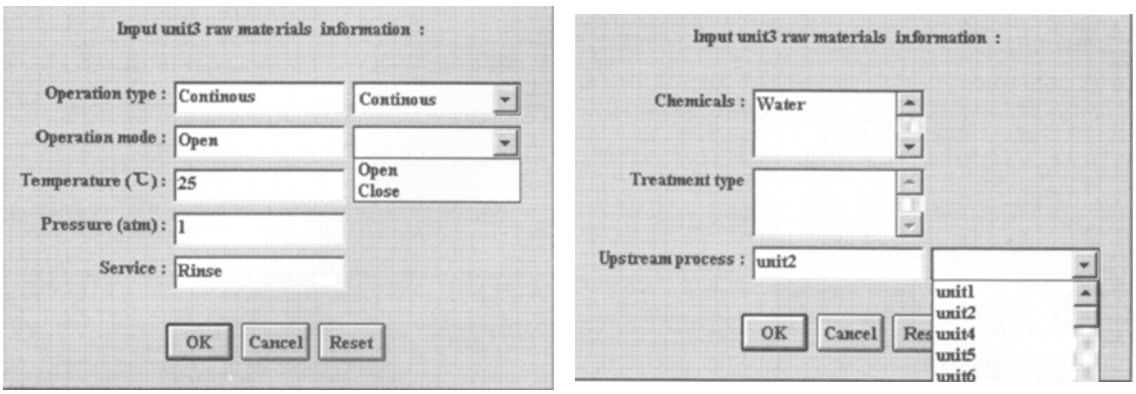


Fig.4 Process units information input menu

According to the inputting order, the computer can automatically define the units successively as unit 1, unit 2, unit 3, etc. The information, such as units name, raw materials used in each unit, materials from the upstream process to the next process, waste type and ingredients, should be inputted into the program at this level, when the user can edit, modify or remove the existing data.

"Add Unit-Operation" has two functions. First, if there is no data in this session, the program will prompt the user to input new process. This function is used to input the process information from beginning to end. Second, if there

is no information on the process, the program will show the exiting data. This function is used to add units. In this situation, one unit operation can be added before or after any other unit operation had been inputted. The later unit will plus 1 automatically. For example, if a unit is added before unit 3, unit 3 will change to unit 4 and so on first; the added unit will become unit 3 (examples as shown Fig.5).

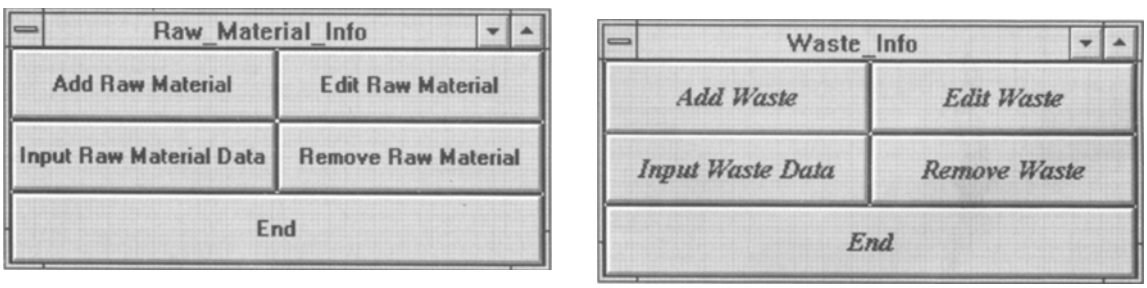


(a) (b)

Fig.5 Unit operation information input menu
(a)menu 1; (b)menu 2

3. "Inventory"

"Inventory" requires the user to input information on the quantity of raw material used in each process and amount of waste produced in each unit. According to these data, the computer can calculate the material balance itself, and then show what kind of materials will be used in every unit, and which unit will generate waste. Therefore, the designer and process operator can make their decisions to change hazardous and toxic materials or consider the corresponding recovery or recycling methods. There are two small windows for carrying out these functions (see Fig.6a-b).



(a) (b)

Fig.6 Unit operation information meun
(a)raw meterial window; (b)waste window

"Add Raw Material" and "Add Waste" are used to input forgotten input data. Fig.7 shows some examples.

4. "Waste treatment"

Waste treatment includes waste reusing/recovery and end-of-pipe treatment. One can input the treatment method, materials type and quantity used in treatment, recovery efficiency, content and amount of waste after treatment at this level. After the button is pushed on, a small window as shown in Fig.8 will come into view. The operator can use the proceeding window to enter reuse or treatment information (see Fig.9).

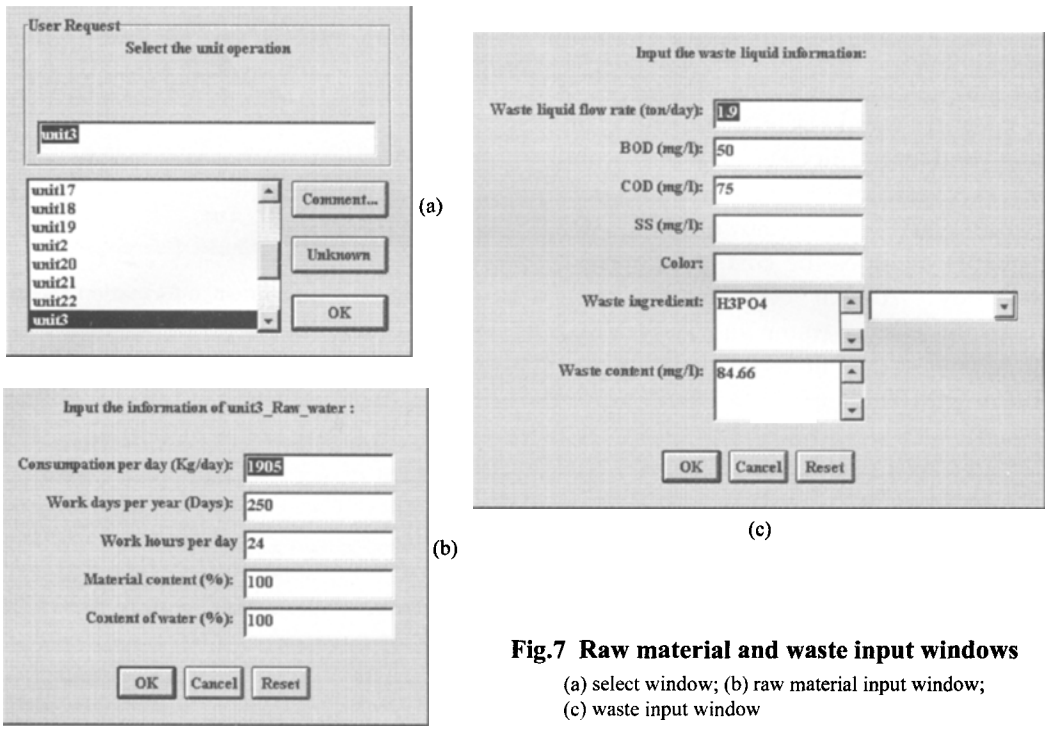


Fig.7 Raw material and waste input windows

(a) select window; (b) raw material input window;
(c) waste input window

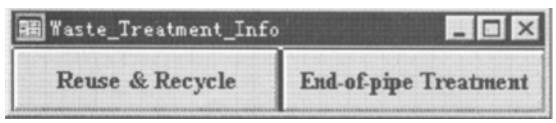


Fig.8 Waste treatment information menu

5. "Economics"

Many factories pay more attention to economics than to environmental problem, but now they realize that reuse/recovery of waste will reduce the quantity of raw material needed, diminish

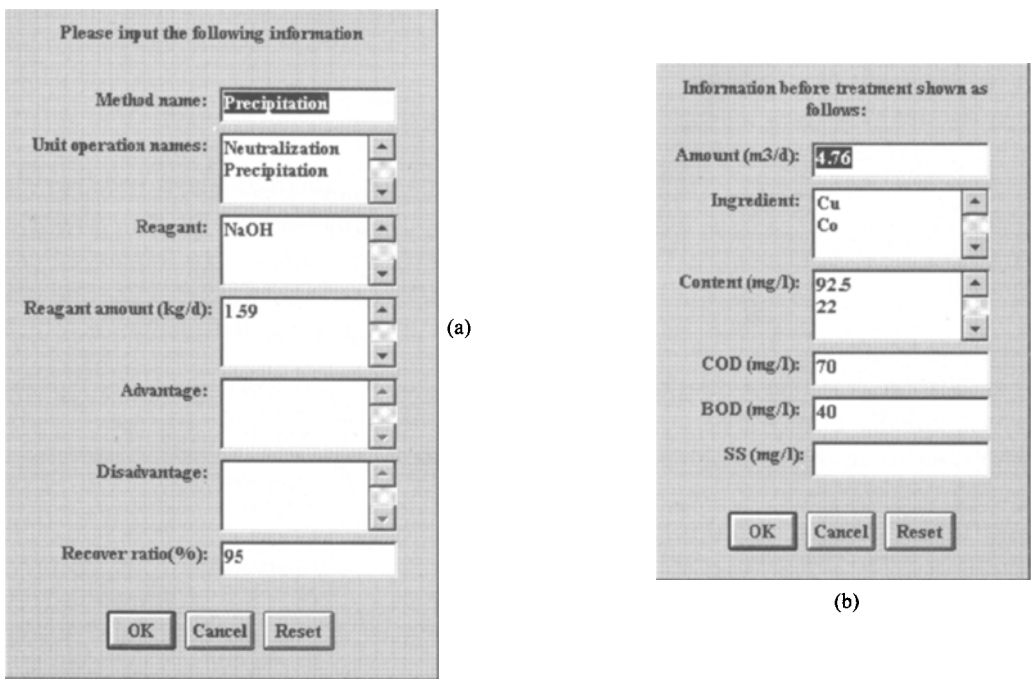


Fig.9 waste recovery and treatment information input menu

(a) recovery menu; (b) treatment menu

the cost of a waste treatment plant, then increase the profit of the factory. Hence, MEPPI involves the inputting and calculation of the economics of production, recovery, and waste treatment. This level contains production process investment and annual cost, recovery and treatment equipment investment and annual cost as shown in Fig.10. Investment mainly includes the cost of equipment that factories buy. Annual cost involves four items, such as the cost of water and electricity, salary, maintenance, raw material used in production, and waste treatment.

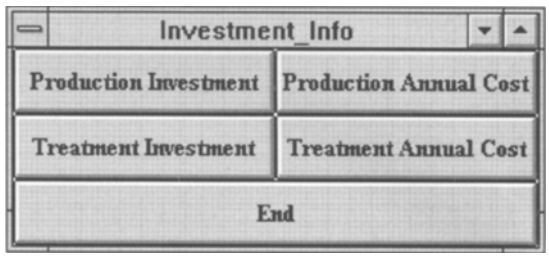


Fig.10 Investment information menu

The user can input economic information into the proceeding windows (Fig.11 shows some

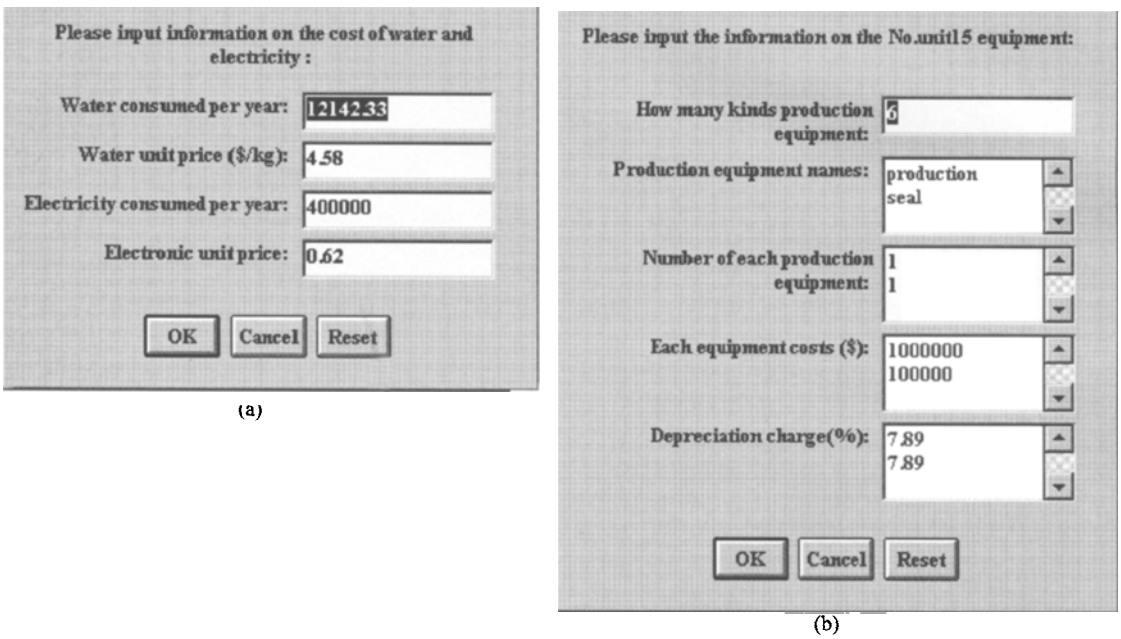


Fig.11 Economics information input windows
(a) cost of water and electriaty; (b) investment of equipment

examples).

A CASE STUDY

A typical electroplating industry in Hong-Kong that has been selected as a case study used copper, gold, cobalt, tin, lead, and other chemical materials in its electroplating process. The main waste of the industry is wastewater containing all the above metals and some chemicals. The gold is a very expensive and must be recovered; the other metals are harmful to human health if released into the environment, so these metals must be pretreated in and recovered before wastewater outflow. After inputting the industry information as required by MEPPI, the window "Object Browser" will be filled with the units operation of the industry, raw materials used in each unit, waste released from different process es and the window will change from that shown in Fig.12 to that shown in Fig.13.

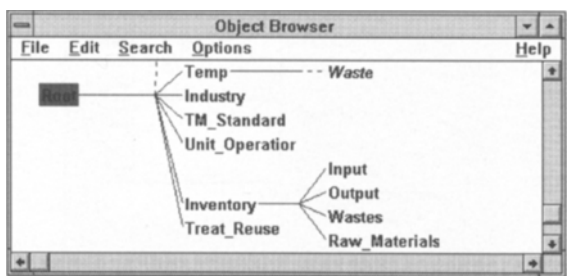


Fig.12 Object browser window before information input

After the button "Process Sketch" is pushed on, a flow chart of all processes will show. There are 22 unit operations in this industry, three windows will show the whole process because each window can contain 10 units(Fig. 14 (a),(b),(c).

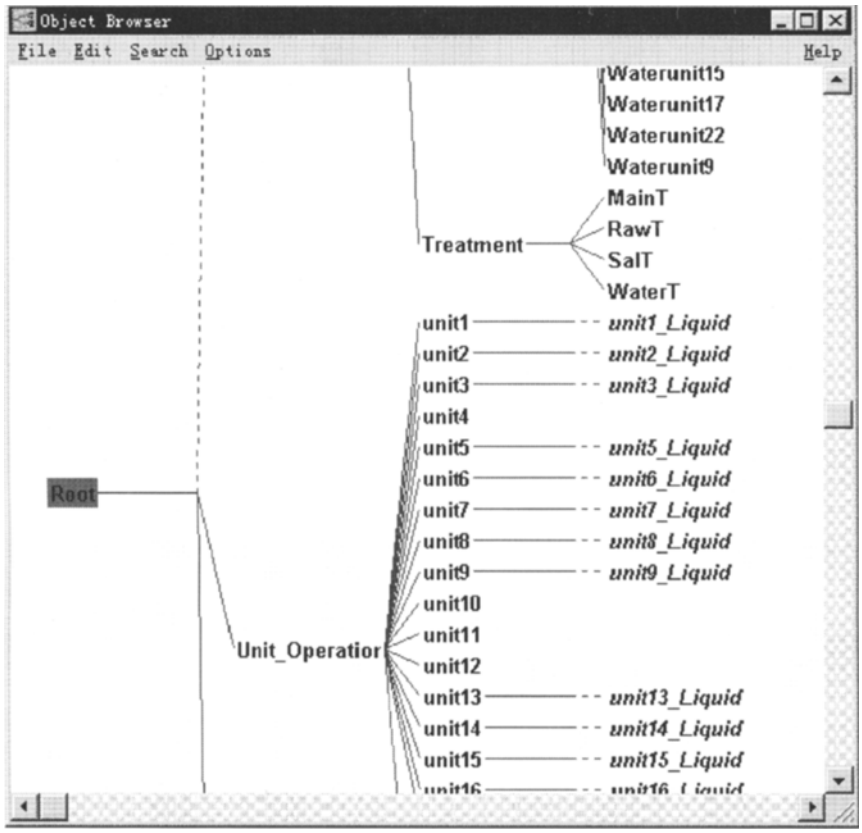
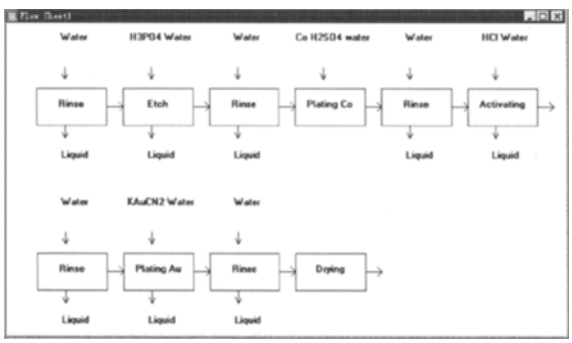
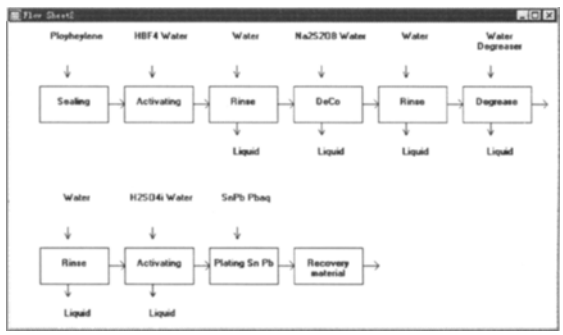


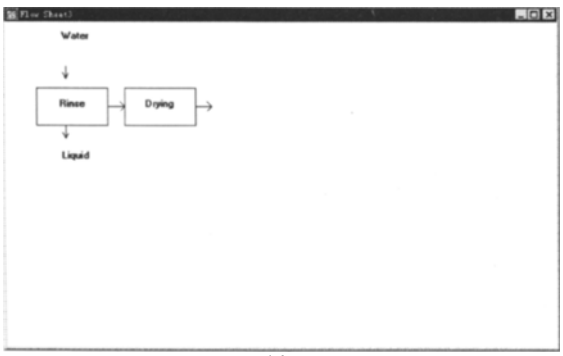
Fig. 13 Obiect browser window after information input



(a)



(b)

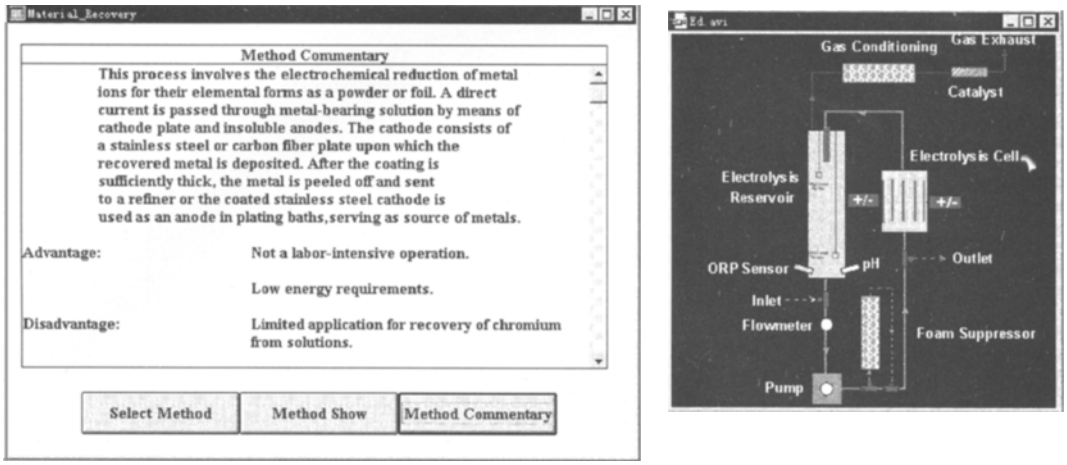


(c)

Fig. 14 Flow chart of electroplating industry

(a) window 1;
(b) window 2;
(c) window 3

Some process modifications, material recovery, and inventory control database will be displayed in "Recommendation", which can suggest to the units' operator and designer how to eliminate waste in each of the process steps. Fig. 15 is the example of recommendations on material recovery.



(a) (b)

Fig. 15 Material recovery database presentation windows(Michael, 1986; Tavlarides, 1985)
(a) method commentary; (b) method flow figure

Computer calculation are listed in a final report table (Fig. 16) summarizing consumption of raw material, equipment type and quantity, waste amount and content, reuse and treatment methods and effective investment and operating cost of production and waste treatment.

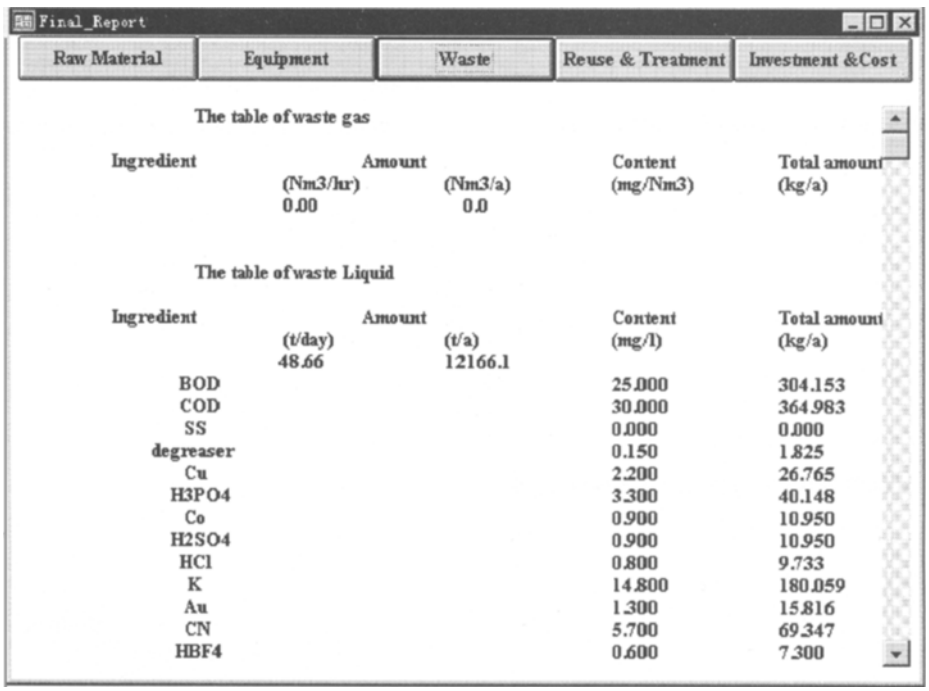


Fig. 16 Final report menu

CONCLUSION

Waste minimization techniques may not only reduce the hazardous waste generation in process by means of process modification, raw materials reduction, and resource recycling and recovery, but also increase the economics of industries by reducing the operating cost of conventional waste treatment plants. MEPPI is a user-friendly, easily interactive knowledge-based system. MEPPI is composed of four major information sources: industry, inventory, waste treatment, and economics. According to the information, data ana-lysis calculation in the waste minimization audit program may be carried out first, and then a process can be drawn with the process sketch. Then recommendations on the issues of minimizing hazardous or toxic waste generation will be produced, and a final report table of raw materials, equipment, waste type and amount, resource recycling and recovery method, and investment and annual cost will be generated.

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