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How coffee-making can help one understand cleaner production

J. Fresner[1,*] and H. Schnitzer[2]

[1]*Stenum GmbH, Geidorfgürtel 21, A-8010 Graz, Austria*
[2]*Institut für Verfahrenstechnik, Technische Universität Graz, Inffeldgasse 25, A-8010 Graz, Austria*

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Cleaner production works. This has been proved by numerous case studies over the last few years in Austria[1-4], as well as in the USA, Sweden, the UK and The Netherlands. Programs such as PREPARE in Austria, the US-American EPAs 33/50 program, the Landskrona Project in Sweden, the Aire and Calder Project in the UK and PRISMA in The Netherlands have demonstrated that in all sectors of industry it is possible to increase efficiency in the use of materials and energy in industrial processes and at the same time avoid waste and emissions at their source and save companies—sometimes enormous amounts of—money.

The cities of Graz and Stenum have developed the program Ökoprofit (Ecoprofit)[3], which aims to provide a cost-effective way of involving regional enterprises in a Cleaner Production Project. The approach consists basically of two arms: (1) nine 1-day workshops to give feedback on the progress of the companies, to teach basics of emission prevention, project management and law; (2) consultations with individual companies to help them with specific problems, between the workshops.

The teaching sessions during the workshops consist of a short lecture followed by active work in small groups on examples, presentation of the results, a discussion of the findings and the possibilities of applying them to the actual companies of the participants. In one workshop, participants analyse the coffee-making process for its potential to minimize emissions; in another, they analyse it for its energy-saving potential. This article describes how these two interactive training modules for mass-flow analysis and energy analysis are conducted. © Elsevier Science Ltd

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Difficulties in disseminating cleaner production

It seems hard to sell the concept of 'cleaner production' (CP). Consulting models are usually limited by public funding: as soon as a project is no longer free, the interest in participation diminishes.

In the PREPARE projects, it was shown that the main obstacles to the further dissemination and adoption of CP techniques are not so much publicity of the concept, lack in technologies or readiness to change or to invest, but trust that the idea of pollution prevention works and hands-on experience. The basic idea is readily understood, but there is lack of understanding of how to make it work under real-world conditions[5]. We therefore started to think about a procedure in which the participants could learn several methods for analysing processes and industrial organizations by practising them during a seminar. As one of the first steps in an industrial CP project is to work out an overview of the inputs and outputs of the company, we decided to use a very practical example to show the participants how to obtain and handle the relevant data for material and energy balances.

Special strategies for dissemination of cleaner production

From programs such as Ecoprofit, we know that a seminar approach to CP programs helps in many ways. In this approach, the companies meet every month for a seminar, in which they exchange their experiences and learn about new tools and special areas of waste reduction (e.g. allocating costs, legal requirements, logistics). Between seminars, the consultants work together with specific companies. In this way, detailed work within the companies is combined with a 'club'

* Correspondence to J. Fresner.

approach, which helps develop peer pressure and the exchange of experience between different companies.

In most cases, we found that one of the main obstacles for a further dissemination of CP in companies is a lack of hands-on experience with methods of analysing environmental problems. We therefore decided to use real-world problems and role-play in our seminars to provide participants with experience of actual projects.

Some modules were therefore developed that were used in Ecoprofit workshops in Austria and internationally, in seminars with university students and in training future CP consultants.

Theory and practice

The core pieces of the workshops are: one session on CP strategies, one on data collection and material flow analysis, and one on energy. These consist of an information block of about 45 min, which provides basic information on the context and the method, together with 'tips' and 'tricks'. Practical examples are very valuable; they explain how the theory has been used in practice, show the context of actual problems and provide a useful introduction.

Then follows an interactive session. People learn more by actively doing than by passively listening. As Luskin states[6]: 'The idea is to have a real process in the classroom; a real process, however, which does not need any technological background information or a lot of preparatory materials.'

We have selected a very simple example process—one that is known to all of us in detail, and even performed a couple of times a day, but which has for sure never been done before in the way it will be done in this workshop: we analyse the process of making coffee in a coffee machine.

Coffee-making and material flow analysis

Analysing the flow of materials, raw materials, water, lubricants, etc., through a process is necessary to locate the sources of and reasons for waste. In practical work, a lot of experience and imagination is often needed to find the sources of waste and generate ideas for improvement. However, we can give a general method for locating waste minimization options; it consists of seven steps:

1. define the material, compound or element you want to trace;
2. define the system boundaries;
3. define the time period;
4. define the process steps;
5. draw a flowchart (qualitative analysis);
6. do balances (for the system as a whole and for the single process steps);
7. interpret the results, formulate them graphically and present them, together with your conclusions, to the management.

After the training session the participants should be able to:

- set priorities for their work in their own company;
- draw flowsheets;
- collect data;
- do mass balances;
- interpret this information and develop options;
- present the options to the management.

This method is presented in an introductory lecture following through some examples. [One example deals with the different sources of paint waste in a machine paint shop. Here, paint is taken from the cans, made ready by the addition of thinner, then sprayed through guns to the work pieces. Some of the paint, the so-called overspray, is removed from the air by filters. A flowchart of this operation is developed, waste streams are located, waste amounts are determined. The use of graphics and indicators is explained.]

After a short discussion, we proceed to practical work. The aims of the module are to analyse the flow of materials in the coffee-making process in a filter coffee machine and to define options to optimize the use of materials and energy.

The participants are organized into groups of three to five. Participants from the same company are split up among the groups. The trainer checks that there is an equal distribution of people with management, economic and technical job functions. According to our experience, the educational background of the participants can vary to a great extent without impacting on the success of a working group. Each group has a coffee grinder, a coffee machine, scales, coffee filters, coffee beans, spoons, bowls, etc. (*Table 1*). We use different types of filter coffee machines to provide different findings. Then the task is presented. The task for each group is to conduct the process of coffee production (grind the beans, introduce coffee powder, water and filter to the machine, operate the machine, empty the machine), to develop a flowchart of the process, analyse qualitatively the flow of water and coffee, and to determine the quantities of the streams of materials (input water, evaporation losses, water in used filter, water in coffee, coffee beans, ground coffee, coffee losses, coffee residues in used filter, coffee

Table 1 Equipment and materials used in the material flow analysis of coffee-making

Equipment
Coffee machine, with jar
Coffee grinder
Scales
Bowls
Cups
Spoons
Materials
Coffee beans
Water
Filter
Paper and pencil
For cleaning: Wettex

Table 2 Tasks for the group exercise 'material flow analysis of coffee-making'

- Make a jar of filter coffee
- Develop a project plan
- Organize the work in the team
- Draw a flowchart of the process
- Calculate balances for water and coffee
- Draw a Sankey diagram for water
- Develop at least three options for improvement
- Prepare transparancies for a 10-min presentation
- Present your results and options

extract in coffee). They have to arrange the data in a flowsheet and interpret them. They create a Sankey chart for the flow of water and a pie chart for the composition of the used wet filter with the coffee residues. [A Sankey chart is a flowsheet showing mass or energy streams in a process by using arrows with a width proportional to the respective flow.] They also have to generate options for reducing waste and emissions (*Table 2*).

During the group work, the trainer is available for questions and tips. He will also contribute actively if there are problems that cannot be solved by the group.

Work starts with the development of a work plan and splitting the work between the group members. The steps of the process are defined (unpacking, grinding, heating water, extracting, disposing of the waste, drinking the coffee), the material flows (input water, coffee beans, filter, product coffee, wet grounds, wet filter, rest in machine, losses) are defined and methods to determine the weight of the water streams and the coffee are developed. Then the process is conducted and the predefined information collected.

A flowsheet of the process is developed (see *Figure 1* for an example) and balances are made. From this, losses can be quantified. The flow of water is visualized in a Sankey diagram (*Figure 2*) which at the same time serves as a basis for interpretation and generation of options. Consequently, the groups research the potential for process optimization and develop options for improvement.

Each group then gives a short presentation featuring the flowchart, the Sankey chart and the options. The data describing the wastes and emissions of the groups are collected by the trainer on a transparency or a flipchart. He then compares and evaluates the results. Different machines, according to their construction, will have different evaporation losses or residues in the tanks. Usually, the groups will use different recipes to produce weaker or stronger coffee. This needs further discussion. Which is the optimum product to serve the customer best?

The collection of the options on another flipchart usually leads to a creativity session, in which options are further processed and additional options are generated. Usually we end up with 10–15 possibilities to improve coffee-making. Examples of such options are given in *Table 3*. Then we enjoy the coffee together and compare the quality of the different recipes. Coffee-making can become really scientific.

Afterwards, the participants are asked to select one problem relating to their company to which they will apply what they have learned. The results have to be presented during the next workshop.

A typical schedule for such a session is as follows: 45 min for the basic lecture, 15 min for the introduction to the group work, 1 h for the group work, 10 min per group for the presentation of the results, 30 min for the discussion and interpretation, and 15 min for the selection of the homework tasks.

Coffee-making and energy analysis

Saving energy is an important part of CP. Energy savings can lead to significant economic effects. Energy transformation causes significant environmental problems. Thus optimization of the use of energy is the

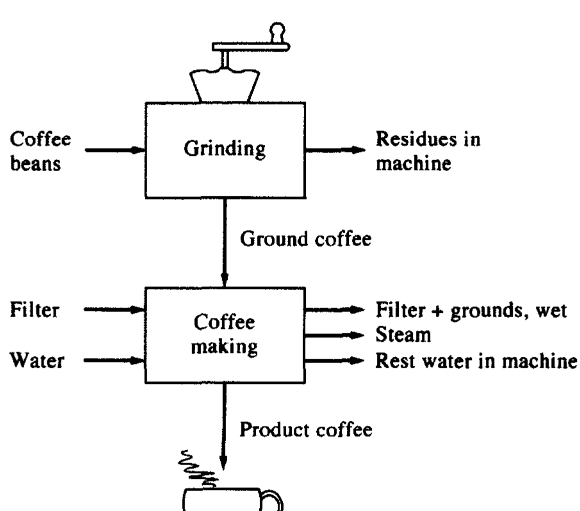

Figure 1 Example flowchart from a workshop.

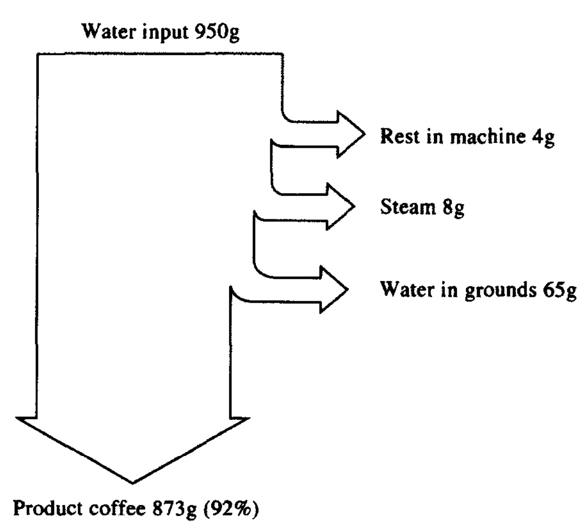

Figure 2 Example Sankey diagram from a workshop.

Table 3 Options for improvement generated in the material flow analysis of coffee-making

Change of product
Nescafe
Turkish coffee
Good housekeeping
Grind in bigger machines
Empty grinder better
Develop a recipe
Check storage practices
Substitution of raw materials
Metal film filter
Use of ground coffee
Buy coffee in reusable packaging
Changes in technology
Improve construction of machine to allow for easy cleaning
Improve construction of coffee machine to minimize evaporation losses
Use Italian-style espresso machine
Internal recycling
Reuse coffee grounds
External recycling
Use coffee grounds and filter for composting
Use coffee grounds as a sewage cleaner
Use coffee grounds as an insecticide
Other options
Develop indicators (e.g. coffee input per litre of coffee, evaporation losses)
Compare different recipes and customer reaction

main focus of our Cleaner Production Projects, and there is a special workshop dealing with energy.

This module is designed to help participants to:

- understand the terms 'power' and 'work';
- understand how the cost of energy is calculated;
- identify the elements of an energy management system;
- identify basic measures to increase energy efficiency.

This workshop again starts with an introductory presentation on the methodology of analysing the energy consumption of processes by first checking the structure of energy consumption and the weekly loads in order to identify peaks and losses. Then come hints on how to reduce the energy consumption of particularly large energy consumers, such as dryers, large drives and cooling systems.

The interactive module also makes use of the coffee example. This time, additional equipment is used: stop watches and meters for power and current.

The task of the groups is now to heat 0.5 l of water to boiling using different coffee machines, a stove with a matching pot as well as a very small one, and different water boilers. The current, the power and the time taken are recorded.

The power demand and the work for producing a jug of coffee per day are then calculated, as well as the costs. By this means, the participants learn the importance of monitoring the power demand, as this exerts a significant influence on the price of energy.

Then the different power demands are discussed: machines with high power are quick, but generate high costs; keeping the coffee warm by electrical means brings a significant cost, and can be achieved by using an insulated jug.

The small pot causes significant losses compared to a matching one. The lesson for practical work is: check your apparatus in the company, whether it really matches requirements, or is old technology which is only used because it has already depreciated in value. The electric stove has significant heat storage; thus check for cycles and try to run processes continuously. And put the lid on: you can tell that from the increased time it takes to heat the water to boiling. Specialized equipment, such as water boilers, has a significantly better efficiency. And so on and so on.

Conclusions

Working on actual, albeit 'toy', problems in small teams has several advantages. There are no barriers to understanding complicated technologies or machinery. The problems serve as models for real-world problems, presenting the complexity of the real-world problem-solving process and therefore challenging the trainees with the actual problems of data collection, team work, deciding how to get started, etc., but in a laboratory atmosphere which is not encumbered with the everyday problems encountered back at the office, in time-lapse and with a helping trainer in the background. Participants usually become deeply involved in the process. The results in terms of learning are especially good when the trainer provides gentle guidance and a clear summarizing interpretation of the analogy to the real problems in the companies. This corresponds with the observations of Luskin[6].

The experiences with these modules show that such interactive aids can do a lot to help people get a better understanding of CP and to motivate them and stimulate their creativity to find good, perhaps new and environmentally useful, solutions to problems. Analysing the feedback from the participants of two courses in Graz and approximately ten workshops in two other Austrian cities, we can say that the approach of these modules was rated 'very good' or 'good' and we think it is a successful one. It is easier to fully understand and memorize concepts that you have used yourself. The participants are also better prepared to put these concepts into action in their own companies.

Acknowledgements

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