Introduction to cleaner production assessments with applications in the food processing industry

René van Berkel, IVAM Environmental Research, University of Amsterdam, P.O. Box 18180, 1001 ZB Amsterdam, the Netherlands

Abstract

A cleaner production assessment aims at the identification, evaluation and implementation of CP opportunities in a company. A systematic working method, which facilitates the *execution of a CP* assessment, generally consists of *three* separate, interrelated options: method; procedure; *and guidance and supervision. in addition* to introducing these elements *and their applications in the food processing industry, this article presents plant-level assessment results to illustrate the possible benefits of CP in various food processing sectors.*

Résumé

Une évaluation de production plus propre a pour objectif d'identifier, d'estimer et *de mettre en oeuvre le potentiel de production plus propre au sein d'une entreprise. Une methode de travail systimatique susceptible de faciliter une telle mission d'evaluation comporte généralement trois options distinctes mais liées entre elles : méthodologie; procedure; assistance et supervision. Cet article présente ces différents éléments et leur application dons le secteur alimentaire; il rend compte également des résultats de I'évaluation au niveau des usines afin de montrer les avantages potentiels d'une production plus propre* dons diverses branches *du secteur alimentaire.*

Resumen

Una valoración sobre producción limpia (CP) apunta a la identificación, evaluación y puesta en práctico de las posibilidades de CP en una empresa. Un método de trabajo sistemático, *que* facilite la ejecu*ción de una valoración CP consta generalmente de tres opciones diferenciadas pero interrelacionadas: el método, el procedimiento, y las poutas y supevisión. Además de introducir estos* elementos y sus *aplicaciones en la industria de procesamiento alimenticio, en este articulo se presentan lOS resultodos de una valoración a nivel de planta para ilustrar las posibles ventajas de CP en lOS diversos sectores de esta industria.*

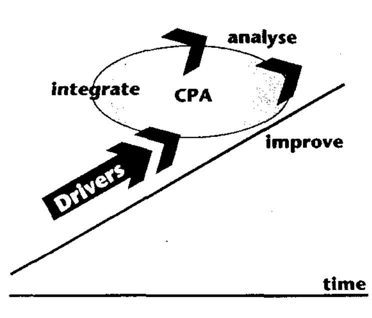
Cleaner production assessments

Crucial for cleaner production (CP) is the continuous application of an integrated preventive strategy to industrial processes and products in order to avoid, or at least minimize, the generation of waste and emissions. The application of this preventive mindset to existing production facilities normally results in a diversity of CP opportunities. A comparative evaluation of these opportunities is then needed, in order to exploit the economic and environmental benefits of CP. A systematic working method facilitates the development, evaluation and implementation of CP options tailored to the company's products, processes and operations.

The plant-level working method for CP, or assessment, is often characterized as a systematic planned procedure with the objective of identifying ways to reduce or eliminate the generation of waste and emissions[2] Furthermore, an assessment should initiate an ongoing CP programme, catalyzing the corporate effort to achieve continuous environmental improvements in its operations. In order to emphasize the ongoing improvement process, CP assessments are sometimes also referred to as "environmental improvement" cycles. Such a cycle serves three functions:

1) *analysis* of the environmental burden of the production processes and its causes;
2) inventory and evaluation of *improvement* options for the production processes;
3) *integration* of the feasible improvement options into the production processes and into the daily operation of the company.

Figure 1
A CP assessment (CPA) as "vehicle" for ongoing environmentall improvement



Consecutive cycles enable the company to achieve environmental improvement in key areas such as:

- *resource conservation:* improvement of the material and energy efficiency of production in order to reduce the input of natural resources (materials, energy and auxiliaries)per unit of production;
- *toxics use reduction:* reduction and - to the extent feasible - elimination of the use of "hazardous" materials. In this respect, all materials exerting a highly negative environmental impact could be considered as "hazardous" (including toxic substances, ozone-depleting chemicals, global warming chemicals, etc.).
- *waste minimization:* reduction and - to the extent feasible-elimination of the generation of "waste" materials (including by-products, solid waste, hazardous waste, air emissions and/or wastewater discharges).

The environmental improvement process is visualized in Figure 1.

A systematic working method for the execution of a CP assessment normally consists of a "method", a "procedure" and (external) "guidance and supervision".[3] The *methodserves* as the tool for the identification of CP options. The *procedure* organizes the necessary activities and thus fosters the development and implementation of CP opportunities. The (external) *guidance and supervision* guides, informs and stimulates the responsible assessment team at the plant-level. Working methods used for the introduction of CP in the food processing industry differ for all these components. Therefore, each of them is dealt with in detail below.

Generating alternate CP options

As CP focuses on the production process that causes the waste stream, the central element of the CP method should be to examine and re-evaluate the production process. This re-evaluation consists of a "source identification" followed by a "cause evaluation" and "option generation". For the *source identification*, an inventory should be made of the material flows entering and leaving the company with the associated costs. This results in a process flow diagram, allowing for the identification of all sources of waste and emission generation.

Next is the *cause evaluation,* an investigation into the factors that influence the volume and composition of the waste and emissions generated. A checklist of possible waste generation causes is used to assess all possible factors influencing the volume and/or composition of the waste stream or emission. The checklist should correspond to the general prevention techniques. Therefore product requirements, input material specifications, technology, process execution (operating practices), and waste and emission characteristics are generally used as possible cause categories. A materials and energy balance is needed for the evaluation of the relative importance of each of the possible waste generation causes.

The purpose of the next logical step *(option generation)* is to create a vision of how to eliminate or control each of the causes of waste and emission generation. The CP approaches (or prevention techniques) specified in the conceptual framework are used to develop appropriate Cl' options. Once CP options have been identified, these should be evaluated like other investments or technical innovation options.

Source identification

Source identification starts with the drafting of a list of unit operations, with their associated material inputs and outputs and transformations. Production generally comprises a number of such unit operations. These can be defined as an area of the process or a piece of equipment where materials are input, a function occurs and materials are the output - possibly in a different form, state or composition. It is important to choose the right level of detail during division of the production process into unit operations. It might be wise to start with a general list, with the main unit operations, and go into details at a later stage only for those unit operations that cause serious waste generation. By connecting the individual unit operations in the form of a block diagram, one can prepare the process flow diagram. To reduce complexity, one should try to start with the raw materials at the top of the diagram and end with the final product at the bottom of the diagram. For each unit operation, material inputs are placed at the right side of the diagram and material outputs at the left side.

An essential step is checking the process flow diagram. What goes in must come out somewhere. So all inputs should have related outputs, as product or waste, and all outputs have to be traced back to inputs. All unit operations can be the source of various waste streams. Therefore, the completed process flow diagram should be used to check all unit operations for waste generation and thereby compile the list of all waste sources.

A factory producing deep-fried salted peanuts using shelled, blanched peanuts can be taken as an example.[4] The peanuts, which are supplied in plastic bags, are emptied directly onto a conveyor belt. They are transported through a deep-frying oven; then they pass through a cooling unit; and finally they are sprinkled with

Figure 2
Sources of process waste in a factory producing salted peanuts

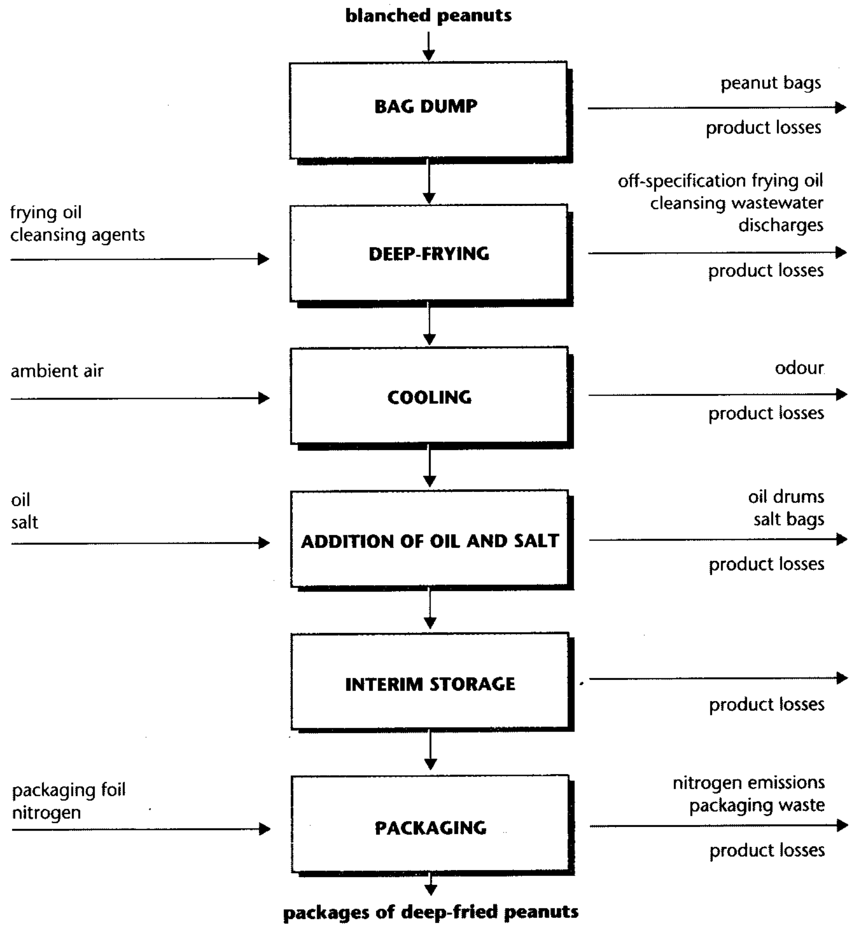


Figure 3
Cause evaluation: five possible causes of waste generation

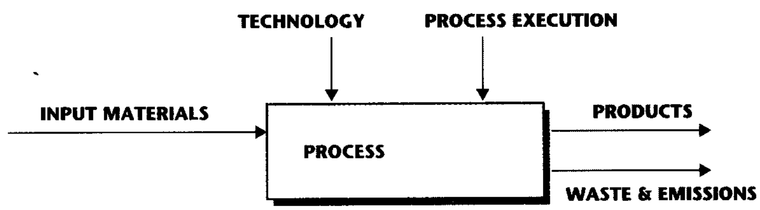


Figure 4
Cause evaluation for deep-frying of peanuts

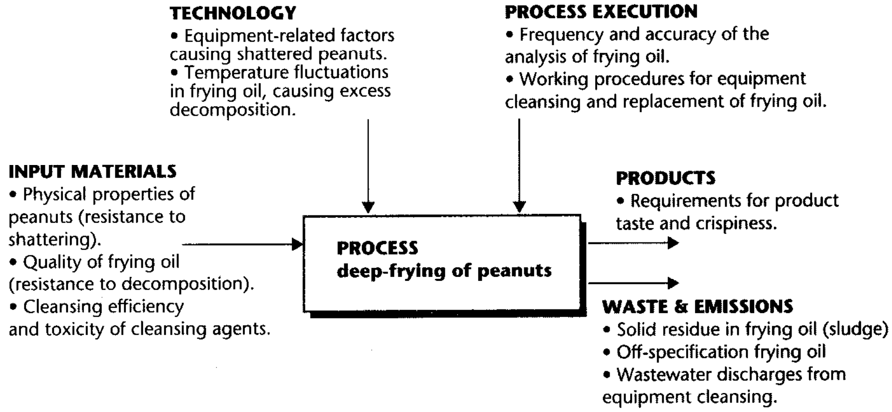


Figure 5
Option generation: application of the general CP approaches

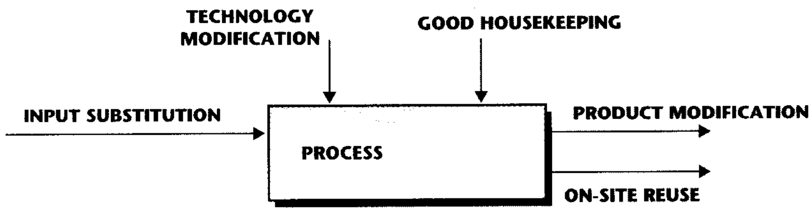


Table 1
Selection of audit focus at Beijing Brewery

Production units	Production (10,000 tonnes/yr)	Beer loss (%)	Water consumption (tonnes water/ tonnes beer)	COD discharge (kg COD/tonne beer)
Old brewery	5.82	9.25	14.2	21.8
New brewery	4.48	9.73	17.0	24.0
Factory average	10.31	9.39	15.4	10.4 (after EOP)

oil and salt. The peanuts are then poured into containers for interim storage. After several hours they are ready to be packaged. The containers are attached to a packaging machine, which forms bags from rolls of foil and then fills them with peanuts.

To prevent loss of flavour, the air is removed from the bag using nitrogen. From time to time the oil used for deep-fat frying must be replaced, as a residue gradually accumulates at the bottom of the oven (due to broken peanuts and decomposition of the oil). The deep-fried peanuts are cooled by means of outside air. The salt is brought into the plant in paper bags and the oil in metal drums.

The process flow diagram for this factory has six unit operations (bag dump, deep-frying, cooling, addition of oil and salt, interim storage, and packaging). Each unit operation is also the source of one or more types of process waste (see Figure 2). When using this process flow diagram for source identification, care should be taken not to neglect non-process waste sources like maintenance, cleansing, etc.

Cause evaluation

The next step is to evaluate all material flows. One should try to quantify the volume and composition of all material flows which could result in a mass balance for all individual unit operations or for the entire company.[5] As there is generally a lack of detailed data, it is hard to compile such mass balances for each of the constituents of the input and output material flows. For the purpose of CP evaluating the unit operation is as important as compiling a reliable mass balance. This evaluation should result in an understanding of the cause of waste generation at the unit operation. Generally speaking, one can distinguish five factors that influence the volume and composition of the waste streams (see also Figure 3). Following these five factors, the process evaluation should give an answer to five basic questions:

1) Do product specifications have an impact on volume and/or composition of the process wastes and emissions?
2) Do input materials have an impact on volume and/or composition of the process wastes and emissions?
3) Do technological factors (like process design, equipment, piping, etc.) have an impact on the volume and/or composition of the process wastes and emissions?
4) Do operating practices (like planning, workers' training and motivation, etc.) have an impact on the volume and/or composition of the process wastes and emissions?
5) Do waste handling procedures have an impact on the volume, composition, and/or recycling potential of the process wastes and emissions!

Discussions between operators, supervisors and plant management on these questions generally result in a thorough understanding of the causes of waste generation.

Once again, the application of the cause evaluation can be illustrated with the example of the peanut factory. In this factory the peanuts are dumped onto a conveyor belt which transports them at a constant speed through a frying oven filled with oil. They are deep-fried for ten minutes in this frying oil, which is kept at a constant temperature of 160°C. Broken peanuts might fall from the conveyor belt and drop to the bottom of the oven, and this residue hastens the decomposition process of the frying oil. For this reason the quality of the frying oil is monitored every 15 minutes. If the concentration of decomposition products is too high, the process

Figure 6
Example of CP options for deep-frying of peanuts

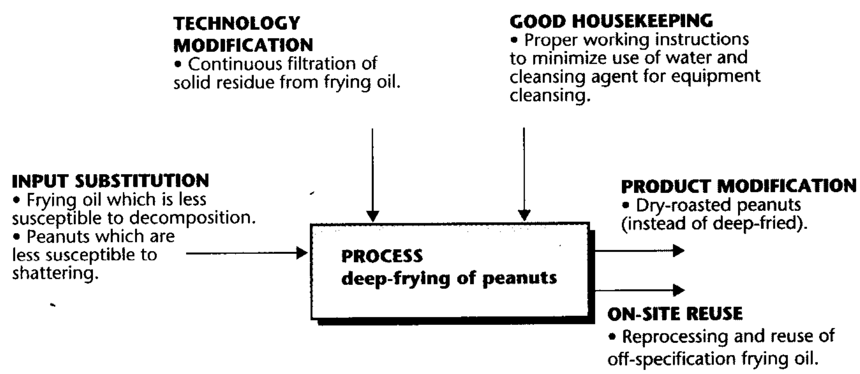


Table 2
Summary of the feasibility study results

	Yeast Recovery	Beer Recovery
Explanation	At present, the beer liquid from the fermentation is directly fed into the diatomae filtration, which results in loss of the yeast with the diatomae filter cake. Once a centrifuge has been placed in front of the diatomae filtration, the yeast suspended in the beer liquid can be recovered and sent-back to fermentation house for reuse.	At present, waste yeast pulp from fermenter wash-out is collected for off-site reuse. Once a filter press is installed, the yeast pulp can be compressed in order to recover the beer liquid it contains.
Technical Details	Equipment is readily available and commonly used in breweries around the world.	Equipment is readily available and commonly used in breweries around the world.
Environmental Evaluation	40% COD reduction 20 tonnes (dry weight) yeast recovery	1.9% overall beer loss reduction
Economic Evaluation	Investment: 2.7 million yuan Pay-back period: 2.6 years	Investment: 2.6 million yuan Pay-back period: 3.0 years

is halted and the frying oil is replaced. The used frying oil is stored in a drum, and the oven is thoroughly cleaned with hot water and detergent. When the oven is completely clean, the oven is filled with new frying oil and the process is restarted.

The factors influencing waste and emission generation in the deep-frying process are shown in Figure 4.

Option generation

The next logical step is to develop alternate methods ("CP options") for eliminating or controlling the causes of waste generation. To this end, five general prevention techniques can be used. These are: product modification, input substitution, technology modification, good housekeeping, and on-site reuse and recycling. All five possible causes of waste generation can be dealt with using a particular prevention technique (see Figure 5). Information from the cause evaluation is used for the identification of the most appropriate CP approach, and information from the source identification for targeting to the source unit operation. Generating appropriate prevention options is still a creative step; the information obtained so far is used as a guiding tool in this creative process. The basic questions for the option generation are:

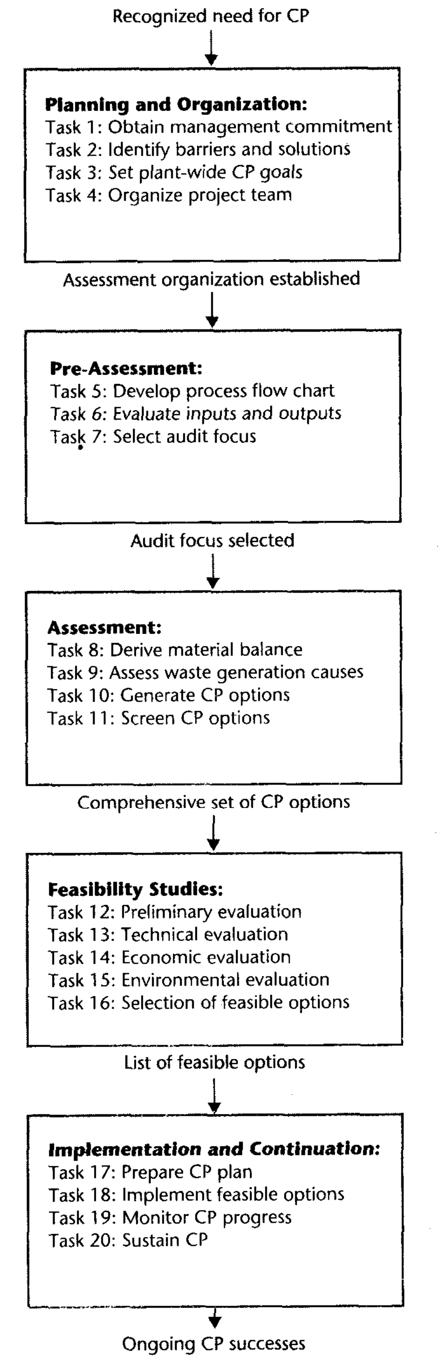
1) How should the product be modified to minimize or eliminate process waste generation?
2) Which input substitution is necessary to minimize or eliminate process waste generation?
3) How should the technology be modified to minimize or eliminate process waste generation?
4) How should the housekeeping be improved to minimize or eliminate process waste generation?
5) How could waste materials be recycled on site?

Brainstorming about these questions by the assessment team proves successful for generating options. In order to fully exploit the benefits of CP it is essential to perform such assessments of unit operations frequently at various levels and departments within the company.

To illustrate option generation, the CP approaches have been applied to the peanut deep-hying process. The result is shown in Figure 6. The change to a dry-roasting process is an example of product modification, since it changes the product specifications considerably. The environmental burden caused by dry-roasting of peanuts has to be compared with the environmental burden caused by deep-frying them, in order to assess whether net environmental improvement occurs.

Changing the input materials could help reduce waste generation. A type of peanut would have to be found that is less subject to shattering. This would reduce product loss, as well as slowing down the decomposition process of the frying oil. Another opportunity is to switch to a type of frying oil which is less susceptible to decomposition. It would not have to be changed as often, which would help reduce waste (off-specification frying oil) and wastewater discharges (from equipment cleaning). Moreover, if an environment-friendly oil were used, the waste oil produced would be less harmful to the environment.

Figure 7
Overview of the CP procedure[16]



Certain adjustments to plant equipment might be considered. As we have seen, broken peanuts left behind in the oven hasten the decomposition of the frying oil. If this residue were continuously filtered out of the deep-fryer, the decomposition of the frying oil would be slowed down. This would mean that the frying oil could be changed less frequently, thus reducing the amount of waste oil. According to the process description, the production processes in the peanut factory are highly automated. However, at the cleansing stage simple good housekeeping is an important factor.

The amount of water and the cleansing agent used could be reduced to a minimum, leading to a considerable reduction in waste generation. It may be possible to recycle the frying oil within the plant, if it can be reprocessed. It is not clear from the description whether this is feasible.

Next the options have to be evaluated, in order to figure out which combination of options generates the best economic and environmental benefits.

Organizing the CP efforts

The method described above should be embedded in an organized procedure. Following this procedure should be instrumental in organizing the CP efforts, informing the necessary stakeholders within the company and bringing together those persons who can develop, evaluate and implement the CP opportunities. The use of a four-step procedure, originally developed by the US EPA,[6] is still widespread although a number of modifications have been incorporated in more recent publications.[7] The original phases were: planning and organization, assessment, feasibility analysis, and implementation. With a view to minimizing the necessary efforts for CP the use of a pre-assessment as a planning tool for the development of the CP activities has become widely accepted, especially for application in small and medium-sized enterprises in Europe.[8] In Figure 7 the CP procedure has been elaborated into 20 tasks, which have to be conducted by the plant level project team. The procedure can be illustrated with a practical application in a brewery.

Beijing Brewery is a medium-sized enterprise under the Beijing First Light Industry Corporation. The production was 102,500 tonnes of beer in 1992, having a production value of 149 million yuan (US$l = 8.6 yuan). The brewery employs 1550 persons. Due to the extension of the production capacity in the course of 1991-1992, the existing anaerobic wastewater treatment plant became highly overloaded. This incited the management to participate in the Preparation Phase of the China Cleaner Production Project.[9] In the course of 1993, a CP assessment has been executed by a plant-level assessment team with guidance from the Beijing Environmental Protection Bureau, the Chinese Research Academy for Environmental Sciences, and international experts from UNEP. The following results have been achieved in each phase of the assessment procedure.[10]

Planning and organization

Right from the start of the project, the management has been very positive about the cost-saving potential of CP for Beijing Brewery. The project team has done a good job-in keeping the management informed about the progress of the CP assessment. In particular, the early CP results through improvement of the operating practices in the bottling workshop - have fostered the ongoing involvement of management and contributed to the success of this CP project.

Next, the anticipated barriers have been classified as conceptual, institutional, technical and economic. To overcome these barriers, several CP information dissemination meetings have been organized in different departments of the brewery in order to raise awareness among the staff, workers and management of the entire company.

CP goals for COD reduction have been set at 20 per cent for the short term and 70 per cent for the long term. The short-term goal is based on the current overload of the wastewater treatment plant. The long-term goal is based on comparison of key production figures of the brewery with international figures.

The project team consists of six representatives from management and technical and environmental departments, and technicians from the production workshop. The limited size of the project team, as well as the enthusiasm of the team members, have made it a particularly successful one. Although the production manager did not formally participate in the project team, he was kept informed and actively involved in option generation and in the implementation of the good housekeeping options. The participation of the well respected technical director, as well as the enthusiastic manager of the environmental department, in the project team has created good factory-wide support for the CP project.

Table 3
Overall results of short- and medium-term options at Beijing Brewery (1000 yuan equals ±120 US$[19])

Company	Beijing Brewery (at 120,000 tonnes annual beer production)					
Options	Short- and mid-term options					
Item	Units (1000 yuan/ tonne)	Price (tonnes/year)	Rate Before CP (tonnes/year)	Rate After CP (tonnes/year)	Difference (tonnes/year)	Annual benefit (1000 yuan/yr.)
INPUTS						
Raw materials						
Malt	tonne	1.7	22,464	21,000	1464	2488.8
Rice	tonne	1.8	8640	8640	0	
Diatomae earth	tonne	3	480	240	240	720
Glue	tonne	3.3	80.4	67.2	13.2	43.56
Lubricant	tonne	3.3	240	204	36	118.
Fresh water	tonne	0.0003	1,800,000	1,200,000	600,000	180
OUTPUTS						
Products						
Beer	tonne	0.7	120,000	124,800	-4800	3360
By-products						
Distillers grain	tonne	0.0005	12,960	11,880	1080	-0.154
Used yeast	tonne	2.2	45	48	-3	6.6
Wastewater	m^3	0.006	1,440,000	900,000	540,000	324
Solid waste						
Diatomae cake	tonne	0.02	600	300	300	6
Total Benefits (1000 yuan/yr.)						7247.22

Pre-assessment

The pre-assessment at Beijing Brewery was mixed up with other parts of the assessment procedure. The preferred sequence for the pre-assessment is: development of a process flow chart, evaluation of inputs and outputs, and selection of the audit focus. Beijing Brewery worked the other way around, starting with the selection of the audit focus on the basis of a comparison of the key environmental figures between the two beer production units **(see Table 1).** Additionally, a process flow diagram was made in order to prepare for the assessment. Consequently, the pre-assessment is not comprehensive in terms of coverage of all input and output energy and material flows, and evaluation of the CP potential for all waste generating sources. However, the choice of the new brewery as the audit focus is evident since it is far more polluting then the old brewery.

Assessment

The assessment team devoted a lot of effort to the establishment of the materials balance. Analysis of the production statistics was combined with on-site observations of operating practices and working procedures, and on-site wastewater monitoring. The work on mass balances contributed to the understanding of the production processes and the waste generation sources, which in turn enabled the generation of 27 CP options in four categories: adjustment of product mix, control of the raw material inputs, optimization of the production processes, and recovery for on-site reuse. A first screening of the options took place on the basis of four criteria (expected technical feasibility, expected economic benefit, expected environmental benefit, and expected ease of implementation).

Feasibility studies

Beijing Brewery divided the feasibility analysis into a qualitative evaluation of the benefits of the implementation of the low- and non-cost CP options and a detailed (quantitative) feasibility evaluation for the expensive CP options. Thus far, two (equipment-based) options have been extensively evaluated for technical and economic feasibility and environmental desirability. The results of these feasibility studies are summarized in **Table 2.**

Implementation and continuation

An implementation schedule for all options has been made, with an indication of the departments in charge for the implementation. The options are divided in non- and low-cost options (ten options) and investment-requiring options (**17** options). The non- and low-cost options include good housekeeping practices and strengthening of management, and were implemented in the course of 1993. The planning for implementation of the remaining options has been elaborated as follows:

Step 1: 30,000 yuan was invested in 1993 in the implementation of nine low-cost options;

Step 2: Set of technology-based options with high cost and high COD reduction potential. The total investment amounts to 5.96 million yuan, of which half had been commissioned by the end of 1993;

Step 3: Obviously beneficial options with poorly accountable benefits (total investment 1.47 million yuan).

In 1994, progress has been achieved in the implementation of Step 2 (such as the installation of yeast centrifuges). In addition, Beijing Brewery started to monitor progress at the factory level. In order to sustain CP progress has been linked to the bonus system for staff and operators. Additionally, it is anticipated that new CP assessments will begin targeting energy and water consumption in the brewery.

Learning to prevent waste generation

The role of "outsiders" in the development of a CP assessment is often neglected. However, most CP demonstration projects conclude that external guidance and supervision provided by either independent consultants/trainers (from consulting firms, technical assistance programmes, etc.) or internal consultants (for instance, from specialized staff of the corporate headquarters in multiple-plant companies) proved necessary in order to keep the assessment process going. The ultimate goal is to teach the company to prevent future waste generation. Key supervisory skills to this end are the ability *to challenge the project team,* the ability *to critically review* the assessment results, and the ability *to add to creative thinkingand* problem solving.

As with other industrial innovations, several modes of supervision are possible. *Process-orient-edguidance* and supervision, in which the supervisor contributes to the development of the problem-solving capabilities of the company, proves superior both in terms of results (implemented innovations) and in terms of learning to innovate." The *technical* approach (the supervisor supplies the company with the options and the company implements them) as well as the *programmatic* approach (the supervisor supervizes the innovation - or assessment - process, while the company develops and implements the solutions) are less effective in terms of contributing to the development of ongoing (technical) improvements.

In CP auditing, the supervisor ideally combines the process-oriented approach with the programmatic approach. In the first role, the supervisor teaches the company how to identify and evaluate its waste problems and how to develop opportunities to prevent waste generation. In the second role, the supervisor creates the necessary conditions for the development of the assessment, for instance by planning meetings, writing reports and preparing (internal) presentations. In order to emphasize both aspects, it is often said that the supervisor of a CP assessment should be both a trainer *and* consultant to the company assessment team.

A review of the Dutch PROGRES project evaluated the role of the supervisors (consultants) in initiating the ongoing integration process of CP. It was suggested that the supervisor should strive for achievements in regard to four success factors.'* These are:

1) Achieving visible CP *benefits* for the environment as well as for the company's economic position. At Beijing Brewery it was rather easy to visualize the possible CP benefits; the beer losses in the bottling department were an obvious economic and environmental problem, since as a matter of fact this beer was "not sold as product, but rather discharged as wastewater".

2) Organizing a capable and motivated project team, which should at least have the ability to understand how the facility operates, the authority and support to change the facility's operations, and the ability to maintain the CP spirit as old challenges are met and new opportunities arise. The project team at Beijing Brewery was extremely successful. It obtained its authority from the participation of the technical director in the team. In addition, the cooperation between the technical department, the environmental department and the production department fostered the smooth development and implementation of CP options.

3) Generating new insights, both in terms of waste generation causes and of CP opportunities. The CP assessment at Beijing Brewery made the brewery staff and management aware of the numerous non- and low-cost options for the improvement of operating practices and the strengthening of management. The most important new insight was therefore that CP goes much beyond the installation of advanced equipment.

*4) Introducing a preventive environmental man*agement (or *care) system,* for instance by linking CP with the Total Quality Management System. At Beijing Brewery, the results of the CP assessment incited the management to expand the existing job responsibility system in order to include workers' care for water conservation and loss prevention into the regular job performance reviews.

The total benefits of the CP assessment at Beijing Brewery are summarized in a "before CP" and "after CP" comparison (see Table 3).

Example results

In order to illustrate the benefits of CP auditing in different sectors of the food processing industry, two examples from the Netherlands and China will be evaluated in more detail below.

Nestlé Amsterdam

Nestle Amsterdam is a production plant which produces flavours (liquid or dry form), soups, sauces and bouillon.[13] The company consists of three separate units: flavour plant, soup plant, and the packaging department. The main process in flavour production is the acidic hydrolysis of vegetable protein. The major waste streams generated at Nestle are the flavour residue (solid waste residue from the flavour production), wastewater, and mixed solid waste. At Nestle a CP project was undertaken with assistance from the University of Amsterdam.

After the pre-assessment, three priority areas were selected. These were: flavour residue, wastewater, and mixed solid waste. During the in-depth assessment of these priority areas, twelve viable prevention options were established. The implementation of four of them started within the 16 months of university-industry cooperation. For six options, feasibility studies were begun; for two of them, these were not yet carried out. The other options proved not to be feasible in the short term.

The most successful options for Nestle were: enzymatic hydrolysis, decanting, on-site reuse of pump water, reprocessing of first rinse water from evaporators, substitution of evaporator cleansing agent, and off-site recycling of industrial waste components. Table 4 contains some details of these options.

The project team consisted of the director, the production manager, the manager of the packaging department and the process engineer (all from Nestle), and two researchers from the University of Amsterdam. During the "planning and organization" stage the commitment and involvement of the plant management could be improved through the execution of the pre-assessment. This pre-assessment was rather labour-intensive for researchers, due to the complexity of the plant and its processes. In the "assessment" stage priority was given to the establishment of a coherent package of viable prevention options.

Due to the continuous fluctuations of raw material composition, it was not possible to draw up material balances. The translation of the general prevention techniques into practical prevention options by means of brainstorming by the project team was a great success. The selection of the most promising options was, however, rather complicated. Nestle initiated the

Table 4
The most remarkable second year CP achievements at Nestlé Amsterdam[20]

OPTION DESCRIPTION	IMPLEMENTATION	ENVIRONMENT	ECONOMICS
1. Enzymatic hydrolysis: use of enzymes for disclosure and (partial) hydrolysis of vegetable protein.	Laboratory experiments with promising results, especially regarding product taste.	About 50% reduction in use of adjunct materials (hydrochloric acid, soda and energy) and reduction of salt content of wastewater and residue.	Savings on adjunct material purchases, effluent charges and waste disposal costs.
2. Decanting: Replacement of cloth filtration unit for salt filtration by a decanter.	Implemented in 1991.	ı Improved separation between salt and product, which results in improved product yield. ı Reduction of rinse water usage.	Pay-back approximately 1 year.
3. On-site reuse of pump water: feed vacuum pump wastewater from soup plant into wet scrubbers of flavour plant.	Implemented in 1990.	Reduction of water intake by 118,000 m^3/yr.	Pay-back within 2 months.
4. Reprocessing first rinse water from evaporators: reclaim flavour from first rinse water from evaporators.	Logistic consequences still have to be assessed in detail.	Reduction of water pollution with about 485 population units.	Reduction of effluent charges with Dfl 32,00O/yr. and improved product yield.
5. Substitution of evaporator cleansing agent: substitution of cleansing agent for evaporator.	Implemented in 1991.	Reduction of water pollution with about 127 population units.	Dfl. 11,1OO/yr. savings on operational expenditures.
6. Off-site recycling of industrial waste components: segregated collection of paper, plastic and product spills for off-site recycling.	Segregated collection of cardboard and plastics started in 1990.	In total 98,000 kg/yr. industrial waste suited for off-site recycling.	Dfl. 29,500/yr. savings on waste transportation and disposal cost.

Table 5
Summary of the assessment results at Yantai Second Distillery*'

OPTION	TECHNICAL CONTENT	ECONOMICS	ENVIRONMENTAL IMPACT
1. Good housekeeping in bottling department.	Repair of leaks and proper instruction of workers in order to avoid excess filling of the bottles.	Investment: 12,500 yuan Annual benefit: 523,000 yuan.	4.5 tonnes/yr. production increase.
2. Equipment repair and optimization in alcohol plant.	• Optimization of distillation reflux utilization. • Revamp of steam and condensate pipes. • Reuse of distillation tower condensate for fermenter disinfection. • Recovery of fermenter washout water.	Investment: implemented at no extra cost during yearly overhaul. Annual benefit: 5,040,000 yuan.	Potatoes input reduced from 3.81 to 3.09 tonnes/tonne alcohol. Production increase of 1200 tonnes/year.
3. Differential distillation.	Replace existing multi-tower distillation with differential distillation system.	Investment: 3,454,000 yuan. Pay-back period 1.5 yr.	Steam conservation of 40%. Water conservation of 30%.
4. Continuous fermentation.	Replace batch-operated fermenters with continuous fermentation system in order to improve efficiency and eliminate wastewater from fermenter washout and desinfection.	Investment: 480,00 yuan. Pay-back period: 3.1 yr.	At least 1% production efficiency improvement. Elimination of 5000 tonnes/yr. wash water.
5. Boiler replacement	• Replacement of the boiler • Continuous use of methane gas for power generation instead of co-firing.	Investment: 1,231,000 yuan. Pay-back period: 4.4 yr.	Coal conservation of 635 tonnes annually. Electricity conservation of 750,000 kWh/yr.

feasibility studies. In the meantime the researchers were involved in gathering knowledge from other sectors of industry that could be useful for Nestle. The feasibility studies had not been completed at the end of the 16 months cooperation with the university researchers. The options which had been established as feasible were in the process of being implemented or had already been implemented.

Yantai Second Distillery

Yantai Second Distillery is a state-owned, medium-sized enterprise in the coastal city of Yantai, People's Republic of China. It is engaged in the production of grain liquors and red sweet potato wines. The plant employs 510 persons and has a production capacity of 5000 tonnes of alcohol per year. The production equipment dates from 1982-86. The single largest environmental problem in the distillery is the generation of 14 tonnes of distillers grain per tonne of alcohol. Since 1986, an anaerobic wastewater treatment facility is in operation in order to treat the 50,000 to 60,000 mg/litre of COD in the distillers grains. At present the methane gas is co-fired in the coal-fired boiler.

Although the distillery had already achieved much in preventing and treating pollution, environmental protection had not been linked with process control before. In order to identify CP opportunities, the distillery therefore participated in the Demonstration Phase of the China CP Project. A plant-level assessment team conducted a CP assessment for the distillery during 1994 under the guidance of the Yantai Environmental Protection Bureau, the Ministry of Light Industry and the Chinese Research Academy of Environmental Sciences.[14]

During the pre-assessment it was found that the alcohol plant is the largest source of wastewater. In addition, several obvious good housekeeping options could be detected in the bottling department. The implementation of these options gave rise to an annual benefit of over 500,000 yuan at an investment of 12,500 yuan. This encouraged the team to proceed with the assessment of the alcohol plant. A number of low-cost technology optimization options had been identified which could be implemented at no extra cost during the annual overhaul period (summer 1994). This created another annual saving of just over 5 million yuan. In addition, three high-cost technology replacement options were identified and evaluated in detail in terms of their technical, economic and environmental aspects. The assessment results at Yantai Second Distillery are summarized in Table 5.

Concluding remarks

The examples of assessment results from selected food processing industries in China and the Netherlands illustrate the opportunities, benefits and constraints of CP. Application of a systematic working method has been crucial in achieving positive results in each of these companies; the CP assessment fostered the transformation of the generally-applicable CP "concept" into practical CP "options" tailored to the company-specific circumstances (such as processes, materials, products, organisation, etc.).

A systematic working method for this CP assessment consists of three separate but interrelated components. Each of these components provides an answer to one of the basic questions in implementing CP at the factory level. The method provides an answer to the question of "how to generate alternate CP opportunities"; the procedure deals with the question of "how to organize the CP tasks within the company" and the guidance provides supervision on the issue of "how to prevent future waste generation". Each of these components might be implemented in different modes and with different intensities, which in turn creates a variety of working methods. Elsewhere, a division has been proposed between:[15]

1) *indicators:* industry-specific questionnaires that use process parameters and operating practices as evaluation tools for estimating the order of magnitude of the environmental as well as economic advantages of the outstanding CP options in a particular company;
2) scan: general checklists applied by a CP consultant to identify the most obvious CP options in a particular company, as well as the environmental "bottlenecks" in the production practices;
3) *pre-assessment:* plant-level audit tool based on overall process flow charts, inventories of input and output material flows, and a qualitative cause evaluation. The option generation is primarily based on the application of "example" CP options;
4) *assessment:* process-level audit tool based on material and energy balances and quantitative source and cause evaluation. Brainstorming among staff members, operators and technicians is an important option-generating tool, supported by the application of "example" options, benchmarking between companies, and technical reviews.

Each of these core working methods has its strengths and weaknesses. The time requirement for a company to undertake an assessment is remarkably higher than undertaking a pre-assessment or only a scan. The amount, as well as the type, of input from a supervisor are also different. So are the expected outcomes, which in case of an assessment might be an inventory of both the obvious and less obvious CP options as well as a contribution to the establishment of a preventive environmental management system and, in case of a scan, might be limited to just an inventory of obvious CP options. These differences call for a careful selection of the working method once a CP project in a particular company or industry sector is started.

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Notes

1. Rent (C.W.M.) van Berkel is Head of the Department of Product and Process Studies at IVAM Environmental Research, University of Amsterdam, PO. Box 18180,lOOl ZB Amsterdam, the Netherlands. Tel. + 31 20 *525 5080*. Fax + 3120 525 5850.
2. See, for instance: Freeman, H., et al., Industrial Pollution Prevention: A Critical Review, *Journal of the Air and Waste Management Association,* vol. 42, no. 5, pp. 618-656,1992.
3. A detailed description of how to derive a material balance in practice can be found in: *Audit and Reduction Manual for Industrial Emissions and Wastes,* UNEP Industry and Environment Office/UNIDO, Technical Report Series No. 7, Paris, 1991.
4. Berkel, R. van (1994) *Comparative Evaluation of Cleaner Production Working Methods,* Paper presented at the First European Roundtable on Cleaner Production Programs, Graz, Austria, October 16-l8, 1994.
5. First used in: Crul, et *al.* (1991), *Afialpreventie:* cursus *voor* ondernemers *(Wasteprevention: training course for entrepreneurs),* National Environmental Centre, Woerden, the Netherlands.
6. *Waste Minimization Opportunity Assessment* Manual, Hazardous Waste Engineering Research Laboratory, US Environmental Protection Agency, Cincinnati, 1988.
7. Such as, for instance, *Facility Pollution Prevention Planning Guide,* Pollution Prevention Research Branch, US Environmental Protection Agency, Cincinnati, 1992; *Minnesota Guide to Pollution Prevention* Planning, Minnesota Office of Technical Assistance, Minneapolis, 1991.
8. See for instance: Berkel, C.W.M. van and J.G.M. Kortman, Waste Prevention in Small and Medium Sized Enterprises, *Journal for* Cleaner *Production,* vol. 1, no. 1, 21-28, 1993.
9. The China Cleaner Production Project is designed and implemented under guidance from the UNEP Cleaner Production Programme and financed through a World Bank Technical Assistance Loan. A project description is included in: Wang Ji, et al., Toward Cleaner Production in China, in *Nature and Resources,* vol. 28, no. 4, 11-16, 1992.
10. Cleaner *Production Audit Report Beijing Brewery,* Beijing Brewery in co-operation with Beijing Environmental Protection Bureau and Chinese Research Academy for Environmental Sciences, Beijing, December 1993.
ll. Buys,J. Innovation *and Intervention* (in Dutch: *Innovatie en interventie),* Kluwer Publishers, Deventer, 1987.
12. Ibid. 8.
13. Berkel, C.W.M. van, Prevention of Waste and Emissions at Nestle Amsterdam, Report II, Part III in *PREPARE Manual and Experiences Document,* Ministry of Economic Affairs, The Hague, the Netherlands, 1991.
14. *Cleaner Production Audit Report Yantai Second Distillery,* Yantai Second Distillery in co-operation with Yantai Environmental Protection Bureau, Ministry of Light Industry and Chinese Research Academy for Environmental Sciences, Yantai, December 1994.
15. Ibid. 3.
16. Berke1, R. van , R. Boesten, D. Huisingh and L. Baas, *Cleaner Production Trainingfor* Cleaner *Production Promoters of the UNEP/ UNIDO National Cleaner Production* Centres, IVAM Environmental Research, Amsterdam, October 1994.
17. Ibid. 10.
18. Ibid. 10.
19. Ibid. 10.
20. Table derived from: Berkel, R. van, Examples of Successful Transitions Towards Industrial Waste Prevention Effected by Industry-University Co-operation, in Mikkanen, R. and S. Poyry, *Conference Proceedings ENTREE: A Development Conference on Environmental Training in Engineering Education,* October 21-25, Laxenburg, Austria, 1991.
21. Ibid. 14.

Cleaner production activities at the Environmental Management institute En Beijing

Ning Duan,Director, Chinese Research Academy of Environmental Sciences,
Beiyuan, Anwai, Beijing 100012, People's Republic of China

Located in Beijing, the Chinese Research Academy of Environmental Sciences is the single largest research and consulting organization in the environmental field in China. The Environmental Management Institute (EMI) of the Academy works on issues of policy, economic analysis, planning, computer software, managerial theories and their applications, and so on in relation to the environment.

One of the major activities EMI has been undertaking in the last two years is the project on "Improving Cleaner Production (CP) in China". Financially the project is supported by the World Bank. Technically and theoretically it is guided by UNEP Industry and Environment.

Together with experts from UNEP IE, EMI conducted 29 CP audits in 27 companies in the World Bank project. In the 27 companies located in 13 industrial sectors, 690 CP options have been identified. Among them, options of product updating account for 2.5 per cent, raw material substitution 6.2 per cent, technology renovation 35.4 per cent, good housekeeping 39.4 per cent, on-site recycling 14.6 per cent, and others 1.9 per cent.

Among the 620 options whose costs can be relatively precisely calculated, non- and low-cost options account for 66.3 per cent, medium-cost options 14.8 per cent, and high-cost options 18.9 per cent. 60 per cent of the 690 CP options have been implemented, including a few medium- and high-cost options. Actual statistics from the 29 audits show a reduction of 30 to 50 per cent of pollutants at the point where the audit was focused. Some companies changed their previous pollution control plans, which were end-of-pipe oriented and demanded huge amounts of capital investment and O/M costs.

Very encouragingly, EMI has been selected by the UNIDO/UNEP joint NCPC programme as a basis for the China National Cleaner Production Centre. The Centre currently considers six fields as its working focus: policy recommendations, information exchange, training and publicity, CP auditing services, establishment of demonstration projects, and dissemination of CP concepts and technologies.