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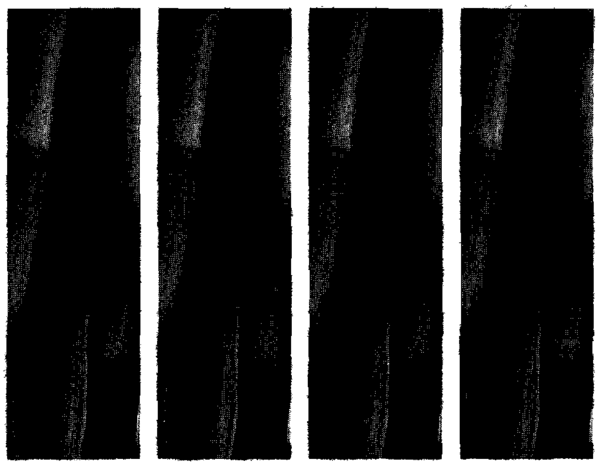
Vol. 1



towards a cleaner industry

An information package on waste minimization and pollution abatement in the cane sugar industry

This information package on waste minimization and pollution abatement in the cane sugar industry was produced, under the direction of Messrs. Sergio Miranda-da-Cruz and Ralph (Skip) Luken, from the Industrial Sectors and Environment Division of the United Nations Industrial Development Organization, based on studies prepared by Mr. Didier Chaux, Ms. Carmen Duran de Bazua and Ms. Marianela Cordoves.

Editor: Marcia Hill
Design/DTP: WorldLinks/Claudia Univazo
Printed in Austria

towards a cleaner and more profitable sugar industry

Vol. 1

An information package on waste minimization and pollution abatement in the cane sugar industry

UNIDO

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Part 1

A programme for minimizing waste and increasing profit

Background

Since 1990, the United Nations Industrial Development Organization (UNIDO) has conducted an extensive, environment-related programme encompassing information and training; and support in the formulation of environmental policies and legislation promoting cleaner, or environmentally-friendly technologies. The program has been specifically designed to increase efficiency and productivity by reducing pollution.

UNIDO has implemented projects for technical assistance to control industrial environmental pollution in the production of fertilisers, pesticides, petrochemicals, paper, cement, metallurgy, electronics, textiles, leather, and agro-industries. Technology transfer is enhanced by the provision of consultancy experts, equipment transfer and training.

Together with the United Nations Environment Programme (UNEP), UNIDO has developed a manual on audits for industrial waste reductions[1]. This manual contains the basic methodology for cleaner production techniques, and is designed to be used by local industries to identify - and implement - waste minimization opportunities.

The **DESIRE** project (**DE**monstration in **S**mall **I**ndustries for **R**educing Wast**E**), funded by the United Nations Development programme (UNDP), was initiated in 1993 after the Indian Ministry of Environment and Forests requested assistance from UNIDO in order to implement their policy on waste minimization. The DESIRE methodology was then successfully applied to four agro-based pulp and paper mills, four textile dyeing and finishing mills and four pesticide formulation plants. Other projects in Egypt and Latin America[2] have proven that these practices can readily be adapted to assist other sub-sectors of industry.

1 Audit and Reduction Manual for Industrial Emissions and Waste — UNIDO Project US/GLO/91/103

2 Demonstration of Cleaner Production Techniques Project US/INT/91/217, 1992-93

The DESIRE project was presented to GEPLACEA (Group of Latin American and Caribbean Sugar Exporting Countries) to illustrate how it could assist the sugarcane industry. GEPLACEA, an organization with 23 member-countries, selected Mexico - and suitable Mexican sugar factories that reflected the industry's problems, and would serve to illustrate possible solutions. The project was then named „Demonstration of Cleaner Production Techniques for the Cane Sugar Agro-industry" (CLEANSUGARTEC).

The concept

The following definitions[3] that were formulated for the DESIRE Project formed the basis of the conceptual approach for CLEANSUGARTEC:

> *"Waste minimization is a new and creative way of thinking about products and the processes that make them. It is achieved by the continuous application of strategies to minimize the generation of waste and emissions through cleaner production techniques" (DESIRE, 1995).*
>
> *"Waste minimization is best practised by reducing the generation of waste at the source itself. After exhausting the source reduction opportunities, in the second step, attempts should be made to recycle the waste within the unit. Finally, modifying or reformulating the product itself may be an option in order to manufacture it with least waste generation"[4].*

Eight approaches to minimizing waste

Waste minimization, an integral part of cleaner production techniques, can be defined using the following eight approaches:

Good housekeeping:

Appropriate provisions to prevent leaks and spills (preventive maintenance schedules and frequent equipment inspections). Enforcement of existing working instructions (proper supervision, training, etc.)

3 Chandak 1995, Durán 1992

4 See Fig. 1: Overview of Waste Minimization Techniques (Chandak 1994)

Input substitution:

Substitution of input materials with less toxic or renewable materials; or by other materials with a longer service lifetime.

Better process control:

Modification of working procedures, machine instructions and process record-keeping to facilitate higher process efficiency and lower the generation of waste and emission.

Equipment modification:

Modification of existing productive equipment and utilities (e.g. by the addition of measuring and controlling devices) to further increase efficiency and lower waste and emission generation rates.

Technology change:

Replacement of the technology, processing sequence, and/or synthesis pathways in order to minimize waste and emission generation during production.

On-site recovery/reuse:

Recycling waste materials either within the process, or by other useful application within the company.

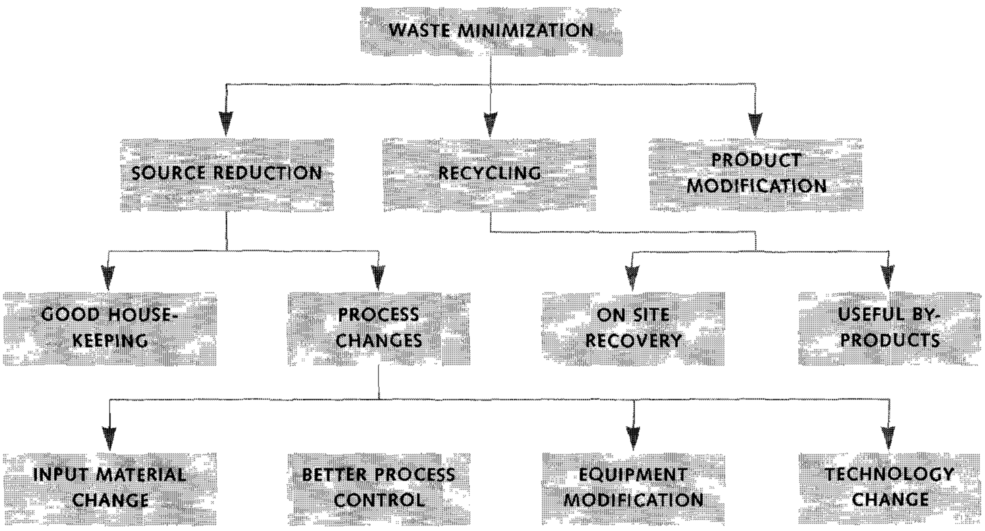
Production of useful by-products:

Transformation of generated waste into material that can be reused – or recycled – for other applications outside the company.

Product modification:

Modification of the product characteristics to minimize their environmental impacts during its use or by its disposal, or to minimize the environmental impacts of its production.

Fig. 1: Overview of Waste Minimization Techniques[5]



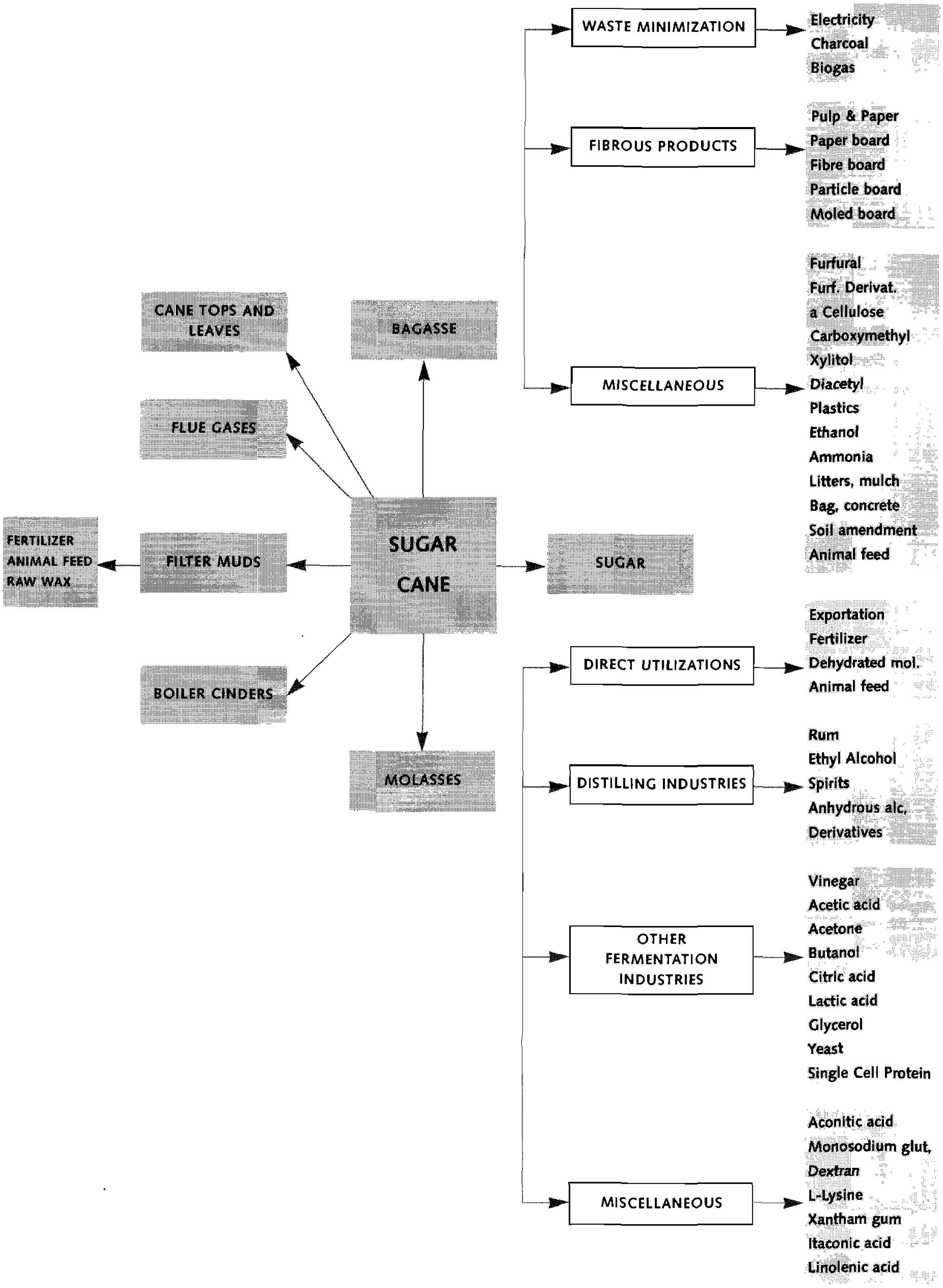
5 Chandak, 1994

Table 1: Examples of waste minimization applicable to the cane sugar agro-industry[6]

1. Good housekeeping	• Repair all leaks • Keep taps closed when not in use • Avoid spillages
2. Input substitution	• Use anti-fouling polymeric coatings in the heat-exchangers tubing inner surfaces, instead of alkaline/acid scale cleaning • Substitute toxic grease in sugarcane mills machinery for one acceptable to the food-administration authorities.
3. Better process control	• Adopt better firing practices in down draught kiln, or in bagasse burners • Install adequate control instrumentation • Maintain process parameters (temperature, pressure, etc.) as close as possible to the desired level using basic minimum instruments
4. Equipment modification	• Install closed circuit condensers for vacuum pans and evaporation station • Use storage tanks of appropriate capacity to avoid overflows
5. Technology change	• Use fully-automated evaporators and/or crystallizers, instead of those manually controlled.
6. On-site recovery/reuse	• Reuse cooling water in the vapor condensing systems of vacuum evaporators by installing cooling towers or cooling pools • Reuse impure condensates as dilution water for imbibition in milling.
7. Production of useful by-products	• Use filter muds, molasses, and bagasse (see Fig. 2) • Use green parts of the plant from cane fields (see Fig. 2) • Use bagasse ash to produce activated carbon for decolorization of sugar syrups
8. Product reformulation or modification	• Use fresh pasteurised cane juice as refreshing drink for school children (instead of artificially flavoured and colored soft drinks) • Manufacture liquid sugars (syrups) instead of powder or crystal sugar for soft-drinks industries

6 Table 1 adapted from Durán de Bazúa, 1992; GEAPLACEA7PNUD, 1990, 1991

Fig. 2 Derivatives of the cane sugar industry



Methodology

Six steps to successful waste minimization:

1. *Getting started*
   Plan and organise a waste minimization audit.
   Create a project team.
   Select the audit focus.

2. *Analyzing process steps*
   Evaluate all unit operations relevant to the selected audit focus.
   Quantify waste generation, how it is created and what it costs.

3. *Generating waste minimization opportunities*
   Identify waste minimization opportunities and make a preliminary selection of those likely to suit the project.

4. *Selecting waste minimization solutions*
   Evaluate the technical and economic feasibility, and the environmental desirability of the waste minimization opportunities in order to select suitable waste minimization solutions.

5. *Implementing waste minimization solutions*
   Implement feasible waste minimization solutions and closely monitor their results.

6. *Sustaining waste minimization*
   Safeguard continuous implementation of the waste minimization solutions and initiate new audits for the remaining waste streams.

Fig. 3: The CLEANSUGARTEC auditing procedure[7]

Interest in waste minimization

Phase 1: **Getting started**

Task 1: Create waste minimization team (audit team)
Task 2: List process steps (unit operations)
Task 3: Identify and select wasteful process steps

Select waste minimization focus

Phase 2: **Analysis of process steps**

Task 4: Prepare process flow chart
Task 5: Make material and, if possible, energy balances
Task 6: Assign costs to waste streams
Task 7: Review process to identify waste causes

List process waste sources and causes

Phase 3: **Generation of waste minimization opportunities**

Task 8: Develop waste minimization opportunities
Task 9: Select workable opportunities

List waste minimization opportunities

Phase 4: **Selection of waste minimization solutions**

Task 10: Assess technical feasibility
Task 11: Assess economic viability
Task 12: Evaluate environmental aspects
Task 13: Select solutions for implementation

List waste minimization solutions

Phase 5: **Implementation of waste minimization solutions**

Task 14: Prepare for implementation
Task 15: Implement waste minimization solutions
Task 16: Monitor and evaluate results

Successfully implemented waste minimization solutions

Phase 6: **Sustaining waste minimization**

Task 17: Sustain waste minimization solutions
Task 18: Identify and select wasteful process steps

On-going waste minimization efforts

7 Figure 3 adapted from Durán de Bazúa and Cordovés, 1995

Implementation

To prepare for the waste minimization audit, the following tasks need to be executed:

1. Getting started

Establish a waste minimization team or audit team.(AT)

The team should consist of representatives from groups within the company that are responsible for different areas. They should also have a major interest in waste minimization. The size and composition of the team should fit the company's organization structure. The team should be capable of identifying potential waste minimization areas, developing solutions and implementing them. Input from both in-house and external experts might be needed.

List process steps or unit operations.

All process steps should be comprehensively listed – including utilities, storage, waste treatment (if one exists) and disposal facilities. This provides a proper overview of the entire manufacturing process. The team should specifically highlight major and obvious waste generating areas and – if possible – identify the reasons for waste generation. In addition, housekeeping and process control practices should be broadly assessed.

Identify and select wasteful process steps.

This can be a preliminary priority-setting activity. Without going into detail, the team should broadly assess all process steps in term of waste: order of magnitude and amounts; severity of impact on the environment; expected waste minimization opportunities; estimated benefits (cost savings) etc. Such preliminary assessments help to focus on one, or a few process steps (audit focuses) for more a detailed analysis.

2. Analyzing the process steps

During this stage, detailed data from selected process steps is collected and evaluated. This information enables waste minimization opportunities to be generated and evaluated in the next phases.

Prepare process flow chart

A detailed flow chart should then be made of the selected process steps in order to identify the sources of waste and emissions. The chart should list and characterize all the input and output streams for every process step. Although it may not be easy to establish a correct process flow diagram, it is crucial for the smooth development of the audit.

Establish material and energy balances

These balances will quantify the process flow diagram and the occurring losses (waste). Later on, these balances can be used to monitor the progress of implementing waste minimization through cleaner production techniques. Given probable lack of records and data on both the composition of input and output material streams, and on complex recycle streams, initially it may only be possible to make a preliminary balance.

Assign costs to waste streams.

To assess the profit potential of waste streams, it is necessary to evaluate the monetary loss they incur. A preliminary estimate can be made by calculating the cost of raw materials and/or intermediate and final products lost along with the waste stream. Examples are sucrose losses during the process – as juice, syrup, and crystal sugar. A more detailed analysis might reveal additional costs, including that of raw materials in waste, manufacturing cost of material in waste, cost of product in waste, cost of treatment of waste, cost of waste disposal, fines due to waste dumping, etc.

Review of process to identify waste causes

This review (or cause analysis) should pinpoint exactly where waste is being generated. A wide variety of possible causes should be considered – including poor housekeeping; operational and maintenance negligence; poor raw material quality; poor layout; inadequate technology or trained staff; and/or lack of employee motivation.

3. Generating waste minimization opportunities

Having identified and assigned causes to waste generation, the audit team can now determine waste minimization opportunities aimed at eliminating these causes.

Develop waste minimization opportunities

Equipped with data, the team now identifies ways to eliminate the cause of waste. Discovering such options largely depends on the team's knowledge and creativity. Techniques like brain-storming and group discussions can be useful motivating forces.

Select workable opportunities

The waste minimization opportunities are now screened in order to eliminate any that are not practical. This elimination process should be simple, fast and straightforward and may often be only qualitative. The remaining opportunities are then subjected to more detailed feasibility studies.

4. Selecting waste minimization solutions

The feasibility of workable waste minimization opportunities must then be evaluated to select the most practical set of solutions.

Assess technical feasibility
The technical evaluation determines whether a proposed waste minimization opportunity will work for the specific application. The evaluation takes into account impacts of the proposed waste minimization on the process, product and production rate. It is also necessary to make an inventory of the necessary technical changes required to implement the waste minimization opportunities.

Assess economic viability
Economic viability will often be the key to evaluating waste minimization opportunities, and priority should be given to suitable low-cost options. These often only require simple analysis, like pay-back calculations. A detailed evaluation of higher cost options should include, if possible, all potential savings (possible savings on raw materials, utilities, energy, increased production and lower operation and maintenance costs). This study may require advanced economic methods (e.g. net present value and/or internal rate of return).

Evaluate environmental aspects
The environmental advantages of waste minimization opportunities are usually obvious. When considering complex options involving changes of raw materials and/or process chemical reactions, care should be taken to assess whether they will, in fact, result in a reduction of toxicity and quantity of waste and emissions.

Select solutions for implementation
Results of the technical, economic, and environmental evaluation are then combined in order to select the most practical and viable solutions. Eventual approval – and funds to implement these measures will be enhanced by providing detailed documentation of the selected solutions.

5. Implementing waste minimization solutions

The selected waste minimization solutions must now implemented. Many, like repairing leaks and enforcing working instructions, can be put into effect as soon as they are identified. Others will require systematic planning.

Prepare for implementation

This stage includes arranging financial resources, establishing task forces and detailed technical preparation and planning. It is important to encourage the involvement of key departments and personnel by good liaison practices and the dissemination of information.

Implement waste minimization solutions

Implementing waste minimization solutions can be compared to any other industrial modification. Simultaneous training of labor is an important factor in optimising the results of implementation.

Monitor and evaluate results

Good record-keeping is essential. Continuous performance evaluation will assess results and identify the causes of deviation. Monitoring and evaluation will also keep personnel informed and sustain their commitment to the application of waste minimization in particular, and cleaner production techniques in general.

Waste minimization objectives

Technical experts considering waste minimization should address the following five objectives:

1. *Establish the potential for waste minimization;*
2. *Offer waste minimization as the solution;*
3. *Provide a set of practical approaches;*
4. *Offer a framework for the implementation of waste minimization;*
5. *Offer a guide to additional assistance.*

Recognising and overcoming constraints

The introduction of successful waste minimization practices into the cane sugar industry may be hampered by certain constraints. The following extract from the DESIRE project suggests how they might be recognised.

> *"The implementation of waste minimization requires a shift in the way environmental factors are dealt with at the company level. Instead of dealing with environmental problems once waste and emissions are generated, a proactive approach should be developed in which environmental concerns are integrated into the design and operation of industrial activity, thereby avoiding waste generation in the first place. International experiences however, show that the development of such proactive*

approaches is hampered by a number of constraints and might be fostered by various incentives. These might be as diverse as conceptual factors (e.g. "resistance to change"), organizational factors (e.g. "inappropriate job division"), economic factors (e.g. "low resource prices"), and technical factors (e.g. "technology gaps to solve waste generating processes")[8]. Some of these factors encourage a company to take a preventive approach, while others inhibit, or even obstruct a company from doing so. One of the goals of the project was therefore to map out this field of influences in order to be able to formulate recommendations for waste minimization".

Seven different types of constraints may be encountered:

1. *Attitude constraints*
2. *System constraints*
3. *Organizational constraints*
4. *Technical constraints*
5. *Economic constraints*
6. *Governmental constraints*
7. *Other constraints*

Each constraint can delay, or even block the waste minimization process and stand in the way of effective implementation of cleaner production techniques. It is therefore essential to set up policies able to tackle as many potential constraints as possible.

The CLEANSUGARTEC project has shown that intensive guidance and company-specific supervision by outside trainer/expert consultants can eliminate a number of these constraints.

Changing attitudes and creating incentives

Fig. 4: Attitude constraints: catalysts and enabling measures.

CATALYSTS	CONSTRAINTS	ENABLING MEASURES
• Early success of waste minimization • Employee involvement in waste minimization	• Indifference towards housekeeping and environmental matters • Lack of professional management skills • Resistance to change	• Encourage experimentation • Publicise early success • Develop simple management indicators

8 OTA, 1986; Dieleman, 1991; Hirshorn, 1991; UNEP, 1994.

Fig. 5: Systemic constraints and incentives

CATALYSTS	CONSTRAINTS	ENABLING MEASURES
• Proper documentation (and planned lay-out) • Proper housekeeping and maintenance provisions	• Low quality production records. Quantity of waste, water and energy used or produced, per unit mass product • Inadequate and ineffective management systems	• Training of plant-level waste minimization team (audit team) • Top-down housekeeping drive • Dissemination of success stories

Fig. 6: Organizational constraints and incentives

CATALYSTS	CONSTRAINTS	ENABLING MEASURES
• Close supervision • Sharing of information (on costs, etc.)	• Concentration of decision-making powers • Emphasis on production • No employee involvement	• Organize a capable project audit team • Recognize efforts to put waste minimization, encompassed in cleaner production techniques into effect • Assign costs to production

Fig. 7: Technical constraints and incentives

CATALYSTS	CONSTRAINTS	ENABLING MEASURES
• Technically skilled staff (in-house research and development) and quality control • In-house fabrication facilities	• Limited technical capabilities • Limited access to technical information • Technology limitations	• Disseminate waste minimization and cleaner production techniques and technologies • Needs-based support for environment-driven research and development

Fig. 8: Economic constraints and incentives

CATALYSTS	CONSTRAINTS	ENABLING MEASURES
• Companies financially-sound • Financially-attractive options	• Prevalence of production quantum over production costs • Resources pricing and availability • *Ad hoc* investment policy • Capital availability and costs	• Proper cost allocation and planned investments • Long term industrial policies • Financial incentives

Fig. 9: Governmental constraints and incentives

CATALYSTS	CONSTRAINTS	ENABLING MEASURES
• Management concern for the environment	• Industrial policies • Environmental policies	• Area-wise, voluntary waste minimization groups • Improvement of environmental legislation and its enforcement

Other factors

Other factors, beyond the influence of industry and government may also have to be considered.

Seasonal variations

The entire sugarcane agro-industry is susceptible to seasonal variations. Most enterprises tend to work in the so-called dry season. As most of the installations are partly open to reduce the problem of high temperatures, this can result in rain damage. Unexpected unseasonal rains can create huge problems, particularly in housekeeping practices.

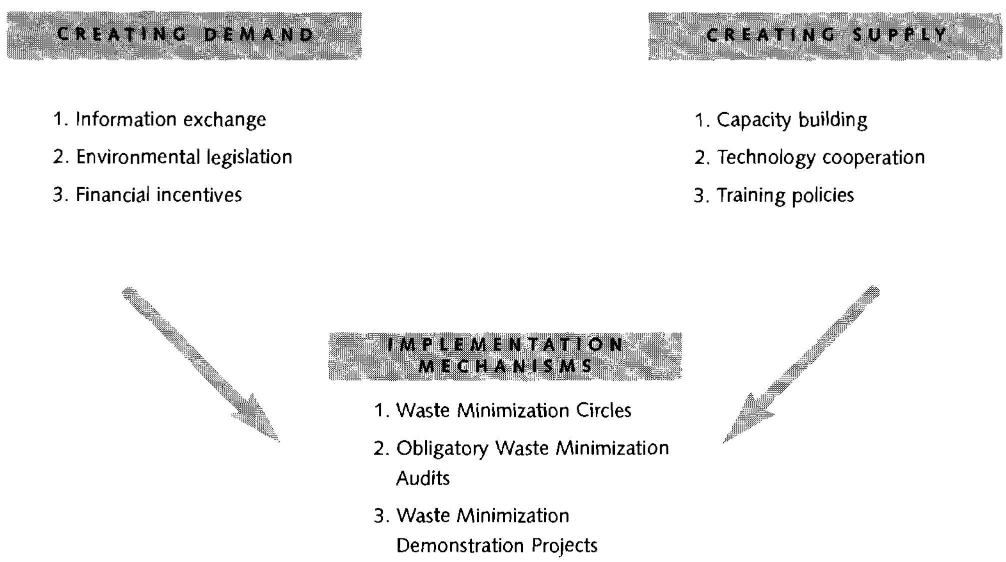
Lack of - or insufficient - public pressure

Entrepreneurs not subject to outside pressures - from non-governmental organizations (NGOs) and the general public – may lack sufficient commitment. To ensure proper enforcement of environmental legislation by governmental agencies, industry needs pressure from both these sources.

Towards and action programme

A policy strategy for waste minimization must now be formulated. The model depicted in Fig.10 may be expanded by contributions from individual companies and industrial and environmental authorities.

Fig. 10: Recommended strategy for promotion and dissemination of waste minimization[9]



Creating demand

The objective is to encourage companies to start waste minimization - by joining a waste minimization circle; by applying for financial benefits based on a completed waste minimization audit; and/or by participating as a demonstration company. Information transfer and awareness-raising are key starting elements.

Information exchange and awareness raising
Public promotion of waste minimization should aim at making industrialists aware of its financial and environmental benefits. It should also encourage them to initiate their own waste minimization experiments within their own factories. A tailor-made communication strategy

9 From DESIRE, 1995

should be developed and implemented, identifying specific target groups within the cane sugar industry. Appropriate messages and communication in the form of manuals, seminars, leaflets, newsletters etc. can then be distributed to these groups. As many are covered by the umbrella of a national chamber, special emphasis should be given to getting the message directly to each company through these channels.

Two goals can be distinguished in the public promotion of waste minimization:

- To build awareness of waste minimization, leading to investigation and implementation of the obvious available options; and
- To achieve long-term organizational change that integrates waste minimization in all functions and activities of industries.[10]

Evaluating why companies have failed to adopt waste minimization is also important. Industrialists may simply lack understanding of the consequences of their present practices – especially regarding total waste costs. They may also fail to understand how waste minimization can be adapted to suit their production. Filling in these information gaps can be a catalyst towards the adoption of waste minimization.

Motivation is also very important, especially as industrialists rarely take a holistic view of their environmental practices. If encouraged to look at the bigger picture, they will realise they can gain efficiency and save money if they practise waste minimization.

Enforcement and improvement of environmental regulations

Indications are that industry often fails to recognise the need to seriously address environmental concerns. Proper enforcement of environmental regulations should assure that companies actually comply with existing environmental regulations, and that they incur the real cost of doing so.

It is essential that environmental agencies also take a holistic approach. Instead of inspecting end-of-pipe provisions, they should become familiar with waste minimization concepts in order to comprehensively evaluate all environmental initiatives. In developed countries with mature environmental enforcement practices, local environmental authorities are often involved in the planning and implementation of waste minimization demonstration projects.[11]

10 WRITAR, 1994
11 van Berkel, 1994

As well as the enforcement of existing environmental regulations, local environmental authorities should analyse opportunities for improving environmental regulations. Waste minimization, as part of implementing cleaner production can benefit from:

- a change from concentration to load-based environmental standards;
- development of regulations for solid, non-hazardous waste and industrial use of ground water;
- a shift from single media to multi-media environmental regulations, covering all environmental concerns (waste water discharges, air emissions, solid waste, hazardous waste etc.); and
- the development of requirements and reporting systems for company environmental managements.

Development of financial incentives

Industrial entrepreneurs may be unconcerned with waste and emission generation problems and excessive resource consumption because the cost is still a minor consideration. Proper resource pricing – especially for fuel, electricity, ground water, cooling water and land – should make adopting effective waste minimization through cleaner production techniques more attractive. Initiatives in investment subsidies and tax benefits for companies adopting these methods will also have a positive effect.

Creating supply

Creating institutional capacity to support companies in waste minimization is an essential supply element. Practical training of waste minimization experts and linking technology development to the needs and capabilities of the cane sugar industry are also vital.

Capacity building

The cane sugar industry still largely relies on outside experts to solve its waste minimization problems. Practical training of experts from small industries, service institutes, professional organizations, industry associations, consultants and technical institutes or universities is also considered important. Because each institution plays a separate role in fostering waste minimization within sugarcane plants, it is necessary to tailor-make different training packages. Industry associations and small-scale service institutes should be trained in communication and out-reaching skills so that they have the capacity to convince entrepreneurs of the need to undertake waste minimization. Consultants and technical institutes should be trained in the technical and methodological aspects of waste minimization. They can then support industries by conducting on-site, waste minimization audits. These future waste minimization experts can be trained in the course of practical company audits, or as part of demonstration or dissemination projects.

Establishment of technology co-operation chain
Limited access to technical information and the technology employed by sugarcane plants can be significant constraints. Both may illustrate a lack of co-operation between end-users and agencies involved in technical development (small industries, service institutes, technical institutes, universities).

In order to fine-tune technical development to suit the needs, capabilities and environmental concerns of the sugarcane industry, part financing of technical research institutes could be allocated to environment-driven, technical development.

Training policies
Most internal training policies tend to be of a general nature, focusing on improving management techniques and enhancing entrepreneurial skills among sugarcane processing plant owners and/or managers. Training policies should be expanded to foster waste minimization skills, giving special attention to new generation personnel. Training should encompass business administration and industrial management in engineering education and professional curricula, as well as practical, on-the-job training. This can be achieved by holding short workshops with practical experts prior to a company dinner or social activity. The seasonal nature of the sugar cane industry lends itself to interaction during shared meals and other out-of-work activities.

Implementation mechanisms

Once external enabling measures have been identified and discussed with appropriate government and industry authorities and representatives, it is necessary to develop implementing mechanisms which can be used by environmental authorities, and which generally support the industry. Examples are:

Waste minimization circles
Support for industries in a given area who voluntarily co-operate by identifying waste minimization opportunities and provide the mechanisms for solving environmental problems.

Obligatory waste minimization audits
Linking the requirement to submit to a waste minimization audit with procedures to obtain financial benefits — sales tax exception, soft loans for investments etc.

Waste minimization demonstration projects
Free-of-charge external assistance to selected establishments in a particular industry sector and/or region in order to demonstrate the potential of waste minimization. Training of waste minimization experts and dissemination of results are integral parts of such demonstration projects. Both

measures ensure that waste minimization skills and practices spread to companies beyond those participating in the demonstration project.

Waste minimization circles and demonstration projects are effective ways of sharing waste minimization experiences. They may contribute to the initiation of environment-driven research and development (R&D) and improve the level of enforcement of existing environmental regulations.

Table 2: Impact of implementation mechanisms on 'external enabling measures'

External enabling measures	Implementation mechanisms		
	Circles	Obligatory Audits	Demonstration Projects
1. Dissemination of success stories.	****	-	**
2. Dissemination of waste minimization techniques and technologies.	**	-	****
3. Needs-based support for environment-driven R&D.	*	*	***
4. Long term industrial policies.	-	***	-
5. Financial incentives.	-	**	-
6. Area-wise, voluntary waste minimization groups.	*****	-	*
7. Enforcement of environmental legislation.	*	*	*

Note:
Number of asterisks indicates the expected contribution of each implementation mechanism to the establishment of the respective external enabling measure.

- * *only indirect contribution*
- *** *direct contribution*
- ***** *targeted contribution*
- \- *no contribution*

Starting conditions

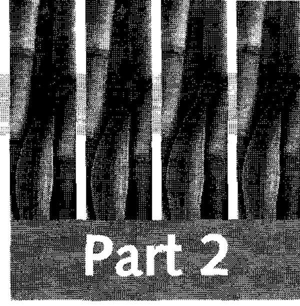
Once a concept for implementation mechanisms has been created, an assessment should be made of how to create the demand for, and supply of, these mechanisms.[12]

Table 3: Key features of waste minimization implementation mechanisms[12]

IMPLEMENTATION MECHANISM	EXPECTED OUTCOME	CONDITIONS	REMARKS
1. Waste Minimization Circle	• Increasing number of companies in region and/or sector starts with waste minimization. • Dissemination and implementation of comparatively-obvious, low- and no- cost options via social mechanisms. • Co-operation between companies for environment-driven technology development.	• Environmentally-conscious industrialists should to take the lead. • *Appropriate technical* and methodological back up. • Establishment of a national network for information exchange. • Funds for support to, and activities of, waste minimization circles.	• CETP (*) boards are probably not the best organizations to start waste minimization circles, given the non-voluntary nature of the CETPs. • Linking suggested between waste minimization circle and a local demonstration project.
2. *Obligatory Waste Minimization Audits*	• *Strong drive for the* implementation of both low and high cost waste minimization options. • Preferential allocation of finances for waste minimization as compared to end-of-pipe control and treatment.	• *Establishment of* provisions for independent quality evaluation for the approval of the waste minimization audits submitted by industry. • Agreement with industrial authorities on financial schemes to be used to this end.	• Impact depends heavily on the selection of the financial schemes that will be subjected to obligatory audits. • Only effective for the organized sector.
3. Waste Minimization Demonstration Projects	• Convincing company-level examples of the implementation of waste minimization. • Inventory of practical waste minimization opportunities for dissemination to other companies. • Training of experts and institutional capacity building for waste minimization.	• Willingness of companies to act as demonstration units. • *Interest of industry* associations, professional organizations and/or technical research institutes to become involved in the dissemination of results. • Funds for providing subsidised waste minimization consultancy to the demonstration companies.	• Demonstration projects can be used to catalyse the establishment of a *waste minimization* circle. • A recommendation to explore opportunities for participation of local environmental authorities in the demonstration projects can be useful.

*CETP: a group of companies operating a common effluent treatment plant

12 from DESIRE 1995



Part 2

The sugar industrial sector in Mexico (a case study)

Industry profile

Sugar production:	4,758,000 tonnes (1995-96)
Sugar exports:	450 tonnes (1995-96);
Sugar imports:	50 tonnes (1995-96)
Sugar consumption per head of population:	47.4 kg. (1995)
Number of factories:	about 70 - processing daily between 3,000 and 15,000 tonnes of cane
Harvesting season:	end of November to end of April (130 to 150 days)

Project objectives

The project objectives of CLEANSUGARTEC were to demonstrate the environmental and financial benefits of waste minimization to environmental management within the Mexican sugarcane industry. The project has designed and tested a methodology to minimize waste and to introduce the concept of clean technology.

Project goals

- To illustrate to Mexican sugarcane industry owners and managers that waste minimization - and the subsequent implementation of cleaner technologies - are possible in the short term, and do result in financial and environmental advantages;

- To devise and test the usefulness of a systematic (assessment or audit) approach to waste minimization through cleaner production techniques;

- To identify obstacles to the introduction of waste minimization encompassed in cleaner production techniques, and to formulate strategies to overcome them;

- To formulate policy recommendations for the promotion of cleaner production techniques - with its consequent waste minimization; to enhance its implementation within other industrial branches through governmental authorities; the sugarcane industry sector through its chamber; and into the professional community through technical and professional associations (Association of Mexican Sugarcane Professionals, ATAM; Mexican Institute of Chemical Engineers, IMIQ, etc.)[13]; and further

- To disseminate the results of case studies and proposed policy recommendations by means of a written report, seminars and workshops.

The approach

The overall approach follows the strategy and methodology of the DESIRE system as set out in the earlier guidelines (Part 1: this manual).

Work plan

Planning and activities undertaken in Project CLEANSUGARTEC are summarised in Table 4. At the project level, the organization of the sectorial introduction, review workshops and experts reviews have been crucial to the success of the demonstration project.

The programs of the sectorial review workshops included:

- Presentation of the company-level achievements (by company representatives);
- Summary of sector-level achievements (by Group of Latin American and Caribbean Sugar Exporting Countries National Expert - GEPLACEA E/NE);
- General comments on organization of waste minimization activity in companies by responsible audit teams - ATR);
- General comments on technical content of company achievements (by National Expert/responsible audit team - NE/ATR; and

13 In December 1995, a cooperation agreement between UNIDO and the National Polytechnical Institute was signed to create a Mexican Center for Cleaner Production (NCPC),

- General comments on methodological aspects of company assessments (by Group of Latin American and Caribbean Sugar Exporting Countries Expert. - GEPLACEA/E)

Table 4: Work plan for the CLEANSUGARTEC project

PROJECT PHASE	TIME	ACTIVITIES
Preparation	CNIIAA[14]; 6/92 8/92 10/92	• Establishing working relationships with industry associations and professional institutes • Collection and evaluation of preliminary data. • Obtaining interest from companies to participate
Sectorial introduction workshop	26/10/92 2-12/11/92	• Introduction to waste minimization concept, working methodology and obvious options • Company visits. Planning by International Experts and National Experts (IE &NE) to boost commitment and involvement, and to provide initial on-site guidance
Company Pre-Assessment Work	21-26/1/93 26-29/3/93 11-12/4/93 6-8/5/93	• Technical visits of IE/NE to the participating plants forming the audit teams (AT), with the authorities designating the audit team responsible person in each company (ATR) • Analysing and evaluating data by NE with AT, and compiling available information to produce theoretical material balances and evaluate feasibility of first batch of options
Sectorial Review Workshop	1/6 to 31/8/93 CNIIAA; 9/93 11/93	• Review of preliminary waste minimization experiences by IE/NE • Preparation of draft CLEANSUGARTEC general waste minimization document (covering activities from 10/92 to 9/93, and the PROJECT REPORT, from 11/93 to 9/94)
Company Assessment Work	11/94 to 5/95 6/95 to 11/95 11/95	• Two to four visits by GEPLACEA E/NE team to generate and evaluate additional waste minimization options and to evaluate progress in implementation of these options (and complementary real measurements in situ by IMIT personnel) • Completion of the CLEANSUGARTEC general waste minimization documents • Completion of the barriers and incentives survey
Implementation period	6/95 to 11/95 10 to 11/95 12/95 to 5/96	• Final evaluation of the companies achievements by GEPLACEA E/NE/AT • Preparation of draft sectorial technical waste minimization documents • Ongoing implementation activities in the companies
Dissemination workshops	9/93, 10/93, 8/94 3/95	• Sectorial workshops • International Seminar • Preparation of policy recommendations
Reporting	6/95 to 11/95 12/95	• Preparation of draft final report • Completion of the sectorial technical waste minimization documents

14 National Chamber of the Sugarcane/Ethanol Industries.

Project organization

A project of such magnitude and complexity can only be successful with the active involvement of various institutions. In the case of CLEANSUGARTEC these were:

- Governmental organizations:
  Group of Latin American and the Caribbean Sugar Exporting Countries (GEPLACEA) – representatives from 24 member countries; regional government representatives; and for the period June 1994 to April 1995, the Mexican Institute for Technical Research (IMIT).

- Industry Association:
  Mexican National Chamber of the Sugarcane/Ethanol Industries (CNIIAA).

- Participating sugarcane companies:
  Grupo Beta San Miguel (San Francisco Ameca Mill); Grupo Machado (Central Motzorongo Mill); Grupo XAFRA - from 1992 to 1993; and Grupo CAZE (El Potrero Mill) - from 1994 to the present time.

- Technical associations:
  Association of Mexican Sugarcane Professionals, (ATAM); and Mexican Institute of Chemical Engineers, (IMIQ).

- Research and teaching organizations:
  Mexican National Autonomous University of Mexico (UNAM); Mexican National Polytechnic Institute (IPN).

In addition, UNIDO took responsibility for the overall project management and provided the national expert for the entire duration of the project. UNIDO also supported travelling expenses for the GEPLACEA expert during the second year activities (June to December 1994). In the first five months of the project (October 1992 to February 1993), UNIDO provided an international expert.

The project, its structure, planning and organization, were carried out in joint consultation by UNIDO and GEPLACEA.

The Project Management Board consisted of:

- UNIDO senior environmental expert (National Expert, NE);

- A representative of GEPLACEA (Assistant Secretary);

- A sugarcane industry international expert from GEPLACEA (GEPLACEA Expert, GEPLACEA E); and
- The responsible audit teams (one ATR for each participating company).

In addition, UNIDO officials from Vienna and Mexico City provided active support.

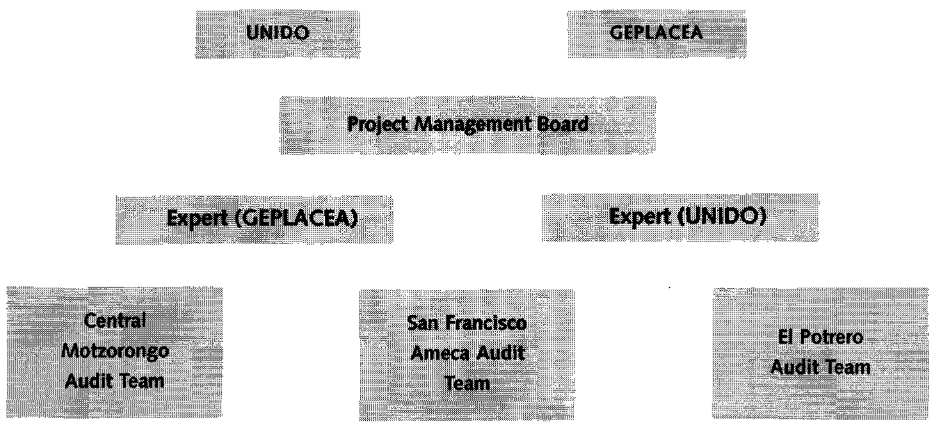


Fig. 11: Organizational Structure of CLEANSUGARTEC

Systematic auditing method for companies

The implementation network

Consultants from UNIDO and GEPLACEA - together with personnel from each plant - conducted a waste minimization assessment/environmental audit. International methodology and industrial sector experts provided parallel guidance both during periodic visits to the plants, and from a distance. To identify the key barriers and incentives for waste minimization through the implementation of cleaner production techniques, GEPLACEA and the Mexican National Chamber of the Sugarcane and Ethanol Industries (CNIIAA) also monitored the assessments.

The results of the demonstration project have been disseminated using two different approaches. First, at the industry sector level though the CNIIAA, and in close co-operation with GEPLACEA and the government. This took the form of industry-specific workshops, and the preparation of simple, Spanish-language technical articles published in journals and proceedings that are accessible to all owners and personnel. Second, information targeted at industrial and environmental authorities has been disseminated at the general level, also in close co-operation with GEPLACEA and CNIIAA. Others invited to participate were: The Mexican National Water Commission Authorities (CNA); the Mexican Federal Environmental Protection Agency professional and technical staff (PROFEPA); and the Mexican Environmental Protection National Institute personnel (INE). The latter is responsible for composing laws and regulations to be presented to the legislative federal bodies.

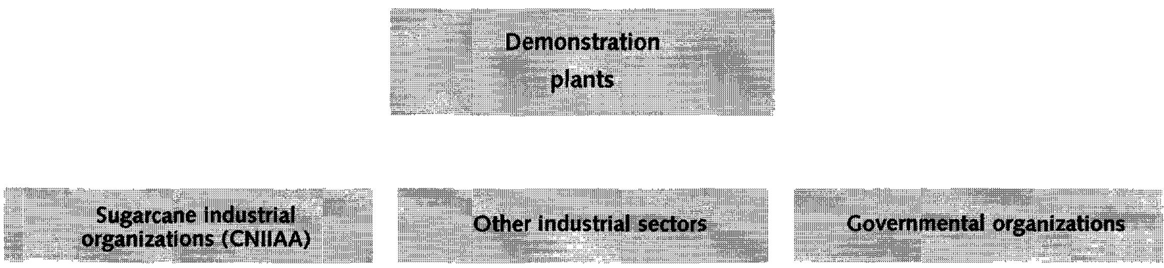


Fig. 12: CLEANSUGARTEC approach to information dissemination

General document guide

Under previous projects, a general Spanish-language, waste minimization document guide[15] was developed for the Mexican sugarcane agro-industry. The concept was to create an attractive introduction to waste minimization, explain its potential and to set out the conditions for its implementation at the factory level. It includes a short description of the systematic working method and its application to the project.

The guide has essentially been created for the benefit of company managers and/or owners. It aims at awakening their interest in cleaner production techniques through waste minimization so they develop the "DESIRE" to experiment in their own plants. The guide stresses the potential financial benefits of waste minimization and, as a second consideration, details auditing procedure details. Actual examples from the three companies under study have been cited to illustrate to company managers and/or owners that they are not alone in experimenting with waste minimization.

The guide sets down the following waste minimization aims:

- Attracting *attention* to waste minimization;
- Establishing the *need* for waste minimization;

15 Durán de Bazúa and Rosales, 1994

- Offering waste minimization as the *solution*;
- Offering a *framework for the implementation* of waste minimization;
- Providing a guide to *additional assistance*.

The document can be read in about one hour and includes examples and illustrations. The contents are summarized in Fig. 13.[16]

DEMONSTRATION OF CLEANER PRODUCTION TECHNIQUES FOR THE CANE SUGAR AGRO-INDUSTRY

Chapter 1: Sugar (money) down your drain
An attractive introduction based on the previous sugarcane industry case study. illustrates how this particular company was unaware how much money was lost through waste and emissions, or how these could be converted into extra profits.

Chapter 2: Or even more!
Explanation and illustration of additional benefits - e.g. improved working environment, quality enhancement, image, compliance and new market opportunities.

Chapter 3: Waste minimization gets it
Explanation of the waste minimization concept and how to approach it, citing industry examples. The essential conditions for waste minimization are summarized - management commitment, involvement of operators and an organized approach.

Chapter 4: Let's do it
A step-by-step summary of the essentials of waste minimization. The explanation of this systematic auditing procedure runs parallel to a case history in which it has been successfully applied.

Chapter 5: Just in case
A list of useful documentations and contacts for additional assistance.

Fig. 13: Summary of the contents of the General Waste Minimization Guide

16 Ibid

Practical auditing procedures

The practical auditing procedures are divided into six stages:

- Check list to identify obvious lapses in housekeeping, process control and maintenance, and to generate no- and low cost solutions to eliminate these lapses (first stage: initiation);

- Conceptual explanation of the option generation process. Waste generation causes and waste minimization opportunities must be classified into logical groups of 'problems' and 'solutions'; second stage: analysis of process unit operations; third stage: generating waste minimization opportunities);

- Suggestions for performance indicators. This should include possible performance indicators, together with suggested applications (type of options for which these might be applied; fourth stage: selection of waste minimization opportunities); monitoring provisions (fifth stage: implementation of waste minimization solutions); and

- Suggestions for employee reward and/or recognition schemes in order to sustain employee involvement in the on-going implementation of waste minimization solutions. (sixth stage: maintaining waste minimization and implementation of cleaner production techniques)

Table 5: Practical auditing method experiences.[17]

FIRST STAGE: INITIATION

Audit tasks	Bottlenecks encountered	Supervisory tasks	Suggested improvements (*)
• Form the audit teams	• Industrial plants are not used to systematic project work	• Assist in team building; instruction in data evaluation and problem solving approaches	• Inclusion of check lists with frequently occurring poor housekeeping practices and generally applicable low and no- cost waste minimization opportunities
• List process unit operations	• Lack of good housekeeping attitudes hampers identification of obvious lapses in process control, maintenance, etc.	• Pinpoint to obvious lapses in housekeeping; check completeness of list of process unit operations	
• Identify and select wasteful process unit operations steps	• Tendency exists to overlook excessive use of 'cheap' resources like water, grease, etc.	• Support priority setting; advocate implementation of obvious no- and low-cost opportunities	

(*) See some examples of suggested improvements in Table 1, Part One

17 Adapted from the DESIRE project, 1995

SECOND STAGE: ANALYSIS OF PROCESS UNIT OPERATIONS STEPS

Audit tasks	Bottlenecks encountered	Supervisory tasks	Suggested improvements (*)
• Prepare process flow chart	• Unplanned development and extension of facilities hampers preparation of correct flow chart	• On-the-spot verification of flow charts	• Improve conceptual explanation of waste minimization within cleaner production techniques. The checklist of possible waste generation causes should fit the available set of applicable waste minimization techniques
• Make material balance	• Lack of sufficiently detailed data; lack of monitoring equipment.	• Assist in data collection and evaluation; supply necessary equipment. Emphasise first-instance monetary losses (raw materials, product, and/or manufacturing cost).	
• Assign costs to waste streams (water)	Resistance to include environmental costs		
• Review of process to identify waste causes	• Lack of skills and experiences to evaluate processes	• Participate in process evaluation; question process details with operators and supervisors	

(*) See some examples of suggested improvements in Table 1, Part One

THIRD STAGE: GENERATING WASTE MINIMIZATION OPPORTUNITIES

Audit tasks	Bottlenecks encountered	Supervisory tasks	Suggested improvements (*)
• Develop waste minimization opportunities	• Difficult to create right environment for workers, technicians and supervisors to contribute to creative problem-solving	• Participate in option generation session; challenge workers, technicians and supervisors to share experiences; systematic evaluation of all waste generation causes.	• None (with only one company exception, directing the application to water saving, confinement of spills, and water reuse)
• Select workable opportunities	• None	• Check whether 'acceptable' criteria and arguments are used	

(*) See some examples of suggested improvements in Table 1, Part One

FOURTH STAGE: SELECTION OF WASTE MINIMIZATION OPPORTUNITIES

Audit tasks	Bottlenecks encountered	Supervisory tasks	Suggested improvements (*)
• Assess technical feasibility	• Non availability of engineering details to elaborate equipment-related options	• Support the technical evaluation; identify technical know-how and suppliers	• None (with only one company exception, looking for some quotations and evaluating costs of equipment versus water savings)
• Assess economic viability	• Tendency to limit analysis to short term, direct savings (under-estimation of benefits)	• Contribute to 'reasonable' quantification of less obvious financial benefits	
• Evaluate environmental aspects.	• None (except water, due to regulations)	• Broadly verify figures	
• Select solutions for implementation	• Tendency to set a priority on low cost options, regardless of inferior technical and/or economic performance	• Check consistency of the selection with outcome of feasibility studies	

(*) See some examples of suggested improvements in Table 1, Part One

FIFTH STAGE: IMPLEMENTATION OF WASTE MINIMIZATION SOLUTIONS

Audit tasks	Bottlenecks encountered	Supervisory tasks	Suggested improvements (*)
• Prepare for implementation	• Most solutions require minimal investments enabling almost immediate implementation	• Assist in seeking support and funds for implementation	• Include suggestions for performance indicators for monitoring waste minimization progress
• Implement waste minimization solutions	• Instruction of personnel not always seriously addressed	• Pinpoint to, and illustrate need for, proper instruction of employees	
• Monitor and evaluate results	• Lack of simple performance indicators	• Suggest appropriate, easy to monitor, performance indicators	

(*) See some examples of suggested improvements in Table 1, Part One

SIXTH STAGE: MAINTAINING WASTE MINIMIZATION AND IMPLEMENTING CLEANER PRODUCTION TECHNIQUES

Audit tasks	Bottlenecks encountered	Supervisory tasks	Suggested improvements (*)
• Sustain waste minimization solutions	• No experience gained in CLEANSUGARTEC project	•Advise on appropriate reward and/or recognition systems	• Include suggestions for simple, but effective, employee reward and recognition opportunities
• Identify and select wasteful operations	• No experience gained in CLEANSUGARTEC project	• Assist in the selection of audit focus for second waste minimization audit	

(*) See some examples of suggested improvements in Table 1, Part One

Demonstration of economic and environmental dividends in three separate companies

Basic considerations for selection

For the purpose of the demonstration, the cane sugar industrial sector was divided into three types of activities. In each case a company was selected as representative of a specific sub-sector:

Plants that produce standard or plantation white sugar without recycling long fibre bagasse or molasses:

These plants burn all the bagasse to produce steam and electricity. There are no second systems of evaporation and crystallization units, since the sugar produced – although not very white – is acceptable to consumers. To avoid discoloration and browning reactions (through the activation of naturally occurring enzymes that promote the formation of darkening compounds in the juice) a sulphitation unit is added before the cane juice is clarified. If an energy balance is conducted on these plants, it shows that most of them tend to misuse energy. Thermodynamically, there should be a surplus of energy when bagasse is correctly burned, as no energy is required for sugar refination.

San Francisco Ameca plant was selected as representative of this type of activity

Plants that produce standard, or plantation white sugar, with recycling of long fibre bagasse or molasses

In these plants bagasse is depithed by removing the soft centre tissue of the cane stems. The depithed pulp can be used for making soft or hard building board, and for paper production by a technology known as the sulphitation process. The pith is used as boiler fuel for generating the production of steam and electricity. Since the long fibre is sold to a paper factory, additional fossil fuels are used to complement energy needs. An energy balance may reveal the need for additional, fossil fuel energy - especially if low-pressure boilers are used.

Central Motzorongo plant was selected as representative of this type of activity.

Plants that produce refined white sugar, and which recycle long fibre bagasse and molasses to produce ethanol or cane alcohol

In this type of plant, the bagasse is depithed by removing the soft centre tissue of the cane stems. The depithed pulp is used for making soft or hard building board and paper production by the so-called sulphitation process. The pith is used as boiler fuel for generating the production of steam and electricity. There are second systems of evaporation and crystallization units which produce refined (white) sugar. An energy balance may show that there is an additional need for energy to be provided by fossil fuels.

El Potrero plant was selected as representative of this type of activity.

San Francisco Ameca plant

The San Francisco Ameca mill is located in the town of Ameca, in the State of Jalisco, Mexico. It can process up to 4,800 tonnes of sugarcane and produce about 500 tonnes of standard sugar every 24 hours. During the first year of the UNIDO project (1993-1994), a global assessment of the mill was carried out, estimating water consumption, possible dissolved pollutants, generation of solid residues, air pollution and other problems that reduce the overall quality and contribute to environmental pollution. In this second phase of the project (1995-1996), data concerning the use and quality of water and the generation of waste water within the plant was collected and analysed .

Technical solutions that were economically feasible for the mill, and that allowed a cleaner and more efficient operation, were carried out in the last maintenance period (1994).

These involved:

- Segregation of sanitary sewage from process waste water sewage lines, and cooling and recycling of the condensing water in a cooling pool;
- Recycling wash water used in chimney cleaning to remove flying ash;
- A mill-designed system to cool and recycle water used in the cane receiving (batey) and mill areas;
- Building of confined areas for all equipment prone to overflowing, thus avoiding the discharge of fluids containing sugar (or oil or grease) into the drains;
- The installation of hygienic floors to improve cleanliness. (Due consideration was given to the fact that this enterprise produces food for human consumption.);
- Building of multi-purpose modules for workers and engineers (with hygienic installations); and
- The controlled disposal of sanitary-type waste waters.

The original technical audit team was made up of one UNIDO international consultant (for the first four months); one UNIDO national consultant and one GEPLACEA international consultant, plus the in-house team: general manager; unit operations managers or superintendents and the workers. In co-operation with the technical audit team, about 10 waste minimization options were generated and evaluated. The most successful options are summarized in Table 6.

At the end of the 15 months co-operation period, the project CLEANSUGARTEC (allowing about five months for each *zafra*[18] period in 1992-93, 1993-94, and 1994-95), San Francisco Ameca has succeeded in implementing seven feasible options. Another three options proved feasible - one is already being implemented; the two others are yet to be acted upon. Finally, three minimization options were rejected, given their limited technical and/or economic viability. The implementation of the first batch of feasible waste minimization options required an investment of US$1,700,000 and generated net annual savings of US$780,000. The overall pay back at San Francisco Ameca company was therefore about two years. The overall environmental impact included a drastic reduction in the comsumption of fresh water. That in turn created additional savings on effluent disposal fines and costs.

18 Harvesting period

19 See Booklet II: Pollution Prevention and Abatement Guidelines for Cane Sugar Processing and Refining, incorporting extract from Pollution Prevention and Abatement Handbook - Part II (World Bank)

Table 6: Most successful options at San Francisco Ameca company

WASTE MINIMIZATION MEASURE	ECONOMIC VIABILITY	ENVIRONMENTAL IMPACT	REMARKS
1. Segregation of sanitary sewage from process waste waters sewage lines by construction of special "social" modules (these include staff meal tables, toilets, hand wash-basins and drinking water facilities) and further discharging of waste water into municipal sewage	I=US$200,000 S = 0 P = 0	Reduction in both coliforms and eventual danger of cholera epidemics	None
2. Construction of a cooling spray pond for the cooling and recycling of condensing water in evaporation and crystallization sections	I=US$1,100,000 S=US$1,200,000 P < 1 year	Considerable reduction in volumetric flow	TSS and COD are not reduced
3. Construction of a system to recycle wash water used in stacks to remove flying ash.	I=US$100,000 S = 0 P = 0	Reduction in volumetric flow	Care has to be taken for pH and TSS
4. Controlled disposal of solids precipitated in the circular tank used for storage of heat surfaces acid and alkaline wash water	I= Already built S = 0 P = 0	Reduction in electric conductivity of effluents	Care has to taken to keep track of the confined area.
5. Construction of spills confinement units in target equipment	I=US$100,000 S=US$30,000 P < 4 years	Reduction in COD, BOD and TSS	Good housekeeping measures
6. Changing of floors characteristics to make them more hygienic	I=US$100,000 S=US$30,000 P < 4 years	Reduction in COD, BOD and TSS	Good housekeeping measures
7. Construction of a cooling system for water sent to batey and mill sections equipment	I=US$100,000 S=US$30,000 P < 4 years	Reduction in volumetric flow	Care has to be taken for pH and TSS
8. Construction of a degreasing unit for waste water from batey and mills sections	Not yet finished	Reduction in grease and oil	Good housekeeping measures
9. Construction of a waste water treatment unit for sanitary liquid waste	Not yet started	Reduction coliforms, BOD and COD	None
10. Improvements in steam use (co-generation)	Not yet started	Reduction in energy costs	None

I = Investment
S = Net savings (after deduction of annual operating costs)
P = Pay back period

General composition of the supply water and generated waste water is presented in Table 7. According to most parameters, it can be seen that discharged waste water does not comply with Mexican norms, and even less with World Bank recommendations.[19]

Table 7: Characteristics of water supply and generated waste water (Including standards imposed by the Mexican National Water Commission)

CHARACTERISTICS	SUPPLY WATER (AMECA RIVER)	PROCESS WATER	CONDENSERS WATER	MILLS AND BATEY WASTE WATER	EXIT WASTE-WATER *	NORMS FOR WASTE WATER
Volumetric flow, L/s	1,000.0 (65.0*)	30.0	700.0	15.0	60.0	-
pH	7.4	4.4	7.6	5.95	5.6	6 to 9
Temperature,°C	17.3	37.3	32.6	28.0	25.9	4°C above the normal temperature
Settleable solids, mL/L	0.3	40.0	less than 0.1	1.7	4.0	1.0
Total suspended solids, mg/L	30.0	517.0	74.0	83.0	40.0	200.0
Electric conductivity, micromho/ cm	559.0	4,350.0	785.0	684.0	883.0	2,000.0
Grease and oils, mg/L	35.0	91.5	40.0	48.5	36.5	10.0
Total coliforms, MPN/100 mL (E*-6)	24.0	0.024	2.4	46.0	15.0	0.01
Floating matter, g/L	0	0	0	0	0	0
Dissolved chemical oxygen demand, mg/L	155.0	70,000	1,780	2,700	5,950	260
Dissolved biochemical oxygen demand in five days and 20°C, mg/L	101.0	4,550	1,160	1,755	3,868	200.0
Phosphate, mg/L	-	-	-	-	-	5.0
Phenols, mg/L	-	-	-	-	-	0.5
Nitrogen total, mg/L	-	-	-	-	–	10.0
Arsenic, mg/L	0.1	Negative	Negative	Negative	0.1	-
Lead, mg/L	0.5	Negative	Negative	Negative	0.4	-
Copper, mg/L	0.03	Negative	Negative	Negative	0.28	-

* After water saving measures have been taken

** *Norma Oficial Mexicana NOM-002-ECOL-1993*

After the implementation of waste minimization measures incorporated within cleaner production techniques, the San Francisco Ameca Plant reduced water consumption by about 95% - from 111 cubic meters per tonne of produced sugar, to only seven cubic meters per tonne. There was also a reduction of about 20% of the pollution load.

Central Motzorongo plant

The Ingenio Central Motozorongo sugarcane mill is located in the State of Veracruz. The factory, built at the end of the last century, is situated - typically for the time of construction - along a river bank. It has been modernised, developed and grown into an enterprise producing crystalline standard sugar.

Over the years, waste water, undesirable by-products and residues were never considered in terms of financial losses. Nor were they linked to possible inefficiency. As a result, simple moves - like segregation of sewage lines - were not even considered. This situation was forced to change when, in 1988, the Act for Environmental Protection and Ecological Balance came into force, creating a ministry (SEDUE) and setting standards for liquid discharges from sugarcane mills.

Except in the reuse of long fibre bagasse, the process steps in the Central Motzorongo and San Francisco Ameca sugar mills is basically identical. Central Motzorongo does, however, have a different geographic setting and this determines a completely different approach to waste minimization and the implementation of cleaner production techniques.

The original technical audit team consisted of one UNIDO international consultant (for the first four months), one UNIDO consultant and one GEPLACEA consultant, plus technical staff (general director, general manager, controller, technical director, laboratory head, environmental control supervisor, manufacturing superintendent, machinery superintendent, electricity superintendent and boilers head.

This area is also characterised by tropical rain conditions which create additional operational problems. (The harvest is carried out in the so-called dry season). These conditions preclude the use of some possible options (e.g. open tanks to evaporate alkaline/acid waste waters resulting in a low volume solid residue) that were successfully implemented at San Francisco Ameca.

The technical audit team generated and evaluated several waste minimization options, the most successful of which are summarized in Table 8. After 15 months co-operation in the DEMCLEANPROTECANE project (allowing about five months for each harvest period, 1992-93, 1993-94, and 1994-95), Central Motzorongo has isolated eight waste minimization options. Four are already implemented, two are in the process of being implemented and two more have not yet commenced (full implementation has been hampered by the plant's severe financial problems). Another six were rejected because of their limited technical and/or economic viability.

Table 8: Most successful options at Central Motzorongo company

WASTE MINIMIZATION MEASURE	ECONOMIC VIABILITY	ENVIRONMENTAL IMPACT	REMARKS
1. Remodelling of a cooling spray pond for the cooling and recycling of condensing water in evaporation and crystallization sections	I=US$60,000 S=US$60,000 P = 1 year	Considerable reduction in volumetric flow	TSS and COD are not reduced
2. Conditioning of the existing activated sludge waste water treatment plant to separate pri mary suspended solids (sending them to cane fields); addition of an anaerobic upflow sludge blanket reactor to reduce biological aerobic solids volume	I=US$55,000 S = US$30,000 P < 2 years	Reduction in TSS of effluents sent to river	Care has to be taken to monitor the confined area and operation of the plant (avoiding spills)
3. Conditioning and automation of evaporation domes vapours separation to avoid entrain ment and contamination of condensates	I=US$340,000 S=US$400,000 P < 1 year	Reduction in energy consumption, by recycling condensates to boilers	Good housekeeping measures
4. Changing of pipelines to use the heat contai ned in boiler purges to increase juice tempe ature	I=US$10,000 S=US$10,000 P = 1 year	Reduction in energy consumption	Good housekeeping measures
5 Construction of a cooling system for water sent to batey and mill sections equipment	I=US$160,000 S=US$30,000 P < 3 years (80% advanced)	Reduction in volumetric flow	Care has to be taken for pH and TSS
6. Construction of a pumping system to recycle rain water to the cooling spray pond	I=US$40,000 S = 0 P = 0 (5% advanced)	Reduction in floods during winter rains to avoid operation problems	None
7 .Construction of a sanitary waste water sewage line separated from process lines, to transport sanitary effluents to the biological treatment plant	Not yet started	Reduction in coliforms, BOD, and COD	None
8. Construction of a system to recover alkali ne/acid wash waters to avoid it being dumped in the cooling spray pond	Not yet started	Reduction in TSS, COD, and BOD	Care of increasing dissolved ions concentration

I = Investment
S = Net savings (after deduction of annual operating costs)
P = Pay back period

El Potrero plant

The El Potrero mill is located at about 20 km north-east of Córdoba, Veracruz, Mexico and can process up to 11,000 tonnes of sugarcane, producing about 1,400 tonnes of refined sugar every 24 hours. The mill also produces between four and six million litres of ethanol per year. During the first year of the UNIDO project (1993-1994), a global assessment of the mill was carried out estimating water consumption and possible dissolved pollutants, generation of solid residues, air pollution and other problems that reduce quality and contribute to environmental pollution. In the second phase (1995-1996), data on water use, quality and waste water generation were collected and analysed. The result has been to propose technically and financially viable solutions for better efficiency and a cleaner concept.

The in-house team (general manager, unit operations managers or superintendents and the workers) and the technical audit team have generated and evaluated about 15 waste minimization options. At the end of 15 months co-operation in the CLEANSUGARTEC project (five months for each operational season, 1992-93, 1993-94, and 1994-95), El Potrero had not been able to implement any options due to a complicated process of privatization of government-owned sugar mills. The enterprise has already had two different owners, and as most of the options require some financial input, decisions concerning their implementation have been delayed.

Suggested waste minimization measures:

1. Installation of a cooling spray pond or a cooling tower system for the cooling and recycling of condensing water in evaporation and crystallization sections.
   ** The environmental impact will be to considerably reduce the volumeric flow.*

2. Installation of a biological waste water treatment plant for all process effluents in order to separate primary suspended solids (these are to be returned to the cane fields using anaerobic upflow sludge blanket reactors); to reduce the generation of biological solids; and to produce biogas, useful for energy consumption in the ethanol plant.
   ** The environmental impact will be a reduction in TSS of effluents sent to the river.*

3. Conditioning and automation of evaporation domes vapours separation to avoid entrainment and contamination of condensates.
   ** The environmental impact will be to reduce energy consumption by recycling condensates to the boilers.*

4. Construction of a cooling system for water sent to batey and mill sections equipment.
   ** The Environmental Impact will be to reduce volumetric flow.*

5. Construction of a pumping system to recycle rain water to the cooling spray pond or cooling tower system.
   * *The environmental impact will be a reduction in floods during winter rains thus avoiding operational problems.*

6. Construction of a sanitary waste water sewage line, separated from process lines to send these sanitary effluents to a sewage sanitary biological treatment plant.
   * *The environmental impact will be to reduce coliforms, BOD and COD.*

7. Construction of a system to recover alkaline/acid wash water to avoid its dumping in receiving bodies.
   * *The environmental impact will be to reduce TSS, COD and BOD .*

Conclusion

Participation in the CLEANSUGARTEC project allowed all three companies to identify a range of waste minimization options, some of which were implemented during the project. (See Table 10 for breakdown of implementation status.) A large portion of the options (11 of 25) have been implemented within 15 months of plant-level, waste minimization activities. Another three options are considered feasible and implementation has either started, or is planned for the near future. Seventeen of 42 generated options proved unfeasible - either because of unavailable, or unsuitable technology adaptation, or because they were considered too expensive. These options have been rejected by the companies.

Table 9: Comparison of the implementation status per industry studied

Implementation status	**San Francisco Ameca**	**Central Motzorongo**	**El Potrero**	**Total**
Implemented	7	4	0	11
Started	1	2	0	3
Planned	2	2	7	11
SUB-TOTAL	**10**	**8**	**7**	**25**
Rejected	3	6	8	17
TOTAL	**13**	**14**	**15**	**42**

Given the considerable differences in the complexity, nature and impact of the various options, the number is not an indication of their economic and/or environmental impact. Table 11 summarizes the economic impact following implementation of the first (11 out of 25) feasible options. These were carried out during the CLEANSUGARTEC project.

Both investments and net annual savings are potentially the highest in the refined white sugar and ethyl alcohol production plant (El Potrero), however waste minimization options have not been implemented because of the lack of available funding, and for other practical reasons.

It is clearly shown that many waste minimization options pay for themselves in a short period of time. About one third of the options have a pay-back within one year. In total, half of the options have a pay-back time of less than three years. The remaining options either have a longer pay back period (over three years) or have economic benefits that cannot be quantified within the framework of project CLEANSUGARTEC.

Table 10: Economic impact of the options implemented during the project

Economic indicator	Standard sugar plants	Refined sugar plant	Total
Number of implemented options	11	0	11
Investments (US$1,000,000 or less)	1.7	7.0	8.7
Net annual savings (US$1,000,000 or less)	1.3	1.5	2.8
Overall pay back period (months)	<25	<56	<37

The implementation of these waste minimization measures has contributed significantly to environmental improvement in areas like minimization of water consumption and waste water discharges, minimization of particle air emissions, minimization of solid waste generation, better use of materials, energy and process water, and a reduction of the use of toxic substances. Most options contribute to environmental improvement in several areas. Because of this multiple effect, it is not feasible to summarize the total environmental impact with one set of environmental indicators.

Part 3

Towards an environmental management system

The introduction of cleaner production, including waste minimization technologies and techniques, represents the first important steps in the process of accreditation to international environment standards. They must also be regarded as the pillars of an Environmental Management System (EMS)[20], which aims to introduce and practice environmental objectives within the policies and the management framework of a company.

An Environmental Management System is a creative and holistic approach – based on various techniques – that allow a company to plan, set up, maintain, manage and continuously improve their internal systems, production processes and maintenance network. Successful implementation of an Environmental Management System allows a company to find and put into effect the best, and most cost-effective solutions, in order to meet its environmental obligations.

Several approaches of EMS already exist, both on a national and an international level. One of the first established management systems was the British Standard BS 7750, which became a guide and basis both for the development of the European Community (later European Union) regulation on the establishment of an Eco-Management and Audit System (EMAS), Council Regulation 1836/03, and of the ISO 14000 Series[21] on Environmental Management Systems.

ISO 14000 (published in September 1996) is being developed to meet the demand for an environmental management system that will be consistent for many kinds of organizations. The ISO 14000 standards and guidelines define the core environmental management system itself, and the auditing procedures necessary for verification. It also defines three sets of tools that are important in implementing an EMS;

- life cycle assessment
- environmental performance evaluation
- environmental labelling

20 EPA-NSF Definition: "An EMS is a continual cycle of planning, implementing, reviewing and improving the actions that an organization takes to meet its environmental obligations."

21 ISO 14000 is a series of standards adopted by the international Standards organization (ISO), located in Geneva, Switzerland. Compliance with the ISO 14000 standards demonstrate the existence of an environmental management system.

Like other EMS models, the ISO 14001 Standard (Environmental Management Systems – Specification with Guidance for Use) is built on the "Plan, Do, Check, Act" model introduced by Shewart and Deming. This model endorses the concept of continual improvement. ISO 14000 standards do not, however, define the specific environmental performance goals that an organization should attain. These are left up to the organization itself.

The main elements of an EMS based on ISO 14001 are:

- the definition of an Environmental Policy;
- the planning of the EMS with all its components;
- the implementation of the system and its operation;
- the checking of the system and corrective actions; and
- the management review

Creating an effective Environmental Management System to suit the organization of a cane sugar factory is not a difficult procedure. A knowledge, however, of the techniques involved in implementing a workable and successful EMS will avoid the loss of time, overcome initial problems and eliminate eventual mistakes.

The International institute for Sustainable Development (IISD) has identified the following benefits attached to an effective EMS:

- Reduces incidents and liability;
- Enhances efficiency;
- Enhances environmental performance;
- Improves corporate culture;
- Third party assurance and recognition;
- Expands market access (ISO 14000 may become a pre-requisite for doing business) ;
- Regulatory relief;
- Enhances public image and community relations;
- Expresses due diligence; and
- Provides better access to financial markets.

Information and assistance can be obtained by contacting the United Nations Industrial Development Organization (UNIDO) which co-operates with industries, international and regional organizations to encourage the implementation of Environmental Management Systems.

Contact Address: **UNIDO,**
Agro-based Industries Branch,
Industrial Sectors and Environment Division,
PO Box 300, A-1400 Vienna, Austria.
Fax + 43 1 211 31 6349.

Part 4

DO-IT-YOURSELF — A very practical manual

Introduction

The methodology and guidelines described in Part One can easily be adapted to a particular context of any given sugar factory. It is the case, however, that even if sugar plant managers and technical staff are already convinced of the benefits of waste minimization programmes, almost all such factories lack the means to measure such benefits. Many are also unable to call upon institutional support to help them.

This DO-IT YOURSELF Manual has been designed to demonstrate how in-house, low cost monitoring programmes can be put into effect, even with limited resources. Such a program *"... leads to the generation of smaller amounts of discharges, emissions and waste and is an essential element in the cleaner production approach to environmental management"*[22]

The document is addressed to plant engineers and the approach favours practical considerations based on the experience of normal, every-day operations in cane sugar plants. Some suggestions may not be justifiable because of lack of means or available resources.

A monitoring programme involves many different factors and considerations. Experience has shown that some constraints are to be expected. Outside guidance and supervision can be helpful in order to successfully implement the methodology.

For more detailed information contact: UNIDO,
Agro-Based Industries Branch,
Industrial Sectors and Environment Division,
PO Box 300,
A-1400 Vienna, Austria.
Fax + 43 1 211 31 6349.

22 From Monitoring Industrial Emissions and Waste Material, UNIDO/UNEP, 1996)

How to evaluate pollution

Basic parameters

The quantitative evaluation of pollution in liquid or gaseous effluents implies the knowledge of the pollutant concentration: c, and of the effluent flow: q. The instantaneous pollutant flow is the product of both factors. Thus, the global pollutant mass during a determined time T is:

$$M = \int_T q\ c\ dt \text{ and the average flow } \Phi = 1/T \int_T q\ c\ dt$$

As the flow and the concentration in a sugar factory are subject to large variations according to the hours, factory work and various events, a single isolated measure has no significance.

Three specific problems that all need to be recognised and addressed are:

- How to determine the effluent flow?
- How to determine the pollutant concentration?
- What is the validity of such determinations?

Other parameters that should be considered may be:

- Physical parameters: turbidity, color, surface tension, temperature.....
- Chemical parameters: total organic carbon, nutrients (azote, phosphorus), pH....
- Biological parameters: bacteria and virus.

In a sugar factory only temperature, pH and solids content are easily measured and of practical use.

Determination of effluents flow

In 1996, UNIDO and UNEP jointly published a "Monitoring Industrial Emissions and Waste" manual which provides guidance for the implementation of monitoring equipment, and procedures for sampling and measurement.

In the absence of specific instrumentation, there are two ways to determine flow of effluents:
a) by implementation of an independent system of measurements; and
b) by calculation.

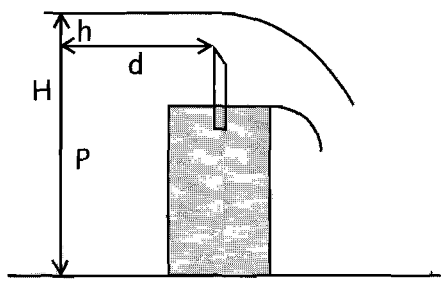
The best solution is to use both methods simultaneously.

How to implement a DO-IT-YOURSELF measurement system

Some examples of the most usual methods are:

a) in open channels

- *from an overflow thin plate*



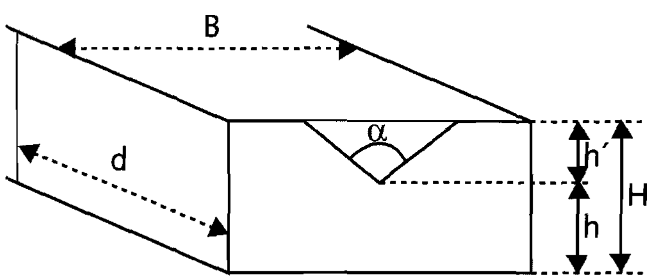
Conditions:
d > 5 h
L > 4 h
h > 0.1 meter

Formula : $Q = 1.8\ L\ h^{3/2}$ in which:

Q = Flow value in cubic meters (per second)
L = Length of the gauge plate (in meters)
d = Distance between the plate and the measurement place (in meters)
H = Level of effluent (in meters)
P = Depth of the channel under the plate edge (in meters)

- *from a triangular V notch (thin plate weir)*

The width of the notch surface edge should be 1- 2 mm and the downstream edges chamfered if the weir plate is thicker than 2 mm.



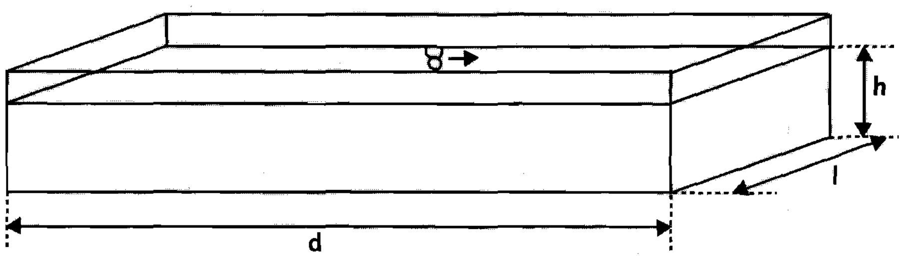
simplified V notch formula : $Q = 1.42 (H\text{-}h)^{5/2} \tan \alpha/2$
with a 90° V notch : $Q = 1.42 (H\text{-}h)^{5/2}$

Q = Flow value in cubic meters (per second)
α = Notch angle (in degrees)
H-h = The measured head over the weir (in meters)

Range of application for a 90° V notch: $0.1 < h/d < 2$; $0.1 < d/b < 1$; $h > 0.09$ m

- *from measurement of the surface speed*

A simple method which consists of measuring the time (t) required by a floating object to cover a given distance (d).



formula: $Q = k\ l\ h\ d\ /\ t$ (in metric system: meters, seconds)

k is a coefficient ($0.8<k<1$) reflecting the true speed of the flow in relation to the apparent surface speed.
very low speed k = 0.8
high speed k = 1
for usual average conditions k = 0.9

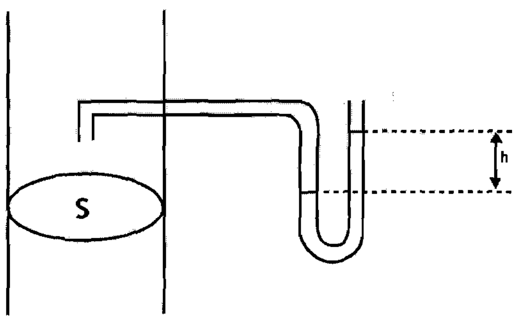
b) in closed ducts

- *water flow measurement*

A volumetric test is the best way, but not always applicable.
Another way is to measure the power required by the pump with an ammeter. The flow can be calculated from the power formula (after the total manometric head has been determined) or compared with the characteristic curves as stated by the manufacturer.

- *gaseous emission flow measurement*

Pitot tubes are most commonly used. A 'DO-IT-YOURSELF' static Pitot tube can be easily constructed from a laboratory glass tube. Because it is not possible to correctly scale such an 'in-house made' apparatus, it cannot be used for direct flow measurement. It can, however, provide interesting indications on flow variations. For instance, it may be possible to find a correlation between the flue gas emission of a boiler and the production of steam. It is important to remember that the flow is not only given by the pressure indication, but is also linked to the gas density.



$Q = k\,S\,(h/\delta)^{1/2}$

k = coefficient (undimensioned)

Flow calculations

a) water balances

The calculation of the water balance supposes that mass and steam balances have already been determined. The water balance is always approximate, and the indications below have to be considered as general guidelines.

Guidelines are defined by:

- Q = the amount of water required (in cubic meters per hour)
- C = the actual working capacity of the factory (in tonnes of cane per hour)
- Temperature of the water supplied to the factory is considered to be in the range of 25°C and 30°C, with an average of 28°C. These represent the usual conditions in cane sugar plants.

The water streams are divided into four categories:

- Waters for vacuum condensers
- Boilers, deheaters and deaerators
- Cooling waters
- Process and general use waters

Water for vacuum condensers

a) barometric condensers:

- Evaporation:

V = weight of vapour from the last body (in kg/tc)
Δt = difference of the water temperature between condenser inlet and outlet in °C
Q = theoretical weight of the required water in the condenser
Q' = practical weight of the required water in the condenser

$Q = 0.58\ VC/\Delta t$ $\quad Q' = 0.7\ VC/\Delta t$

- Vacuum pans:

V = weight of steam or vapour required for the strike (in kg/tc)
Δt = difference of the water temperature between condenser inlet and outlet in °C
Q = theoretical weight of water in the condenser
Q' = practical weight of water in the condenser

$Q = 0.58\ VC/\Delta t$ $\quad Q' = 0.75$ to $0.8\ VC/\Delta t$

- Vacuum filters condenser:

Q = about 100 Kg per tonne of cane Q = 0. 1 C

b) multi-sprays condensers:

$Q = Q' = 0.05\ VC$

Boilers, deheaters and deaerators

The water amounts are directly obtained from the steam balance.

An important effluent - in terms of temperature and solid content - is the boiler bleeding water. It is considered that it amounts to about 2.5% of the produced steam.

Cooling water

	Units	Designation	Formula
Mill turbines			
Power consumption	kW/tch	P	
Cooling water	m3/h	Q	Q =0.02 PC
Mill bearings			
Cooling water	rm3/h	Q	Q = 0.2 C
Power turbines			
Power consumption	kW/tch	P	
Cooling water for alternator	m3/h	Q	Q =0.012 PC
Cooling water for turbine	m3/h	Q	Q =0.012 PC
Sulphitation station			
Sulphur furnaces	m3/h	Q	Q = 0.38 C
Sulphur gas scrubbers	m3/h	Q	Q = 0.38 C
Air compressors	m3/h	Q	Q = 0.38 C
Crystallizers masse cuite C			
Weight of masse cuite	kg/tc	W	
Masse cuite inlet temperature	°C	θ_1	
Masse cuite outlet temperature	°C	θ_2	
Cooling water inlet temperature	°C	t1	
Cooling water inlet temperature	°C	t2	
Cooling water amount	m3/h	Q	
Centrifugal oil coolers			
Cooling water amount	m3/h	Q	Q≈0.25 C
Condenser vacuum pumps			
Cooling water amount	m3/h	Q	Q≈0.8 C

Process and general use waters

	Units	Designation	Formula
Mill imbibition water			
Imbibition % cane	%	k	From mass balance
Cold water temperature	°C	θ_1	
Hot water temperature	°C	θ_2	
Imbibition water temperature	°C	t	
Imbibition water amount	m3/h	Q	$Q = 0.01\ k\ C$
Cold water amount	m3/h	Q_1	$Q_1 = Q\ (\theta_2 - t)\ /\ (\theta_2 - \theta_1)$
Hot water amount	m3:h	Q_2	$Q_2 = Q\ (t - \theta_1)\ /\ (\theta_2 - \theta_1)$
Liming water			
Imbibition water amount	m3/h	Q	From mass balance
Liming water temperature	°C	t	
Cold water amount	m3/h	Q_1	$Q_1 = Q\ (\theta_2 - t)\ /\ (\theta_2 - \theta_1)$
Hot water amount	m3/h	Q_2	$Q_2 = Q\ (t - \theta_1)\ /\ (\theta_2 - \theta_1)$
Filters washing			
Filters washing water amount	m3/h	Q	From mass balance
Liming water temperature	°C	t	
Cold water amount	m3/h	Q_1	$Q_1 = Q\ (\theta_2 - t)\ /\ (\theta_2 - \theta_1)$
Hot water amount	m3/h	Q_2	$Q_2 = Q\ (t - \theta_1)\ /\ (\theta_2 - \theta_1)$
A and B molasses dilution			
Water amount	m3/h	Q	$Q = 0.05\ C$
Magma dilution (eventual)			
Water amount	m3/h	Q	$Q = 0.02\ C$
Remelt (eventual)			
Water amount	m3/h	Q	$Q = 0.02\ C$
Pans washing			
Water amount	m3/h	Q	$Q = 0.03\ C$
Centrifugal washing			
Water amount	m3/h	Q	$Q = 0.02$ to $0.04\ C$

	Units	Designation	Formula
General purposes			
Make up water for condensing system		Q	$Q = \pm \mid q_2 - q_1 \mid$
• total losses in spray pond	m3/h	q_1	q_1 = 5% of total spray flow
• condensed vapours	m3/h	q_2	$q_2 = \Sigma$ (V)
Losses on valves, glands, etc....	m3/h	Q	Q = 0.1 to 0.2 C
Heat exchangers cleaning	m3/h	Q	Q= 0.05 C
Mill cleaning	m3/h	Q	Q = 0.08 C
General cleaning of the factory	m3/h	Q	Q = 0.2 to 0.3 C
Laboratory	m3/h	Q	Q = 0.3 C
Sanitary and other uses	m3/h	Q	$Q = q_1 + q_2$
• for factory	m3/h	q_1	50 litres per worker per day
• for company housing	m3/h	q_2	50 litres per head per day

Sample Recapitulation table

A recapitulation table allows the determination of the effluents flow in the various sections of the factory.

	From outside	Pure condensates	Other condensates	Total	Recirculation or reuse in process	Effluents to drains
Availabilities (description, characteristics and list)						
Uses (description, characteristics and list)						
Total						

Determination of pollutant concentration

BOD_5 or COD ?

Even if it is a matter of discussion between specialists, BOD_5[23] is considered the best indicator of pollutant concentration. Unfortunately, because the five-day period necessary to obtain results is incompatible with the day-to-day requirements of a sugar factor, plant laboratories do not have the means of measuring it. It is therefore considered more suitable to measure COD[24]. This can be done in a plant laboratory (preferably with appropriate equipment). This measurement needs no more time to analyse that that of high-grade products, and requires less time than the analysis of water content in bagasse.

In sugar factories, as in other agro-based industries where pollution is essentially of a biological nature, there is a constant ratio between COD and BOD_5 (the statistic average of the COD/ BOD_5 ratio in sugar factories is about 1.6). As measurement of a sample to determine its BOD_5content (conducted in an outside laboratory and possibly a significant distance from the factory) is of doubtful accuracy therefore, the use of COD measurement instead of BOD_5 is justified.

COD determination

a) in sugar factory effluents

The most recommended method is to provide the laboratory with either inexpensive — measuring equipment (cost = 15,000 US$), or with an even less expensive COD analysis kit (cost = 1, 200 US$).

See Pollution Prevention and Abatement Guidelines for Cane Sugar Processing and Refining[25] (Booklet II, this Information Package) for indications of the usual range of COD in waste waters (reference: Tables 2 and 3). The significant variations between the minimum and maximum value stated in these charts, however, limit their use as references only. For more practical guidance, please refer to the maximum value presently recommended by the World Bank (Emission Requirements, Booklet II, this Information Package).

As pollution in sugar factories is closely linked with the 'ose' content (Saccharose and invert sugars), the balance of non-sugars and the analysis of "undetermined losses"(by calculation) will give an indication of what is happening in the factory. A simple, but effective method involves

23 The Biologic Oxygen Demand: BOD5 (unit=mg O2 /litre) measures the oxygen consumed by micro organisms to assimilate and oxidize organic matters in the analysed water, after 5 retention days, at 20°C and sheltered from light.

24 The Chemical Oxygen Demand: COD (unit=mg O2 /litre) is the result of the oxidation of organic matters by potassium dichromate in an acid medium (50% H2 SO4 in volume).

25 UNIDO, Nov. 1993

the use of the pol balance and the purity of undetermined losses. The nature of undetermined losses can be defined as:

- Mechanical losses, if:

Brix losses > Pol losses	
N.S losses > 0	
If $80 \leq Pu \leq 90$	losses are due to low grade products e.g. clear juice, syrup
If $Pu < 80$	losses are due to high grade products e.g. m.c A and B, molasses

- Chemical (inversion) losses, if:

NS losses < 0
Brix losses < Pol losses i.e. Pu 100

This method is a useful starting point for further investigations.

b) in gas emissions
The simple and inexpensive 'd' Orsat' apparatus (cost = 200 US$, for a portable model) measures the CO_2 content of flue gas. This allows efficient calculation of boiler efficiency but does not permit the determination of unburned particles.

Due to the heterogeneous quality of the bagasse, the emission of unburned particles is especially important in modern boilers equipped with spreader stockers. Pith is more difficult to burn and due to its light density, part of it leaves with the flue gas.

Also important to preserve good boiler efficiency is to limit the excess of air. This can, however, result in the generation of more unburned emission.
According to Hugot[26] the best proportions are:

$12\% < CO_2 < 16\%$ $\qquad$ $25\% <$ air excess $< 60\%$

In average conditions, and in the absence of dedusters, unburned particles rejected into the atmosphere amount to about 5 g/m3 of gas, and some 6 kg per tonne of cane.

26 Handbook of Cane Sugar Engineering 3rd edit.

To complete the measurement of the CO_2 content, an observation of the flue gas color is recommended. (This can be done with very simple apparatus that can be either bought or manufactured in-house). If boilers are equipped with dedusters it is also possible to measure the weight of collected unburned particles.

Using these elements and experiments, it is possible to establish correlations. The color apparatus will verify the efficiency of the dedusters and allow a follow-up of the atmospheric pollution.

c) in distillery stillages (slopes or vinasse)

The advantage of distillery work compared to a sugar factory is the quasi absence of fluctuations. In absence of any instrumentation, the pollution content can still be calculated with sufficient accuracy using the following five steps:

1. Analysis of the composition of final molasses:

Theoretically, Brix, true purity, invert coefficient and ashes content are needed. Generally, only the Brix (B) and apparent purity from the Pol are available.
If B = 80, it can be assumed:

Water content W = 100-B = 20%

Dry matter: B = 80% →
- (Total sugar = 0.6 to 0.65 B (= 50%)
- (Organic matter = 0.2 to 0.3 B (= 20%)
- (Mineral matter = 0.1 to 0.15 B (= 10%)

2. Distillery efficiency (practical)

From operational data sheet.
For example: r = Q molasses (t)/Q' alcohol (hl) = 0.36
Therefore: 360 kg of molasses produce 100 l alcohol at 96° GL.

3. Organic matter in vinasses

Organic matter in molasses	= 360 x 20%	= 72 kg/hl alcohol
+ Produced yeast	= 360 x 1%	= 3.6 kg/hl alcohol
+ Unfermentable sugar	= 360 x 50% x 4 %	= 7.2 kg/hl alcohol
Total organic matters in vinasses		= 83 kg/hl alcohol

4.	COD and BOD_5

If, based on the average analysis in many distilleries, it is assumed that 100 kg of organic matter gives 120kg of COD. Then:

COD = 83 x 1.2 = 100 kg for 100 litres of alcohol.

This example, for the considered distillery, yields 1 kg COD/litre of alcohol.
In distilleries, the COD/BOD_5 ratio = 1.7.
Thus for the distillery considered in this example, there is 0.6 kg BOD_5 /litre of alcohol

5.	Concentration

If 1 litre alcohol yields 12 litres of vinasses, then:

- BOD_5 concentration = 50 000 mg O2 / litre
- COD concentration = 83 300 mg O2 / litre

Organization of sampling and analysis

Identification of effluent discharge points
Draw a detailed effluent flow-sheet of the factory and a map of drains. Mark the map by identifying discharge points and the position where sampling and measurements are to be made.

Number of analysis and frequency
The number and the frequency of analysis depends on the degree of information that is needed. A standard method COD laboratory analysis requires 1.5 hours. Six to eight samples can be analyzed by one operator in a five hour period. In order to not overload the laboratory tasks, it is suggested that the number of routine analyses be limited.
These can be:

- List the liquid inputs and outputs that need to be analysed, and also the nature of the information required.

- Once a year, during the operational season, implement a systematic campaign of measurement and analysis to evaluate pollution loads and other data related to identified liquid inputs and outputs. This campaign (e.g. over a period of one week) is designed to gain a rough estimate of the mean value of pollution loads, and the standard deviation from that mean. It also establishes whether there are accumulative effects from recycled effluents, or cyclic variations. Cyclic variation in mill washing waters occurs, for example, because general factory cleaning is only carried out during certain hours of the day. If one operator is able to complete six effluent analyses each day (36 per week), this is usually sufficient to satisfy the factory requirements.

- Using the preceding data, it is possible to set up the following routine analysis chart:

Type of effluents	Frequency	Type of analysis
from filter condenser	once per day	COD
from pans condensers		
- if recirculated	once per day	COD, t°, pH
- going to drain	once per turn or day	COD, t°, pH
excess of condensed waters	once per day	COD, t°
from sulphitation station	once per day	COD, t°, pH
pan station upstream effluent	once per turn	COD, t°, pH, SS
from hydraulic dedusters (eventual)	once per day	COD, t°, SS
discharge effluent	once per turn	COD, t°, pH, SS

As mill wash waters have no specific discharge point, the incidence of wash waters on the overall pollution load can be evaluated by comparing the difference between night (no washing) and day analysis of the discharge effluents in usual working conditions. (See: Absence of sampling access below).

- If the sugar factory is equipped with a water treatment plant, it is necessary to set up a battery of analyses according to the type of treatment being carried out.

Discrete or composite sampling

A discrete sample represents the composition of given material at the place and time of sampling. A composite sample is formed by mixing a number of discrete samples collected at a single location, over a given period and frequency. It can represent the average composition of the material during the period, but only if the flow has remained constant.

For the sake of efficiency, it is recommended that the collection of some discrete effluent samples be combined with other routine sampling duties. These samples will be mixed in the laboratory and the composition will be analysed in due course.

The following recommendations regarding sampling procedures are considered important:

- sample bottles should be labelled and completely clean; and
- they must be both filled to capacity, and sealed, to avoid the sample coming into contact with air.

Where sampling access is impaired

When there is not a direct access to a pouring place, it is necessary to assess the difference between an upstream and a downstream flow. Because such a system is of doubtful accuracy -- especially when the volumes are quite different, such a method should be a last resort solution. A comparison between the results obtained on the downstream flow – with, and without, incident flow – will be a better solution – e.g. if the final discharge to the river is inaccessible, downstream measurements can be done when the factory is running and during periodic stoppages.

Interpretation of the results.

Interpretation of results should always take into account the actual running conditions of the factory. They should be compared to the results obtained during the analysis campaign.

No result shall be rejected if no previous statistic test has been carried out. This can be a comparison of the difference between the suspected result and the average, in relation to the standard deviation; or a verification of the occurrence of a modification in the running conditions of the factory (e.g. stoppage, overflow or other incidents). In the last case, the result will be maintained.

At the end of the season, a sufficient number of results are at the disposal of analysing personnel to allow a complete interpretation based on statistical considerations. It is recommended that tests be carried out on the existence of correlations between results obtained during crushing (or other running conditions) within the factory. Such correlations are important for further calculations, and for the comparison of results either between various seasons, or at other sugar factories.

Accuracy of the pollution load evaluations

Even when carried out by specialists, the pollution measurement is of doubtful accuracy, especially in the absence of an analytical programme that includes a campaign of measures; statistical treatment of the collected data; and interpretation of the results in relation to the factory's actual working conditions.

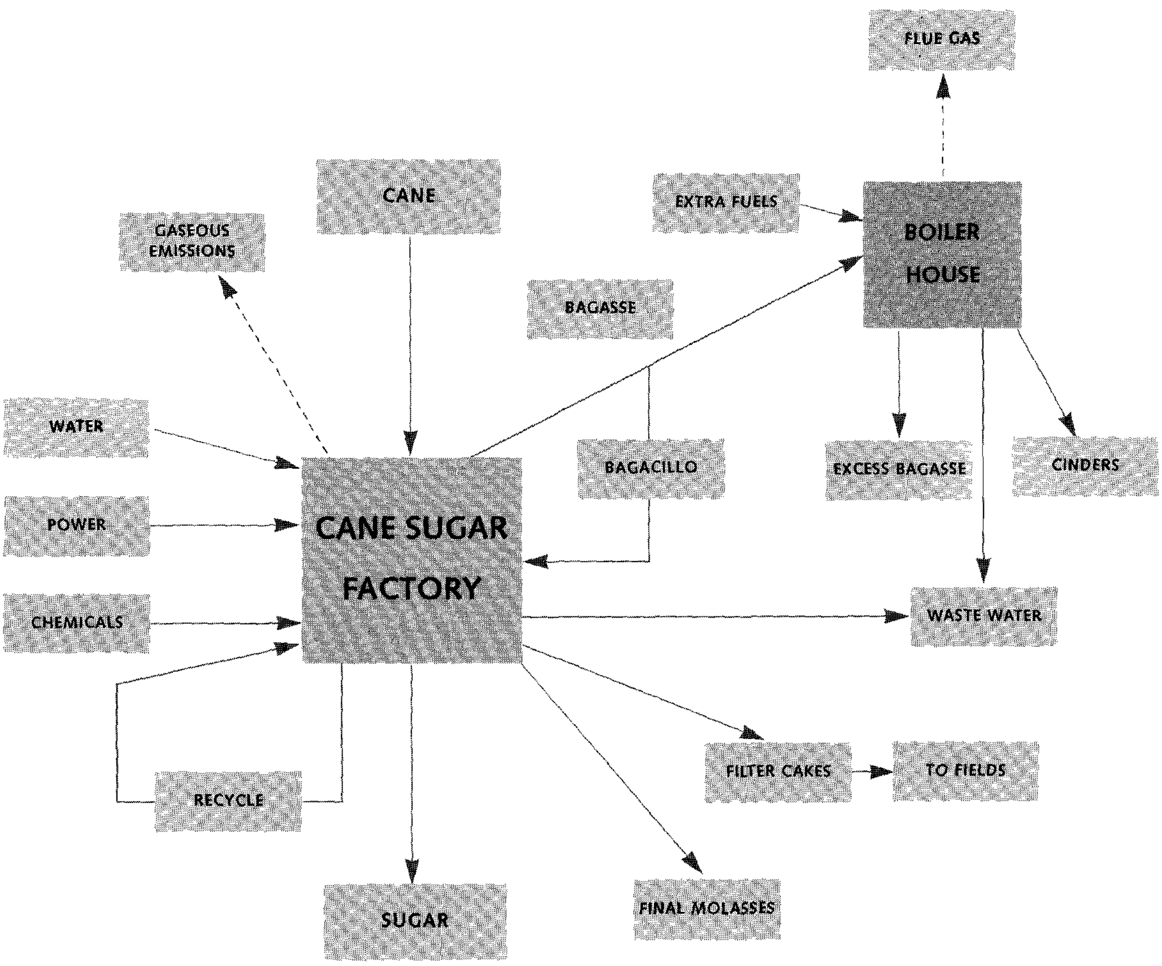
Although the 'DO-IT-YOURSELF' methods outlined above may not result in absolutely accurate results (the range of precision can fluctuate between 20%), they do create more favourable conditions for the interpretation of results.

The purpose of such methods is less a matter of 'accuracy' and more one of ,a better understanding' of what is taking place inside the factory, and for the implementation of a suitable monitoring programme

Reliability, however, can always be improved, and the simultaneous use of the calculation and measurement method is recommended. As calculations are made from periodic and annual reports, they do not necessarily determine the situation. Measurements allow the verification of calculations, and the validity of the hypothesis and formula coefficients. They permit the day-to-day control, once the monitoring programme is implemented.

The overall material balance

Any periodic material balance yields numerous information on input and output data related to the running of the factory. This data can be complemented by the results of analysis and flow measurements, or by evaluation of effluents streams and gaseous emissions. The overall input and output material balance can be illustrated by presenting the information as either a chart or table.



To compliment flow calculations for water balances etc., (see Flow Calculations) a specific table dealing with water use and waste water should be drawn up

Reduction of waste and pollution

Minimization of waste

Table 1, Chapter 1 details examples of waste minimization and cleaner production techniques. Among them:

- Recirculation;
- Process reuse; and
- Valorization of by-product

are three basic ways to minimize solid, liquid and gaseous waste.

Solid waste

Returning filter cake materials to the fields is common practise in almost all sugar factories. It fosters the reconstitution of the soil quality, following its depletion of nutrients by the cultivation of cane (amount 30 to 40kg/tc with water content = 75%; in field application: 10 to 20 t/ha).

This is also the most simple and sensible way to dispose of boiler ash (after eventual grinding, if it contains conglomerates). It can be used as a soil conditioner (1-2 tonnes/ha, after the last ratoon harvesting).

Liquid waste

Cooling waters represent more than 90% of the total water use in sugar factories. The benefits of recycling these cooling waters is clearly demonstrated in the case-study of the San Francisco Ameca plant in Mexico[27].

The recirculation of condenser waters through a spray pond or a cooling tower does require a big investment and may be an unrealistic, in-house programme goal. Cooling systems for other cooling purposes can usually be manufactured within the factory workshop.

27 Part 2, this manual

Regarding recirculation of water, two points require specific attention:

- recirculation of mill-bearing cooling waters requires a pre-treatment station in order to eliminate mineral grease and oil; and
- sugar factories do not generally recirculate water from the vacuum filters condenser because of their pollutant charge, therefore before recirculation is undertaken, a verification of the situation is recommended.

Another important source of waste water is the impure condensate from the last stages of the evaporation station, pans and heat exchangers. This can be partly reused in the factory process - either in mill imbibition, hot liming, washing of filters or other general washing. For mill sanitation and centrifugal washing, the use of super-heated water (from deaerator) is preferable.

Unburned particles in flue gas emission
Nowadays, the addition of dedusters on boilers is a legal obligation. Unburned particles can be removed by use of centrifugal collectors, wet scrubbers or electrostatic precipitators. A centrifugal collector does require a constant emission flow and a homogeneous composition of bagasse to operate efficiently. As these conditions are rarely found in cane sugar factories, a hydraulic deduster - easily manufactured within the factory workshop - is a reliable solution.

A perfect DO-IT-YOURSELF example is to reuse unburned particles instead of bagacillo in the vacuum filters.[28] A previous laboratory test, however, is required.

Some practical recommendations

General Points

- Check cooling water systems and condensers to establish what water is not being recirculated. Study ways to recycle this water.

- Check all glands, flanges, valves, pipes, and pumps for leaks and implement immediate repairs.

- Clean all drains (and remove all collected deposits) both inside and outside the factory once a day. Do not permit any stagnant water to collect in the drains.

- Replace floor washing at different stations within the factory with dry cleaning methods.

28 See Pollution Prevention and Abatement Guidelines for Cane Sugar Processing and Refining, UNIDO 1993, reference: 5.3.2.1).

This can be achieved by sprinkling water on the floor (if necessary) then applying bagasse. The bagasse used for cleaning should then be burnt in the boilers.

- Do not allow any overflow to mix with the effluents. The use of open drains is preferred and a dry cleaning system is recommended for the last stages of the process.

- Isolate the molasses and magma pumps and the final molasses tank with parapet walls to prevent leakages and overflow. Use bagasse to clean it.

- Provide grease and oil traps on both the cooling water outlet from the mill bearings and on the main factory drain.

Specific points

Milling plant

- Use a dry cleaning system on the cane conveyors to remove trash (e.g. a metal brush made from a tube fitted with wires and coupled to the driving gear, and a plate collector).

- Install a super-heated water distribution system instead of steam, or hot (or cold) water to the mill sanitation system. Do not allow the use of hoses.

- Do not allow the use of hoses - use paddles instead - for removing bagasse from the juice troughs. (An excess of bagasse in the juice trough is often due to a poor or defective separation system, and an insufficient rate of imbibation).

- Cooling waters from mill bearing: See Flow Calculations — water balances

Clarification plant

- Liming and sulphitation station: See Flow Calculations — water balances

- Filter condenser water: after measuring the concentration of pollutant, investigate possibilities to recirculate it.

- Filter coat wash water (in case of rotary filter belt type): This water contains sugar and has a high COD content. Recirculate it and use as imbibition water with eventual addition of cold or hot water. (Suspended solids in the water will be filtered by successive passage through the bagasse. As the water pH level rises to more than 8, there is no risk of future inversion).

- Do not allow effluent drains to be polluted by the passage of filter wastes.

Heaters, evaporators and pans.

- Cleaning of tubes: The caustic solution should be collected in a separate tank after use and regenerated by adding soda. Sediment settled at the bottom of the tank should be removed before the regeneration process. After filtration, this sediment can be used as a neutralizing agent in the water recirculation system.

Water recirculation system (spray pond or cooling tower)

- A drop-by-drop application of copper sulphate will avoid any proliferation of algae or fungus, and will also improve the efficiency of the cooling system.

- Maintain the system so that it is perfectly clean. At least once a day, remove all solids from the screen.

Cooling, curing and drying plant

- Drained material from centrifugal pans should be collected and pumped back. This greatly reduces the COD load.

Neutralizing the final effluents

To check for eventual losses, it is necessary to establish the exact pH and temperature for each of the factory's water and effluent streams. This is very important - especially for the sulphitation station cooling waters.

Special care must be made not to indiscriminately apply lime from the liming station. This is neither a scientific nor a recommended method. Instead:

- measure the pH before and after the application point, and adjust the flow of lime to obtain pH = 7; and

- do not allow lime grits to mix with the effluent.

Water management and housekeeping

- Appoint a supervisor to be responsible for pollution control and water management. Their responsibility should be:

  - to work together with the production management to put the monitoring programme into effect;
  - to follow up and control the monitoring programme; and
  - to produce periodic reports on the progress of the monitoring program.

- The monitoring programme should include:

  - Detailed inspection guidelines;
  - Instructions to the operators;
  - Regular progress reporting; and
  - Water and waste audits.

Glossary of some cane sugar processing terms

A,B,C,

Absolute juice: see Juice.

Affination: The first step in the refining process consisting of removing the adhering film of molasses from the surface of the raw sugar crystal.

Apparent purity: 'Purity Pol' percent 'Brix' (see 'True Purity').

Ash: The residue remaining after incinerating the product under specified conditions.

Bagacillo: Very small particles of bagasse separated either from pre-clarification juices or from the final bagasse, either by filtration or other methods.

Bagasse: The residue obtained from crushing cane in one or more mills; 'final bagasse' or simply 'bagasse' - when referring to material from the last mill.

Boiling house: That part of the factory in which sugar is manufactured from mixed juice.

Boiling house recovery: The percentage ratio of sucrose actually recovered in sugar from the sucrose content in mixed juice.

Brix: The percentage by weight of solids in the pure sucrose solution. By general acceptance Brix represents the apparent solids in a sugar solution, as determined by an hydrometer (spindle Brix) or a refractometer (refractometric Brix).

Cane: The raw material delivered to the factory, including clean cane, field trash, water, etc.

Cane to sugar ratio: *Tonnes of cane required to produce one tonne of commercial sugar.*

Cane (or bagasse) diffusion process: A process used to extract juice from the cane through a diffuser.

Cane crushing process: A process used to extract juice from the cane through a tandem of mills.

Cane knives (or cane cutters): Used to cut the cane into chips before the grinding process.

Cane shredders: Cut the cane into tears before grinding the cane.

Cane trash percentage: 'Net' cane % cane. This is obtained by weighing the residual trash and adhering solids after a selected cane sample has been cleaned.

Capacity of factory: Generally expressed in tonnes of processed cane per day (tcd) or per hour (tch).

Clarification process: Set of chemical and mechanical operations which consists of removing as many of the juice impurities as possible.

Curing of masse-cuite: A subsidiary operation of crystallization in motion which consists of cooling masse-cuites in crystallizers in order to exhaust the mother liquor.

D, E, F

Defecation process: Clarification by heat and lime.

de Haan process: A subsidiary clarification by carbonation.

Determined losses: see *Losses*

Dextran: A polysaccharide which can be present in appreciable quantities in cane and mill products, due to microbial activity.

Dextrose (glucose): One of the constituents of reducing sugar. Empirical formula: $C_6 H_{12} O_6$. Dextrorotatory power on the polarization plan of light.

Dilution: The portion of imbibition water which enters the mixed juice.

Dry substance: The material remaining after a product is dried to produce constant mass.

Evaporation: The process of removing water from clarified juice by vaporization. All modern factories employ multiple-effects evaporators in which the vapor from one evaporator becomes steam for the next one.

Extraction (mill extraction): That proportion of a component of cane which is removed by milling. Extraction alone means sucrose (Pol) extraction.

Exhaustibility (of sugar solutions): Sucrose which can be extracted, % of the sucrose content

Fibre: The dry, water-insoluble matter in cane

Field trash: Leaves, tops, dead stalks, roots, soil, etc. delivered to the mill, along with the cane.

Filters: Press filters or vacuum rotary filters that are used to exhaust sugar from clarifier muds.

Filter cake: 1) A pasta-like mixture of bagacillo and clarifier mud, applied on the surface of rotary filters; 2) The solid residue of filtration.

Filtered juice (or filtrate): The juice extracted from filters which is recirculated in the initial clarification stage.

Filter mud (or scum): The solid residue of filtration.

First-expressed juice: see Juice.

Footing: The quantity of products (molasses, magma) used to start a strike.

Froth 'fermentation': Foaming of low-grade masse cuites which is due not to fermentation, but to the decomposition of certain salts and organic non-sugars.

Fructose (levulose): One of the constituents of reducing sugar. Empirical formula: $C_6 H_{12} O_6$. Levorotatory power on the polarization plan of light.

G, H, I

Glucose: see Dextrose

Gums: The precipitate, corrected for ashes, which is obtained by treating sugar liquors with acidified ethyl alcohol.

Grinding season (or crop): In raw sugar factories, the manufacturing season necessarily coincides with the harvesting season.

Horne color scale: A simple set of color standards for sugar color measurement, with wide acceptance in US and Latin American countries.

Imbibition: The process by which water or juice is applied to a bagasse to enhance the extraction of juice at the next mill.

Invert sugar: 1) Monosaccharides obtained by the hydrolytic reaction of sucrose in an acid medium (inversion); and 2) A mixture of 50% fructose obtained by the hydrolysis of sucrose.

I.S.S.C.T: International Society of Sugarcane Technologists.

J, K, L

Juice:

Absolute juice: All the dissolved cane solids, plus the total water (cane minus fibre).

First-expressed juice: The juice extracted from the first two rollers of a tandem of mills.

Last expressed juice: The juice extracted from the last two rollers of a tandem of mills.

Mixed juice (raw juice): The mixture of primary and secondary juices which enters the boiling house.

Residual juice: The juice left in the bagasse (bagasse minus fibre).

Jelly: A boiling concentrate that does not grain, but which will crystallize spontaneously on cooling. The time honoured test is the 'string proof'.

Keeping quality of raw sugar: A safety factor related to the water and impurities contents.

Last expressed juice: see *Juice*.

Leuconostoc: A specific bacteria frequently found in mill juices. An important factor in inversion and dextran formation.

Liming: Adding lime to mixed juice is the most commonly used purification treatment throughout the world.

Losses:

Determined losses: Losses in bagasse, filter mud and molasses which can be determined through calculations and chemical analyses.

Undetermined losses: They are classified as: - **Apparent losses:** errors in weights, analysis or incorrect stock estimations. - **Mechanical losses:** entrainment in condensed vapours, overflows, leakages, etc. - **Chemical losses:** due to inversion and decomposition.

M, N, O

Maceration: A form of imbibition in which the bagasse is steeped in an excess of fluid.

Magma: A suspension of crystals in saturated liquor made by mixing sugar with water, juice, syrup, molasses. etc.

Massecuite (or masse cuite): The mixture of crystals and mother liquor discharged from a vacuum pan. Massecuites are classified according to descending purity as first, second, etc.; or A, B, etc.

Mill sanitation: *see Sanitation*

Molasses: The mother liquor separated from a massecuite by mechanical means. They are classified into intermediate molasses according to the name of the massecuite and final molasses.

Overall recovery: Sucrose (pol) recovered in commercial sugar percent sucrose (pol) in cane.

P, Q, R

Pan boiling: An operation which produces and develops sugar crystals from syrup or molasses, in a vacuum pan.

Phosphatation: A subsidiary clarification process which consists of adding phosphate or phosphoric acid to the treated juice.

Pol: The apparent concentration in weight percent of sucrose in a material, derived by determining the optical rotation of a sample, and attributing that rotation to sucrose. Pol is used in calculations as if it was a real substance.

Preparation of cane for milling: A set of operations which consists of cutting the cane into chips or tears before grinding.

Purity: Three terms are used:

> *Apparent purity:* The percentage proportion of pol in the Brix;
>
> *Gravity purity:* The percentage proportion of sucrose in the Brix; and

True purity: The percentage proportion of sucrose in the dry substance. The term purity alone means apparent purity.

Raw sugar: *see Sugar.*

Reducing sugar: The reducing substances in cane and its products. Major reducing sugars are glucose and fructose.

S, T, U

Saccharose: *see Sucrose.*

Safety factor: *see Keeping quality of raw sugar.*

Sanitation: The term refers to a set of mechanical, physical and chemical measures to fight bacterial infection and maintain cleaning.

Saturated solution: A solution which would neither dissolve nor crystallise in the presence of undissolved solute.

Seed: Magma or fine grained massecuite used as a footing for boiling a massecuite.

Solubility: The concentration of a solute in a solvent in a saturated solution.

Strike: A sequence of operations on a masse cuite including: boiling, curing in crystallisers and centrifuging.

Sucrose: In a quantitative connection the term "sucrose" or "Saccharose" should mean sucrose specifically, as distinct from pol. The term "cane sugar" is used to some extent, signifying pol, not sucrose.

Sugar: The main product of a sugar factory consisting of crystal of sucrose as removed from a massecuite and containing more or less impurities, depending on its type.

Refined sugar: A white and high pol sugar obtained after the refining process

Very high pol sugar: Raw sugar with a pol higher than 99.3°S

High pol sugar: Raw sugar with a pol between 98.0 and 99.3°S.

Low pol sugar: Raw sugar with a pol below 99.3°S

Brown sugar: A direct consumption raw sugar.

White plantation sugar: A direct consumption raw sugar generally obtained through a sulphitation treatment of the raw juice or /and of the syrup.

Sugarcane: 1) A tall grass of the genius Saccharum; 2) The crop produced from hybrids which are the progeny of a number of Saccharum species; and 3) The raw material accepted at the mill for processing.

Sulphitation: A subsidiary clarification process which consists of adding sulphur dioxide into juice and/or syrup.

Supersaturation coefficient: The ratio of the concentration of sucrose in the sample, to the solubility of sucrose in the sample.

Syrup: Concentrated clear juice from evaporators.

Total solids: *see Dry Substance.*

True purity: see *Purity.*

Undetermined losses: *see Losses.*

V, W, X, Y, Z

Wash: Diluted molasses thrown out during washing which is collected separately.

Washing: 1) Addition of water or/and steam in centrifugals to wash the crystal surface from the mother liquor; and 2) Addition of water or/and steam in pans to dissolve remaining crystal before a new boiling.

Sources:

System of Cane Sugar Factory Control; ISCTT (3rd edition).

Cane Sugar Handbook; Meade -Chen (11th edition).

Author's sources.

Glossary of some environmental terms

A, B, C

Abatement: Reducing the degree or intensity of, or eliminating pollution.

Acid deposition: A complex chemical and atmospheric phenomena that occurs when emissions of sulphur, nitrogen compounds and other substances are transformed by chemical process in the atmosphere, then deposited on earth in either wet or dry form.

Activated carbon: A highly absorbent form of carbon used to remove odours and toxic substances from liquid or gaseous emissions.

Activated sludge: Sludge which occurs when primary effluent is mixed with bacteria-laden sludge and then agitated and aerated to promote biological treatment.

Adulterants: Chemical impurities or substances that by law do not belong in a food or a pesticide.

Advanced waste water treatment: Any treatment of sewage that goes beyond the secondary or biological water treatment stage and includes the removal of nutrients, such as phosphorus and nitrogen, as well as a high percentage of suspended solids.

Aeration: A process which promotes biological degradation of organic water. It can be passive 'air exposition) or active (aerators).

Aerobic: Life or process that require, or are at least not destroyed by, the presence of oxygen.

Aerobic treatment: Process by which microbes decompose complex organic compounds in the presence of oxygen and use the liberated energy for reproduction and growth.

Agglomeration: The process by which precipitation particles grow larger, by collision or contact with cloud particles or other precipitation particles.

Agglutination: The process of uniting particles coated with a thin layer of adhesive material or, of arresting solid particles by contact on a surface coated with an adhesive.

Agricultural pollution: The liquid and solid waste from farming.

Airborne particulates: Total suspended particulate matter found in the atmosphere as solid or liquid droplets.

Airborne release: Release of any chemical into the air.

Air pollutant: Any substance in air which could, if in high concentration, harm humans, animals, vegetation or materials.

Algae: Simple rootless plants that grow in sunlight in relative proportion to the amount of nutrients available.

Algae blooms: Sudden spurts of algae growth, which can affect water quality adversely and indicate potentially hazardous changes in local water chemistry.

Ambient air: Any unconfined portion of the atmosphere; open air; surrounding air.

Anaerobic: Life or process that require, or are not destroyed by, the absence of oxygen.

Attenuation: The process by which a compound is reduced in concentration over time, through absorption, degradation, dilution, and/or transformation.

Autotrophic: An organism which produces food from inorganic substances.

Bacteria: Microscopic living organisms which can aid in pollution control by consuming or breaking down organic matter in sewage, or by similarly acting in spill oils and other water pollutants.

Bar screen: In waste water treatment, a device used to remove large solids.

Biochemical Oxygen Demand (BOD): A measure of the amount of oxygen consumed in the biological process that break down organic matter in water.

Biodegradable: The ability to breakdown the or decompose rapidly under natural conditions or processes.

Biological treatment: A treatment technology that uses bacteria to consume waste. This treatment breaks down organic materials.

Biomass: All of the living material in a given area; also call „biota"..

Biomonitoring: the use of living organisms to test the suitability of effluents for discharge into receiving waters, and to test the quality of such waters downstream from the discharge.

BOD_5: The amount of dissolved oxygen consumed in five days by biological processes breaking down organic matter.

By-product: Material, other that the principal product, that is generated as a consequence of an industrial process.

Capture efficiency: The fraction of all organic vapours generated by a process that is directed to an abatement or recovery device.

Chemical oxygen demand (COD): A measure of the oxygen require to oxidise all compounds in water, both organic and inorganic.

Chilling effect: *see Greenhouse effect.*

Clarification: Clearing action that occurs during waste water treatment when solids settle out.

Cleaner Production: A whole set of techniques to preserve environment in industrial activities.

Coagulation: A clumping of particles in waste waters to settle out impurities It is often induced by chemicals such as lime, alum, polyelectrolytes, etc.

Combined sewers: A sewer system that carries both sewage and storm-water run-off.

Comminution: Mechanical shredding or pulverising of waste. Used in both solid waste management and waste water treatment.

Compaction: Reduction of the bulk of solid waste by rolling and tamping.

Compost: A mixture of garbage and degradable trash with soil in which certain bacteria in the soil break down the garbage and trash into organic fertiliser.

Contaminant: Any physical, chemical, biological, or radiological substance or matter that has an adverse affect on air, water, or soil.

Cost-effective alternative: An alternative control or corrective method identified after analysis as being the best available in terms of reliability, permanence and economic considerations

Cyclone collector: A device that uses centrifugal force to pull large particle from polluted air.

D, E, F

Decomposition: The breakdown of matter by bacteria and fungi. It changes the chemical makeup and the physical appearance of materials.

Denitrification: The anaerobic biological reduction of nitrate nitrogen to nitrogen gas.

Digester: In waste water treatment, a closed tank; in solid waste conversion, inside a unit in which bacterial action is induced and accelerated, in order to break down organic matter, and to establish the proper carbon-to-oxygen ratio.

Dilution ratio: The relationship between the volume of water in a stream, and the volume of incoming water which affects the ability of the stream to assimilate waste.

Dispersant: A chemical agent used to break up concentrations of organic material, such as spilled oil.

Dissolved oxygen: The oxygen freely available in water.

Dissolved solids: Disintegrated organic and inorganic materials contained in water.

Dump: A site without environmental controls used to dispose of solid waste.

Ecology: The relationship of living things to one another and their environment, or the study of such relationships.

Ecosystem: The interacting system of a biological community and its non-living environmental surroundings.

Effluent: Waste water, treated or untreated, that flows out of a treatment plant, sewer, or industrial out-fall.

Electrostatic precipitator: An air pollution control device that removes particles from a gas stream (smoke) after combustion occurs, via an electric charge applied to particles.

Emission: Pollution discharged into the atmosphere from smokestacks, other vents, and surface areas of commercial or domestic facilities.

Emission factor: The relationship between the amount of emission produced and the amount of raw material processed.

Enforcement: State or local legal actions designed to obtain compliance with environmental laws, rules, regulations, or agreements and/or obtain penalties or criminal sanctions for violations.

Enrichment: The addition of nutrients from sewage effluent or agricultural runoff to surface waters.
This process greatly increases the growth potential for algae and aquatic plants.

Environment: The sum of all external conditions affecting the life, development, and survival of an organism.

Eutrophication: The slow ageing process during which a lake or an estuary evolves into a bog or marsh and eventually disappears.

Evaporation ponds: Areas where sewage sludge is dumped and allowed dry out.

Fermentation: Chemical reactions accompanied by living microbes that are supplied with nutrients, and other critical and specific conditions (heat, pressure, light, etc.)..

Floc: A clump of solids formed in water or sewage by biological or chemical actions.

Flocculation: The process by which clumps or solids in water or sewage are made to increase in size by biological or chemical action so that they can be separated from the water.

Flue gas: Vented air coming out a chimney after combustion in the burner.

Fly ash: Non-combustible residual particles from the combustion process, carried by flue gas.

Fugitive emission: Emission not caught by a capture system.

Fume: Tiny particles trapped in vapour in a gas stream.

G, H, I

Grain loading: The rate at which particles are emitted from a pollution source. Measurement is made by the number of grains per cubic meter of gas emitted.

Grey water: The term given to domestic water composed of wash water from sinks and tubs.

Greenhouse effect: The warming of the Earth's atmosphere caused by a build-up of carbon dioxide or other traces gases.

Half-life: The time required for a pollutant to lose half its affects on the environment.

Hard Water: Alkaline water containing dissolved salts that interfere with some industrial processes and prevent soap from lathering.

Hazardous substance: Any material that poses a threat for human health and/or the environment.

Heterotrophic organism: Consumers such as humans and animals, and decomposers - chiefly bacteria and fungi- that are dependant on organic matters for food.

Holding pond: A pond or reservoir, usually made of earth, built to store polluted run-off.

Impondment: A body of water or sludge confined by a dam, dike, floodgate, or other barriers .

Indicator: In biology, an organism, species, or community whose characteristics show the presence of specific environmental conditions.

Influent: Water, waste water, or other liquid flowing into a reservoir, basin , or a treatment plant.

Injection well: A well into which fluids are injected for purposes such as waste disposal, improving the recovery of crude oil, or solution mixing.

Inoculum: Bacterium placed in compost to start biological action.

Interceptor sewers: Large sewer lines that, in combined system, control the flow of the sewage to the treatment plant.

J, K, L

Kinetic rate coefficient: A number that describes the rate at which a water constituent such as BOD or DO increases or decreases.

Lagoon: A shallow pond where sunlight, bacterial action, and oxygen work to purify waste water; also used as storage of waste water or spent nuclear fuel rods.

Land farming (or waste): A disposal process in which hazardous waste deposited on/in the soil is naturally degraded by microbes.

Leachate: A liquid that results from water collecting contaminants as it trickles through waste, agricultural pesticides or fertilisers.

M, N, O

Monitoring: Periodic or continuous surveillance or testing to determine the level of compliance with statutory requirements and/or pollution levels in various media or in humans, animals, and other living things.

Neutralization: Decreasing the acidity or alkalinity of a substance by adding to it alkaline or acid materials, respectively.

Nitrification: The process whereby ammonia in waste water is oxidised to nitrite and then to nitrate by bacterial or chemical action.

Non-point source: Pollution sources which are diffuse and do not have single point of origin, or are not introduced into a receiving stream from specific outlet.

Nutrient: Any substance assimilated by living things that promotes growth.

Off/On-site facility: A hazardous waste treatment, storage, or disposal area that is located away from/on the generating site.

Opacity: An indicator of changes in performance of particulate matter pollution control.

Open dump: An uncovered site without environmental control used for disposal or waste.

Outfall: The place where an effluent is discharged into receiving waters.

Oxidation pond: A man-made lake or body of water in which waste is consumed by bacteria. Mainly used with other waste treatment processes, it is basically similar to a sewage lagoon.

Ozone depletion: Destruction of the stratospheric ozone layer which shields the earth from ultraviolet radiation harmful to biological life.

P, Q, R

Particulate loading: The mass of particulate per unit volume of air or water.

Permeability: The rate at which liquids pass through soil or other materials in specified direction.

Persistence: The length of time a compound, once introduced into the environment stays there.

pH: A measure of the acidity or alkalinity of a liquid or solid material.

Photochemical oxidants: Air pollutants formed by the action of sunlight on oxides of nitrogen and hydrocarbons.

Phytoplankton: That portion of the plankton community comprised of tiny plants (algae, diatoms).

Point source: A stationery location or fixed facility from which pollutants are discharged or emitted.

Pollutant: Any substance introduced into the environment that adversely affects the usefulness of a resource.

Pollutant Standard Index (PSI): Measure of adverse health effects of air pollution levels in major cities.

Preliminary assessment: The process of collecting and reviewing available information about a known or suspected waste site or release.

Prenention: *Measures taken to minimize the release of waste to the environment.*

Primary waste treatment: First steps in waste water treatment, screens and sedimentation tanks are used to remove most materials that float or will settle.

Raw sewage: Untreated waste water.

Reasonably Available Control Technology (RACT): The lowest emissions limit that a particular source is capable of meeting by the application of control technology that is both reasonably available, as well as technologically and economically feasible.

Recycle/reuse: The process of minimizing the generation of waste by recovering usable products that might otherwise become waste.

Refuse reclamation: Conversion of solid waste into useful products.

Removal action: Short-term immediate action taken to address releases of hazardous substances that require expedited response.

Residual: Amount of a pollutant remaining in the environment after a natural or technological process has taken place.

Restoration: Measures taken to return a site to pre-violation conditions.

Reverse osmosis: A water treatment process used in small water systems by adding pressure to force water through a semi-permeable membrane.

Risk assessment: The qualitative and quantitative evaluation performed to define the risk posed to human health and/or the environment, by the presence or potential presence and/or use of specific pollutants

S, T, U

Sanitation: Control of physical factors in the human environment that could harm development, health, or survival.

Scrubber: An air pollution device that uses a spray of water or reactants or a dry process to trap pollutants in emissions.

Secondary treatment: The second step in waste treatment systems in which bacteria consume the organic parts of the waste.

Sedimentation: Letting solids settle out of waste water by gravity during waste water treatment.

Sewage: The waste and waste water produced by residential and commercial establishments and discharged into sewers.

Sinking: Controlling oil spills by using an agent to trap the oil and sink it to the bottom of the body of water where the agent and the oil are biodegraded.

Skimming: Using a machine to remove oil or scum from the surface of the water.

Slow sand filtration: Treatment process involving passage of raw water through a bed of sand at low velocity which results in the substantial removal of chemical and biological contaminants.

Sludge: A semi-solid residue from any a number of air or water treatment processes.

Slurry: A watery mixture of insoluble matters that results from some control pollution techniques.

Smog: Air pollution associated with oxidants.

Smoke: Particles suspended in air after incomplete combustion of materials.

Solidification: Removal of waste water from a waste or changing it chemically to make the waste less permeable and susceptible to transport by water.

Stabilisation: Conversion of the active organic matter in sludge into inert, harmless material.

Stabilisation pond: see Lagoon.

Sump: A pit or tank that catches liquid runoff for drainage or disposal.

Suspended solids: Small particles of solid pollutants that float on the surface of, or are suspended in sewage or other liquids. They resist removal by conventional means.

Technology-based standards: Effluents limitations applicable to direct and indirect sources which are developed on a category-by -category basis using statutory factors, not including water-quality effects.

Tertiary treatment: Advanced cleaning of waste water that goes beyond the secondary or biological stage. It removes nutrients and most BOD and suspended solids.

Tide: A proliferation of a marine plankton. This natural phenomenon can be stimulated by the addition of nutrients. A tide can be called red, green or brown, depending on the coloration of the plankton.

Tolerances: The permissible residue levels for pesticides in raw agricultural produces and processed food.

Total Suspended Solids (TSS): A measure of the suspended solids in waste water, effluents, or water bodies.

Trash-to-energy plan: A plan for putting waste back to work by burning trash to produce energy.

Turbidity: 1) Haziness in air caused by the presence of particles and pollutants; 2) A similar cloudy condition in water due to suspended silt or organic matter.

Waste: 1) Unwanted material left over from a manufacturing process; 2) Refuse from places of human or animal habitation.

Waste water Operations and Maintenance: Actions taken after construction to assure that facilities constructed to treat waste water will be properly operated, maintained and managed to achieve efficient levels and prescribed effluent levels in an optimum manner.

Water quality criteria: Specific levels of water quality which, if reached, are expected to render a body of water suitable for its designated use.

Water solubility: The maximum concentration of a chemical compound which can result when it is dissolved in water.

Well injection: The subsurface emplacement of fluids in a well.

Xenobiotic: Term for non-naturally occurring, man-made substances found in the environment.

Zooplankton: Tiny aquatic animals eaten by fish.

Source: Extracts from "Glossary of Environmental Terms and Acronym list" United States Environment Protection Agency (USEPA), Dec. 1989.

List of additional UNEP/UNIDO reference publications and studies

- Audit and Reduction Manual for Industrial Emissions and Waste (UNEP/UNIDO, 1991)
- Monitoring Industrial Emissions and Waste (UNEP/UNIDO, 1996)
- From Waste to Profits: The Indian Experience (Final Report of DESIRE (UNIDO, 1995)
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- La protection de l'environnement dans l'industrie de la canne à sucre (Didier Chaux, Dec.1991)
- Environmental Adjustment of a Sugar Mill in Brazil (Guilherme de Faria Barrero, Humberto de Mello, Bruno Garzon, March 1995)

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- From Waste to Profits: The Indian Experience (1996)
- Beneficios sin residuos: La experienca latinoamericana (1996)
- Sustainable Industrial Development (1997)
- Cleaner Production Worldwide (1996)

List of tables and figures

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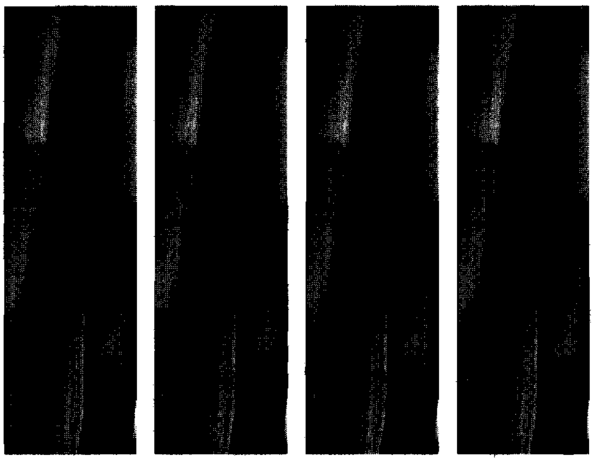

towards a cleaner industry

An information package on waste minimization and pollution abatement in the cane sugar industry

This information package on waste minimization and pollution abatement in the cane sugar industry was produced, under the direction of Messrs. Sergio Miranda-da-Cruz and Ralph (Skip) Luken, from the Industrial Sectors and Environment Division of the United Nations Industrial Development Organization, based on studies prepared by Mr. Didier Chaux, Ms. Carmen Duran de Bazua and Ms. Marianela Cordoves.

Editor: Marcia Hill
Design/DTP: WorldLinks/Claudia Univazo
Printed in Austria

towards a cleaner and more profitable

sugar industry

Vol. 2

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UNIDO

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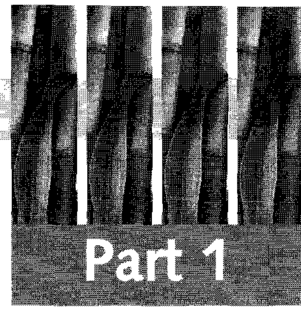


Pollution Prevention and Abatement Guidelines for Cane Sugar Processing and Refining[1]

Executive summary

In 1991 the world sugar production amounted to approximately 114 million tonnes, of which 64% came from sugarcane and 36% from sugarbeet. Sugarcane is cultivated between 30° latitude north and 30° latitude south worlwide. There are more than 2200 sugar processing plants in 111 countries.

Little more than 10% of the sugarcane can be processed into commercial sugar. Furthermore, for every tonne of cane processed about twenty tonnes of water are needed. Thus, recycling and reuse of process water and residuals are very important, both for the protection of the environment and for the overall profitability of operations. A well controlled and balanced production process – with good sanitation – which fully utilizes the possibilities for reusing residuals in the process (or as by-products) should be the starting point for environmental protection. In addition, the treatment of water and air discharges is often necessary.

In the absence of national regulations, the United States New Source Performance Standards can serve as guidelines on achievable discharge limitations. It is however, important to consider factors such as: scale, age and location of plant; the assimilative capacity of the recipient medium during

1 *This document is one of the chapters prepared for a set of pollution guidelines jointly prepared by the World Bank, UNIDO and UNEP. The purpose is to give a succinct overview of the main issues affecting the subject industry sector, and of the best technologies and techniques available to avoid undue environmental impact. The regulatory framework within which the industry operates is briefly described by examples, and target discharge limitations that are economically achievable with currently available technology are suggested. The intended readership includes project personnel in investment and development institutions as well as anyone who wishes to familiarize themselves with the key aspects of the industry concerned. The information is not sufficient by itself for detailed project design. For this more elaborate advice can be obtained from the references quoted or from other specialized sources of information. Comments on the document should be submitted to Mr. Anil Somani, the World Bank, Environment Department, 1818 H Street N.W., Washington DC 20433, USA, fax. (202) 477-0968 with copy to UNIDO, Att. Mr. Ralph Luken, P.O. Box 300, A-1400 Vienna, Austria. Fax +43 1 23 07 449.*

the crop season; and the time needed for plant upgrading (as preventive measures for pollution control are preferred, it must be recognized that these, in general, take more time to implement than end-of-pipe measures).

A considerable development of sucrochemistry and ethanol applications is expected in the near future. This development is expected to bring forth problems of pollution by aggressive molasses and vinasses on a much wider scale than previously associated with the sugar industry.

Introduction

This report describes raw cane sugar processing and cane sugar refining and their respective impact on the environment. Generally, it is the waste from the processing which is of major concern, although residuals occur in both operations. Their potential and actual uses as by-products are important for both environmental and economic reasons.

The environmental concerns associated with sugar production include water and air pollution and the disposal of solid wastes. With proper management, environmental impacts can be negligible. Wastes resulting from the processing and refining of sugar are generally putrescible organic materials which have potential for utilization and reuse.

Manufacturing processes

Although in a few cases raw cane sugar processing and cane sugar refining are carried out in the same plant, they are presented individually because the two operations present substantial differences and are most frequently carried out in separate locations.

Raw cane sugar processing

Sugarcane has a variable composition, average figures are: 70% water; 14% fibre; 13.3% saccharose; and 2.7% soluble impurities. The processing of a tonne of sugarcane yields on average between 105 and 115 kg of commercial sugar. The diagram below summarizes the processing of raw sugarcane to commercial sugar through the so-called three boiling system:

Cane

Washing (if necessary)	→	separation of trash
Preparation	→	cut and shredded cane
Extraction	→	juice + bagasse
Clarification	→	clear juice + mud
Evaporation	→	syrup
Boiling (crystallization)	→	crystal + liquor
Mixing (crystallization)	→	crystals increase
Centrifugation	→	1st strike sugar + A molasses
A molasses recycling	→	2nd strike sugar + B molasses
B molasses recycling	→	3rd strike sugar + final molasses
Drying of crystallized sugar		
Storage	→	in bulk or in bags

Commercial Sugar

A schematic flow diagram for cane sugar processing is presented in the following pages.

Washing (or dry cleaning) is not always needed. The harvesting method used will appreciably affect the amounts of dirt, trash and mud entering a mill, and decide if washing is necessary. After washing, the cane is cut into chips and shredded to enable the extraction of juice and bagasse. This is achieved by crushing in tandems of three roll mills, or a diffusion system with diffuser and press or mills. The juice is separated from the cane fibrous residue called bagasse.

In the clarification stage, impurities in the juice are removed through a process of screening, heating and liming. For the production of white plantation sugar, sulphur dioxide is added (sulphitation). Other supplementary treatments can be added such as phosphatation, carbonation, etc.. The juice is then decanted and the mud filtered.

The clarified juice is concentrated in multiple effect evaporators under reduced pressure to produce a syrup. In the boiling stage, a mixture of syrup, molasses and sugar remelt (known as massecuite) is further concentrated and partially crystallized in individual vacuum pans. Further crystallization is obtained in the mixing stage.

The sugar crystals are separated from the molasses in a series of centrifugations. The first centrifugation yields first strike sugar and A molasses. The A molasses is again concentrated and centrifuged yielding second strike sugar and B molasses. The B molasses is similarly concentrated and centrifuged yielding third strike sugar and final molasses. The third strike sugar is again melted and recycled in the first strike and/or used to initiate the strikes.

After centrifugation, the sugar is dried and packed in bags or stored in bulk. White plantation sugar can be consumed in this state. Crude sugar is refined either in separate refineries or in the sugar plant itself with appropriate equipment.

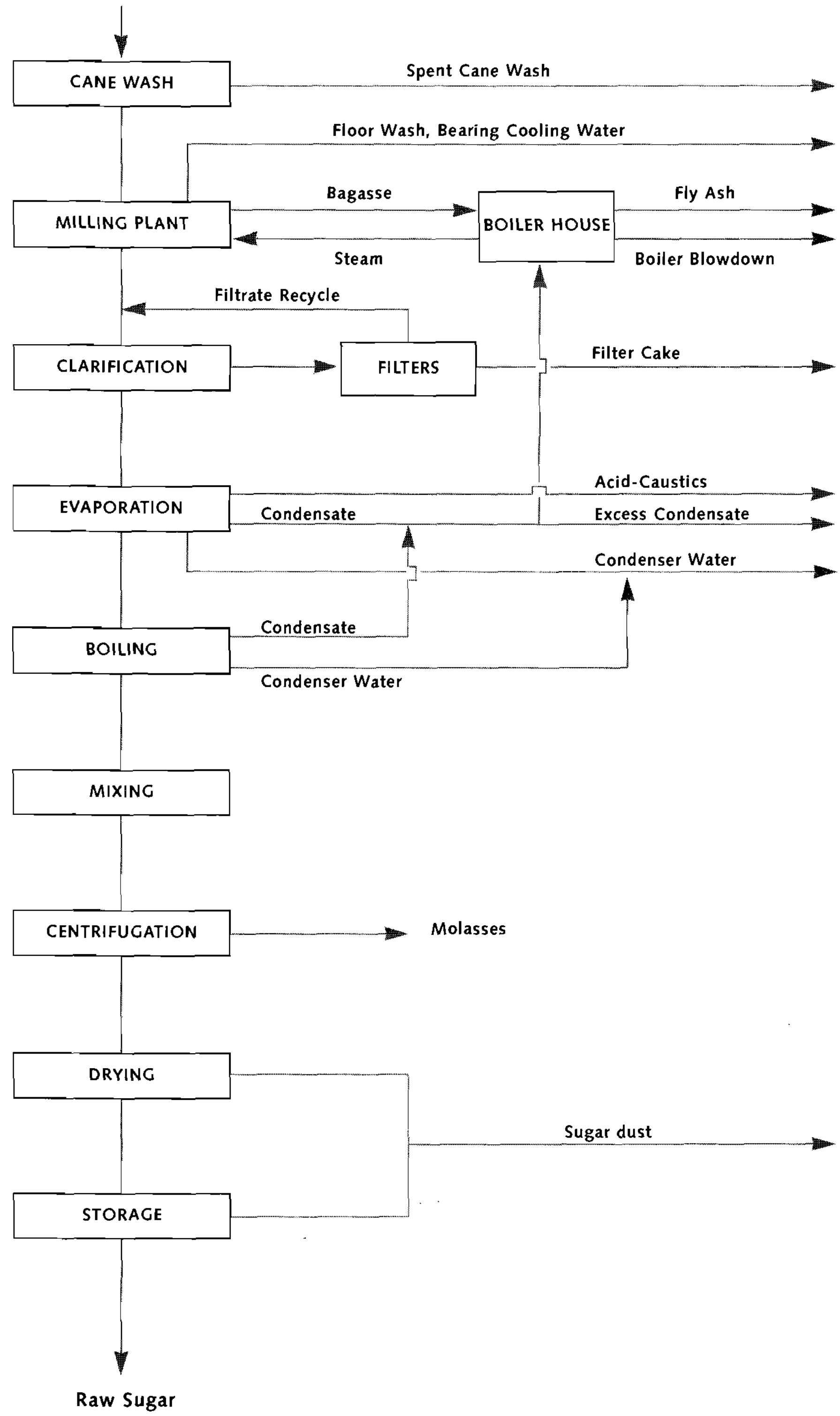


Fig. 1: Schematic Flow Diagram for Cane Sugar Processing[2]. (Ref. 11)

2 Beet sugar manufacturing is similar to cane sugar processing from the point of clarification, only the washing, preparation and extraction processes differ. On arrival at the factory, the beet is analyzed for sugar content. After washing and weighing, the beet is sliced. The slices are drawn into a slowly rotating diffuser and treated with a counter current flow of water which separates the sugar from the beet slices. The juice is then treated by liming and carbonation (see cane sugar refining) after which clarification takes place. In terms of environmental impact a distinct feature of beet sugar processing is the large amount of water used in the early stages of the process. The resulting waste water requires settling and other treatments before it can be discharged. The fibrous residue needs attention as to its handling and re-use.

Cane sugar refining

The raw material for refining consists of the crystalline sugar produced by the raw cane sugar factories. The raw sugar contains a film of molasses, various impurities such as bagasse particles, organic and inorganic salts, and micro-organisms. Refining involves the removal of most of this film and the associated impurities. The steps generally followed include affination and melting, clarification, decolorization, evaporation, crystallization and finishing. A typical process flow diagram is presented in Figure 2. Processes will vary in detail from refinery to refinery. Such differences are particularly evident in decoloration methods, where the medium may consist of bone char, granular activated carbon, powdered activated carbon, vegetable carbon, ion-exchange resins or other materials.

The final product can either be liquid sugar or granulated sugar. Liquid sugar, is obtained by the same process as granulated sugar, except that crystallization and centrifugation are not carried out. Granulated sugar can be produced in various grades of crystal sizes and in cubes.

The following diagram summarizes the processing of raw sugar into commercial refined sugar:

Raw Sugar	Delivery	
↓	Affination (mingling and centrifugation)	→ affined sugar + affined syrup
	Boiling of affined syrup	→ concentration
	Centrifugation	→ recovered sugar + molasses
	Melting	→ melt of affined sugar + recovered sugar
	Clarification	→ liming and carbonation
	Filtration	→ brown liquor + filter mud
	Decolorization	→ char filtering or demineralization
	Evaporation	→ concentration in a multiple effect system
	Boiling	→ Three or four strikes with molasses recycling
	Centrifugation	→ refined sugar + final molasses
	Drying of refined sugar	
↓	Cubing (if necessary)	
Commercial refined sugar	Packaging	

The separation of the film of molasses from the surface of the raw sugar crystal involves mixing the raw sugar with warm syrup and then centrifuging in a process called affination. Water is used to wash the crystals and some sugar is removed with the impurities. This sugar is recovered by concentration and centrifugation.

The affined and the recovered sugar are melted together. The resulting liquor contains impurities which are removed through clarification. Clarification by carbonation basically consists of precipitating calcium carbonate in the melted liquor. This is achieved by adding lime and carbon dioxide gas under controlled conditions of temperature and alkalinity. Mud is separated from the clarified liquor through filtration under pressure in stationary or rotary leaf filters. Decolorization is the key process in refining and is obtained by the use of charcoal or resin, or both. The concentration of the decolorized liquor in a multiple-effects evaporation system results in the production of liquid sugar.

The sugar liquor is then crystallized through boiling and centrifugation in processes similar to those used in raw sugar factories. The concentration consists of boiling in individual vacuum pans and separating sugar and molasses by centrifugation. Intermediate molasses is recycled.

The refined sugar crystals are dried in a current of warm, clean air before being graded, moulded into cubes or tablets if necessary, and packed.

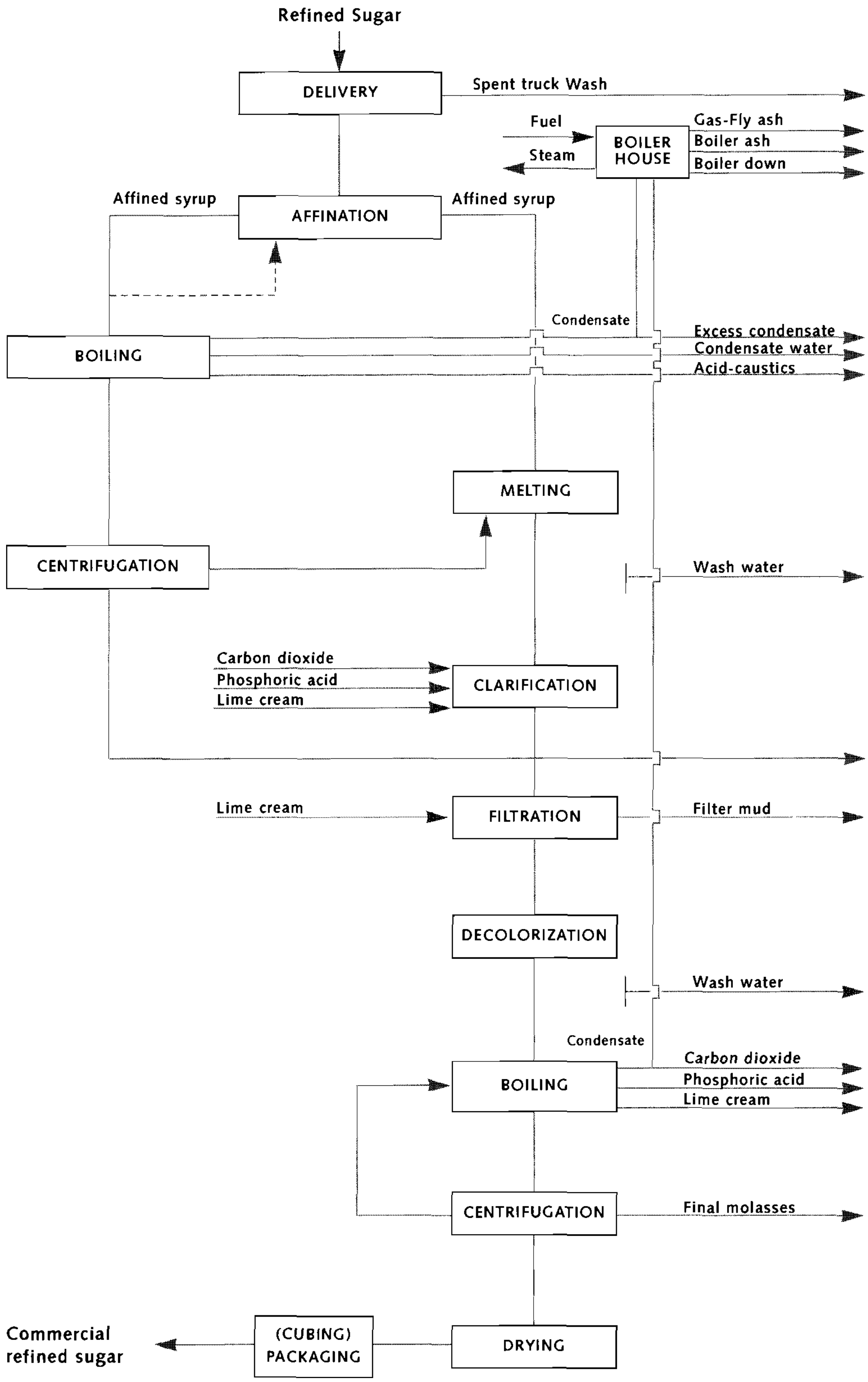


Fig. 2: Schematic Flow Diagram for Sugar Refining

Waste characterization and impacts

The wastes associated with cane sugar processing and refining include water and air pollution and the disposal of solid wastes. The huge amount of biodegradable organic wastes from the processing is a major concern. The pollution load is therefore generally expressed in terms of biochemical oxygen demand (BOD_5) or chemical oxygen demand (COD) and suspended solids. The hydrogen ion concentration (pH) and the temperature are also important parameters in determining the polluting effects of wastes in sugar factories and refineries.

Waste quantities and qualities

Atmospheric Emissions

The atmospheric pollution in the sugar processing and refining industry results mainly from the combustion of bagasse, fuel oil or coal. Examples of other processes giving small air emissions are: gases from juice fermentation; uncondensable gases from the evaporation stage; and sulphurous vapours released from the sulphitation process.

Bagasse combustion results in emissions of flue gas and fly ash. The composition of the flue gas depends on the composition of bagasse, its moisture and on the quantity of air used in combustion. A typical flue gas composition resulting from burning of bagasse is shown in Table 1.

Table 1: Bagasse Combustion - Composition of Flue Gas

Gas	Weight	Percent (%)
N_2	3.455	63.1
O_2	0.346	6.3
H_2O	0.784	14.3
CO_2	0.894	16.3
Total	5.479	100

Source: Bibliography 8

Assuming an average steam consumption of 550 kg/tc and 1 kg bagasse producing 2.25 kg of steam, the production of CO_2 would be 218 kg/tc.[3]

3 Therefore, the whole cane sugar industry is responsible annually for the emission of 145 million tons of CO_2. However, since this CO_2 emission cannot be larger than the amount of CO_2 that the cane sugar plant absorbed during cultivation, the net addition of CO_2 to the atmosphere resulting from bagasse combustion would be zero.

The forced draught in modern boilers implies a large proportion of fly ash in the smoke. Boiler manufacturers estimate amounts to 5.5 kg of fly ash/tc or 4.5 g/m^3 of fly ash in the smoke during bagasse combustion.

Refineries, as well as some sugar processing plants (where the bagasse is used for other purposes) burn fuel oil or coal. This results in sulphur dioxide emissions (besides fly ash emissions) which can be high when using low-grade coal or oil with high sulphur content.

Waste Water

The sugar industry is generally considered a large water consumer and polluter. However, the situation varies from country to country (and inside countries) as shown in Table 2

Table 2: Effluent Characteristics of Various Cane Sugar Processing and Refining Waste Streams in Different Countries[2].

Parameter	Puerto Rico	Hawaii	Philippines	Louisiana (USA)	India
pH	5.3-8.8	-	5.3-7.9	-	6.8-8.4
BOD_5 (mg/l)	112-225	115-699	130-1220	81-562	667- 660
COD (mg/l)	385-978	942-2340	50-1880	720-1430	890-2236
SS (mg/l)	100-700	915-3590	240-5440	150-8120	504-936
TSS (mg/l)	500-1400	3040-4500	-	409	792-2043
Temperature (Co)	31-49	-	34-48	-	-

Source: Bibliography 13

Raw Cane Sugar Processing

Water is essential in sugar processing not only as a sugar solvent, but also for many other uses in the process. It is used, for example, in cane washing; extraction; liming; filter washing; crystallization; barometric condensers; cooling of engines and processing equipment; as well as for general purposes.

In modern sugar factories, water from vacuum condensers is recycled and a large part of condensed water from heat exchangers is recuperated for boiler feeding and other process uses. Older factories do not recycle the vacuum condenser waters and this creates a very large water throughput.

If Q is the quantity of cane processed, then the immediate need of water in a sugar processing plant would be approximately 20Q. This could be reduced to 0.9Q if all possibilities for recycling are employed, and to 1.3Q with partial recycling. Table 3 illustrates BOD_5 and COD values of the main waste water sources in a sugar factory, using partial recycling of process water.

Table 3: Example of Sugar Processing Plant Waste Waters Using Approximately 1.3 m^3 Water/tc.:

Source	BOD_5 (mg/l)	COD (mg/l)
Cane washing	300 - 1500	450 - 8000
Condensate water	35 - 45	80 - 150
Barometric condensers	50 - 200	100 - 400
Filter mud slurry	2900 - 10000	6000 - 20000
Factory cleaning etc.	3000 - 5000	6000 - 10000

Source: Bibliography 11

Cane washing

In some cane-growing regions the cane, though still cut by hand, is loaded mechanically for transportation to the sugar factory. In this case field mud, trash and sometimes stones are brought along with the cane to the factory. All of this creates problems in milling, clarification, juice filtration and bagasse combustion. To resolve these difficulties, washing of the cane has been introduced in some countries. There are many variations in the washing process and some installations are quite elaborate. Water coming from condensers is generally used for this purpose. The amount of mud removed by cane washing varies between 5 kg to 15 kg/tc. A disadvantage of cane washing is the additional loss of sugar. When washed, the amount of sugar loss can reach 0.16% of the total weight of the sugar cane.

Water from barometric condensers

The vapours from the final evaporation stage and vacuum pans are condensed in barometric condensers. This condensation requires large amounts of water (18 tonnes of water/tc, with central barometric station), which gets mildly polluted (see Table 2). This waste water is characterized by high temperature (45°C), low oxygen content and the presence of sugar and gases (CO_2, NH_3) in solution. In the past, the waste water from the condensers was normally directly discharged. Today it is generally recycled to the condensers after passing through an atmospheric cooler.

The water from barometric condensers of vacuum mud filters has a considerable sugar content, but as it cannot be recycled, must be discharged.

Condensate water

The first stages of evaporation also generate condensate water. Some of this (all from the first and some from the second effect) is used as feeding water for the boilers. In case of a tube failure in the heater condensate from heaters cannot be used for this purpose because it may contain juice.

The remainder of the condensates has various uses in the process (milling, liming, cake filter washing, crystallization: melting, clearing, vacuum pan washing, heating of the massecuite etc.). The excess is generally discharged. It is characterized by high temperature (80°C), low oxygen content and the presence of sugar and gases (CO_2, NH_3) in solution.

Cooling water for engines

Cooling of turbo-machines requires very clean and demineralized water which can also be used for cooling pumps, compressors and crystallizers. The cooling water for the mill roller bearings becomes charged with oil and is usually discharged.

Water for general purposes

The water used for factory cleaning of the becomes highly polluted through three main sources of contamination:

1) Fermentation of juice: this occurs mainly in the preparation, extraction and clarification stages of the process.
2) Mechanical sugar losses: overflows, leaking pumps etc.
3) Cleaning of calorific exchangers: chemical cleaning with corrosive products such as sulphuric acid and soda implies a discharge of polluted and corrosive water after washing.

Cane Sugar Refining

Waste water discharges may originate from condensers, filter backwash, truck and equipment washing, floor drains, boiler feed blowdown, engine cooling, floor washing and other miscellaneous processes. The pollutants are primarily:

1) Insoluble suspended solids: mostly water slurries of calcium carbonate or phosphate salts, diatomaceous earth, spent charcoal of carbon etc..
2) Dissolved waste consisting primarily of biodegradable carbohydrates.

The average BOD_5 content in refinery waste water is about 1000 to 2000 mg/litre. Volumes of effluent range typically between 18 to 25 m^3 water per tonne of sugar.

Table 4: Example of Refinery Waste Waters

Source	BOD_5 (mg O_2/l)	COD (mg O_2/l)
Condenser waters	4 -21	6 - 42
Filter mud slurry	730	1200 - 1400
Char waste	750 - 1200	1200 - 2400
Truck wash water	15000 - 18000	22000 - 36000

Source: Bibliography 11

Fugitive emissions

Small, fugitive emissions result from juice fermentation; uncondensable gases from the evaporation stage; and sulphurous vapours released from the sulphitation process.

Upset and emergency conditions

The storage of raw bagasse is a problem due to the large volumes involved, and its low time of preservation. A considerable storage area is required and the rapid degradation cause a risk for internal combustion after only a few months of storage.

Impact on receptors

Most waste waters from sugar processing and refining is not toxic, yet harmful to the environment at higher levels of biological oxygen demand. This is due to the carbohydrate content and the products of their degradation. Organic substances discharged into water (rivers, lakes) are decomposed by micro-organisms which use large quantities of oxygen. The resulting lack of dissolved oxygen affects the breeding of fish and the ecological equilibrium of the receiving medium. Waste water from sugar processing also contain oil solids, caustic and acid. All of these products cause severe non-biological contamination of receiving waters.

On land, the use of residual water or by-products for irrigation must be strictly controlled and used according to the requirements of the crop and the soil, and not as a means of waste disposal. The high Chemical Oxygen Demand/Nitrogen content (COD/N) ratio does not allow an intensive application during the first stages of cane development.

Pollution prevention and control

Management implications

A considerable development of sucrochemistry and ethanol applications is expected in the near future. This development will bring forth problems on a scale (especially associated with pollution by aggressive molasses and vinasses) that make current problems appear insignificant. To counteract, suitable national strategies for environmental protection in the sugar sector must be developed.

Such strategies must consider the current situation of the sugar sector, its achievements and difficulties and its future development. If a national Master Plan for the restructuring, strengthening and development of the sugar sector exists, it is a good base on which to formulate a comprehensive environmental protection strategy. Issues to consider include:

- *How best to establish a step-by-step approach that is suitable for the current situation as well as future developments?* Environmental protection is as much a problem of attitudes as of investment capital. Acquisition of knowledge and training takes time. It took developed countries more than 20 years to modify attitudes concerning pollution problems and reach a wide consensus that action was needed.

- *What legal dispositions and control means must be set up?* What encouraging measures and aids are needed? What penalties should be imposed in case of regulations being violated?

- *How to ensure full and close cooperation between government authorities, sugar institutions and sugar producers, and how to provide them with adequate training and necessary laboratory equipment and facilities?*

Immediate improvements in the environmental performance are possible at the plant level. Sugar producers must be made aware that a well-controlled and balanced factory with good sanitation is the most effective way to prevent pollution. Furthermore, the possibilities for reusing wastes in the process, or as by-products, are rarely fully exploited. Once this awareness is established, the following actions will assist in achieving:

- a corporate environmental policy that gives clear goals, responsibilities, actions and targets

- establishment of a proper environmental management structure to ensure implementation of the policy, to allocate resources, and to monitor (and report) the results.

Source reduction

Cane sugar processing and refining offer many waste minimization opportunities through reduction of wastes at the source, by reuse in the process, or as by-products.

Atmospheric emissions due to uncondensable gases can be decreased by using good sanitation and careful control of the whole operation. Flue gas emissions can be reduced by controlling combustion, air pressure and the rate of excess air.

The sulphitation clarification process is used in many sugar factories for the production of "white plantation sugar". This process, associated with a high pollution load, has been replaced increasingly by other methods, such as: Talo-floc[4] process; uses of bentonite; double centrifugation; and affination etc.

It is important that the cane is processed as soon it arrives at the plant to avoid deterioration with resulting sugar losses and odour problems. Immediate processing will also reduce the storage area needed. Dry cleaning systems which reduce or replace cane washing will result in reduced amounts of sludge.

If the production of slurries is unavoidable, in several cases contamination can be greatly reduced by such precautions as:

4 Registered trademark

- Elimination of refuse, pieces of cane stalk and suspended dirt from the used wash water by screening before lagooning. This precaution allows decreasing the BOD load.
- Maintaining absolute cleanliness at all stations.
- Avoiding fermentation of sugar-cane juices by: appropriate straining; proper sanitation of the mills; controlled application of disinfectants or biocides in mill juices; and systematic cleaning when the milling has stopped.
- Investigation of abnormal sugar losses in order to find and rectify the cause.
- Calculation of the general water balance of the factory for each crop.
- Maintaining a systematic control not only of boiler feeding water, but also of the waste water.
- Periodic inspection and BOD control of lagoons.

A significant source of waste water loading is due to poor housekeeping practices, involving spills of sugar and molasses and poor maintenance of machinery and equipment, which also contribute to oil and grease contamination of effluent. The cost of effective, in-plant control is negligible when compared to the costs of effluent treatment and production losses.

Recycling and/or by-product recovery

Little more than 10% of the sugarcane can be processed into commercial sugar. Furthermore, for every tonne of cane processed about twenty tonnes of water is needed. Thus, recycling and reuse of process water and residuals are very important both for the protection of the environment and for the overall profitability of operations.

Waste segregation

Establishing good water management with as much recycling of process water as possible is essential. The segregation of waste streams with a low BOD load from streams with a high BOD load is vital in this context. Few sugar factories and refineries segregate waste streams in a systematic way. Examples of the potential of this approach are:

- Excess condensate water does not need any treatment because of its low pollution load and can be separated from other streams, see Tables 2 and 3.
- In sugar factories where cane washing is practised, the spent water is generally treated by impounding and recycled to the initial wash. This circuit has to be separated from other treatment circuits because the retention time is different. Fresh water is only used for the final wash.

- Cooling water for mill bearings contains mineral oils and should not be mixed with other waste streams destined for biological treatment without a previous passage through an oil separator (which is a very simple factory-made device). With an efficient oil separation, this water can be recycled.
- In both sugar factories and refineries, acid and caustic waste arise from the cleaning of heat exchangers, evaporators, pans and other equipment. These wastes must be kept separated from other wastes, stored and released gradually into furrows, and blended with general effluent.
- In refineries, the main water pollution load comes from washing trucks and floors. Two waste water circuits are sufficient, one for excess condensate water which needs no treatment and another for treating the wash water
- Vacuum condenser streams are too large for economical treatment. Entrainment channels should be installed to prevent any contamination of this waste stream.
- Concentrate low volume streams can be biologically treated in lagoons or aerobically in an activated sludge plant.

By-Products

In almost all sugar factories and refineries, by-products are recovered for industrial use, for animal feeding and for fertilizing.[5]

Boiler ash and fly ash

Boiler ash and fly ash can be used in glass manufacturing, as a basic fertilizer in agriculture and incorporated in slag cement and road bases. The average quantity produced is about 0.3% of the weight of cane.[6]

Another possibility is to use recovered fly ash in place of bagacillo in vacuum filters. The density and composition of fly ash and the dimension of particles would produce an excellent filter cake. The need of bagacillo for filters is about 6 kg/tc at 49% moisture, equivalent to 4 kg/tc of fly ash which is more dry. Available quantities of fly ash (5.1 kg/tc) adequately fulfil these requirements. The arrangement is very simple and inexpensive and consists of a mixing tanker and a slush pump. This is particularly interesting for those cane sugar plants that are short of bagacillo.

5 Only the main uses are indicated here. Over 150 uses of sugarcane by-products are known (J.M. Patureau - *The State of the Art in the Utilization of By-Products of the Cane Sugar Industry*. ISCTT Jakarta 1987).

6 i.e. 1000 t of bagasse ashes for a factory handling 300.000 t of cane. 1 t of ashes gives some 21 kg of CaO, 8 kg of MgO, 3 kg of P2O5 and 15 kg of K2O.

Bagasse

1000 kg of cane produces some 250/300 kg of bagasse, consisting on average of 49% water, 48.5% fibre and 2.5% of dry matters (sucrose and non sucrose). Most of it is used to generate the steam and energy required by the factory. Surplus bagasse, due to its low density (160 kg/m^3) and relative inflammability, is a cumbersome material to handle and transport. It is generally used to produce paper, board and electricity.

Filter mud

About 30-35 kg of filter mud are produced per tonne of cane. Filter mud consists of 80% water and 0.9 to 1.5% sugar. It can be spread directly on agricultural fields or stored in an intermediary silo for later use as a soil conditioner. When used for this purpose care must be taken to avoid runoff to watercourses; filter mud has a large BOD load.

Molasses

Between 27 kg to 40 kg (average 30 kg) of molasses are produced per tonne of cane. Its average composition is 20% water, 35% sucrose, 20% reducing sugar, 15% sulphated ash and 10% others. Molasses is mainly used as animal feed or transformed into rum, alcohol or ethanol by fermentation and distillation.

In the distillery, 1000 kg of molasses give 400 l of pure alcohol (240 kg) and 380 l of stillage (also called slop or vinasses). Direct distillation of 1000 kg of cane juice yields approximately 70 l of pure alcohol and 910 l of vinasses. Vinasses are often sent to the cane field as fertilizer, either pumped to neighbouring fields or carried to more remote fields in motor tankers. If not adequately controlled by agronomists, this practice constitutes a major risk to the environment and especially for the contamination of ground waters.

The use of dilute molasses and vinasses as fertilizers is much more complicated than the use of ashes and filter mud for such purposes. Successful fertilization with molasses and vinasses must consider the demand of the cane plant which differs with variety, age, soil, climatic condition and season. Furthermore, the retention time needed for the release of the fertilizing elements from the by-product has to be considered in relation to the permeability of the soil.

Irrigation with Residuals

The residual water from cane sugar operations has a high content of organic matter and nutrients and is thus considered a valuable bio-fertilizer. In countries where water is scarce, cane sugar effluent can be used for irrigation. With strict control and norms of application it can be considered the most practicable technology. In Cuba, irrigation with residual water has been systematically used with the following modes of application (Bibliography 9):

- Outflows with high dissolved salt content, particularly sodium, and acidic effluent must be separated from the water used for irrigation. Examples of such effluents are exhausted soda, overflow from the coolers when soda has been used to raise the pH and acidic cleaning water.

- After preliminary treatment to remove oil and suspended matters and correction of pH, the residues are cooled and homogenized before being applied to the soil. A storage system with two reservoirs designed for the total volume of residual water from the sugar factory is used. In the first reservoir the water remains for one or two days, giving time for homogenization and cooling, but without allowing degradation of the organic matter. The second reservoir is only for preventing the water from spilling into a watercourse when steady irrigation is not possible.

- One year of effluent irrigation must be followed by one year of normal irrigation for light soils (two year periods for heavy soils), and in both cases using standards that do not exceed 300 to 400 m^3/hectare at intervals of 10 to 15 days.

- The salt level in the soil subject to irrigation with cane sugar effluent must be checked periodically.

- Where necessary, grease and oil traps are installed and cleaned periodically.

- Due to the high Carbon/Nitrogen (C/N) ratio in this type of water, irrigation must not be applied intensively during the first stages of crop development, during which time plants require more nitrogen. It might be necessary to add a nitrogen fertilizer.

Actual investment, operating and maintenance costs, and savings for a cane sugar effluent irrigation system, compiled in Table 5, is based upon experiences from Cuba.

Table 5: Cost and Benefits of an Effluent Irrigation System of a 6,800 tc/day Sugar Factory in Cuba. (1991 US$)

Technology	Investment (US$)	Maintenance and operating cost (US$/1000m³ effluent)	Savings (US$/1000m³ effluent)
Irrigation system	297,000	59.24	40.76

The plant in question produces about 0.55 m^3 effluent for every tonne of milled cane or 560,000 m^3 per crop season. The pay-back period for the investment is thus approximately 13 crop seasons. 188 hectares are irrigated.

Source: Bibliography 9

Add-on treatment technologies

Atmospheric emission control

The major air emission is suspended particles from boilers. These can be removed from the exhaust stream by use of centrifugal collectors, fabric filters (baghouses), electrostatic precipitators and wet scrubbers.

Wet scrubbing is the most commonly used air pollution control technology in sugar cane factories. The fumes enter a chamber in which water is sprayed. The wet cinders drop and are driven out by a water flow. Another method (the Modave system) involves cast iron columns of triangular section along which water runs. The efficiency of wet scrubbers is as high as 95-96%. Water consumption is 0.4 to 0.5 m^3 for 1000 m^3 of fumes. Well-managed wet scrubbers can be very efficient, but they do not remove the smallest particles which can be scattered as far as 20 km from the factory.

Centrifugal collectors are used for removing particulate and for drawing air through the boiler. They can be of simple-cyclones or multi-cyclones type (efficiency 75% and up to 96% respectively); in the last case the rate of dust can be decreased until 500 mg/m^3.

There are various designs of electrostatic precipitators. They act by ionizing the dust particles in the gas stream and pulling them in an electrostatic field towards an electrode which is periodically cleared. The efficiency can be very high, but the equipment is voluminous and expensive.

Waste water treatment

In raw cane sugar factories, treatment, when it exists, is often of a rudimentary nature, consisting of the impoundment of all contaminated water with eventual recycling of cane wash water. As ponds generally have not been designed with accuracy and are not controlled, the results obtained are unpredictable.

Cane sugar refineries often have a more controlled effluent treatment. Current practices include impoundment systems, sometimes with double lagooning and disposal of process waters into municipal sewers.

Lagooning System

When land is readily available, the double or triple lagooning systems are considered the best and most economic technological solutions (BPTEA). They are both well adapted to the average pollution load of process waters from cane sugar factories and refineries.

The double lagooning system consists of an initial anaerobic lagoon (depth: 2.5 to 3 m), followed by a second, aerobic lagoon (depth: 0.8 to 1 m). The retention time and the surface covered must be calculated separately considering the difference between the two modes of bacterial behaviour. BOD reduction is about 70% in a double lagooning system.

In China, most sugar mills which burn coal remove the furnace cinder by high pressure water jet. This effluent, together with the water used when removing fly ash from the flue gas, is treated in two stages. The effluent is first mixed with a coagulant and solids settle in the first pond where coarse sludge is removed. The clarified water then enters the second pond to remove the fine particles. The treated waste water meets the demand of the national effluent standard. The coarse sludge contains a certain amount of unburned coal, which can be reused. Usually the recovered coal will cover the cost of the coagulant.

In Louisiana, USA, the spent cane wash water is settled, after filtration, in a clarifier and sent to a simple or double lagoon.

The advantages of lagooning systems are low capital investment and insignificant operating and maintenance costs. The major inconveniences are the large areas required, the eventual danger of subsoil contamination and the production of undesirable odours during the anaerobic putrefaction phases. With properly designed ponds the last two disadvantages disappear.

Aerobic Fermentation for Concentrate Waste Streams

Various processes are used deriving from the clarification of sludge waters in beet sugar factories. In the Eimco-Process a clarifier is used with the introduction of oxygen by surface aerators. The clarification and treatment require two hours within which BOD is reduced by 40-60%.

In the R.T. Lefrancois Process the clarification is preceded by a fermentation stage. Oxygen is introduced at the bottom of the fermentor as compressed air. The air achieves also a systematic circulation and agitation of the mixed liquor in the fermentor. The process is suitable for a heavy pollution load (BOD_5 up 5.000 mgO_2/l) and can accomplish 90% BOD_5 reduction. It is characterized by: high concentration of activated sludge (SS 11 to 16 g/l); retention time: 4 h; energy consumption: 0.6 kwh/kg BOD_5.

Anaerobic Treatment

The advantage of anaerobic treatment is the production of methane by methanobacteria through the stages of hydrolysis, acidification, acetogenesis and methanogenesis. Basic industrial applications are: fermentor with mechanical agitator; fermentor with sludge expanded bed; fermentor with fixed bacteria film; and the upflow anaerobic sludge blanket.

Finishing Systems

To meet effluent standards that are stricter than normal, due to, for example, an urban center in the vicinity, sugar factories or refineries may have to use more than one treatment process. The most often used finishing systems are:

- aerobic lagooning: retention time is about eight to 12 days. Oxygenation can be done by aerators or air dispersing turbines.
- oxidation ditch with surface aerators
- bacteriological filters.

Capital, Operating and Maintenance Costs

Estimated capital, operating and maintenance costs for effluent treatment technologies are compiled in Table 6.

Table 6: Capital, Operating and Maintenance Costs for Cane Sugar Effluent Treatment (1991, US$).

Treatment Technology	Investment (US$)	Maintenance & operating cost (% of total plant operating cost)
Natural lagooning for 3000 tc/day factory	120,000[a)]	Insignificant
Double lagooning for 3000 tc/day factory	200,000[b)]	0.3%
Aerobic clarifier for 3000 tc/day factory	700,000	0.8-1.4%
Anaerobic treatment for 30 tonne COD/day (28 kg COD/m^3)	2,000,000[c)]	2%

[a)]Including pumps and civil works.
[b)]Including aerators
[c)]Digestor and annexes = 1,100,000 US$
Civil works and utilities = 700,000 US$
Gas circuit etc. = 200,000 US$

For other capacities than those mentioned the equation $P=P_i(C/Ci)^{0.65}$ can be used, in which: P=investment cost to be determined; P_i=indicated cost; C=capacity of the installation; and C_i=indicated capacity.

Source: Information communicated to the author

Occupational health and safety issues

Some years ago, sugar was thought to be a cause of degenerative diseases such as atheroma, coronary heart disease and diabetes mellitus. Except in the case of dental caries, the evidence for such connections is disputed.

There are few health problems associated with cane sugar processing and refining. The major hazards include bagassosis from handling dry bagasse and inhalation of sulphur dioxide at the sulphitation station (if in use). Both affect few people and can be limited by using a textile mask placed over the nose and mouth. Persons working in bagasse stations and on sulphur furnaces should receive regular medical examinations.

Some precautions should also be taken in sugar drying areas and at storage and packaging stations. The use of protective masks is recommended, and smoking must be prohibited as sugar dust is highly explosive. Fly ash from bagasse fired boilers can also be a severe airborne irritant.

Global overview of discharge guidelines

North America

Under the Federal Water Pollution Control Act Amendments of 1972, the US Environmental Protection Agency issued effluent guidelines and standards for the sugar processing point source category. These cover raw cane sugar processing in several different areas (Louisiana, Florida, Texas, Hawaii and Puerto Rico), as well as crystalline cane sugar refining and liquid cane sugar refining.

The effluent limitations for the State of Louisiana are given as an example of those for raw cane sugar. They represent the degree of effluent reduction attainable by the application of the "best practicable control technology currently available" (BPT), and are given separately for the continuous discharge of waste waters and for factories using waste stabilization.

For crystalline cane sugar refining, effluent limitations for existing refineries are given both for BPT and for the "best available technology economically achievable" (BAT).

Table 7: Effluent Limitations for Raw Cane Sugar Processing (Louisiana, USA)

	Continuous discharge		**Waste stabilization**
Parameter	Maximum for any one day (kg/tonne of cane)	Maximum average of daily values for 30 consecutive days (kg/tonne of cane)	Maximum daily values for entire discharge period (kg/tonne of cane)
BOD_5 [a]	1.14	0.63	0.63
TSS [b]	1.14	0.47	0.47

[a] For barometric condenser cooling water together with treated process waste water.

[b] For treated process waste water only.

Source: Bibliography 16.

Table 8: Effluent limitations for existing crystalline cane sugar refineries (USA)

	Maximum for any one day (kg/tonne of melt)		Maximum average of daily values for 30 consecutive days (kg/tonne of melt)	
Parameter	BPT	BAT	BPT	BAT
BOD_5	1.19 (1.02)[a)]	0.18	0.43 (0.32)[a)]	0.09
TSS	0.27[b)]	0.11	0.19[b)]	0.035

a) For barometric condenser cooling water together with treated process waste water.
b) For treated process waste water only.

Source: Bibliography 16.

Table 9: Effluent limitations for existing liquid cane sugar refineries in the USA.

	Maximum for any one day (kg/tonne of melt)		Maximum average of daily values for 30 consecutive days (kg/tonne of melt)	
Parameter	BPT	BAT	BPT	BAT
BOD_5	0.78 (0.45)[a)]	0.3	0.32 (0.15)[a)]	0.15
TSS	0.50[b)]	0.09	0.17[b)]	0.03

a) Applies to refineries discharging barometric condenser cooling water only.
b) No limitation imposed on refineries discharging barometric condenser cooling water only.

Source: Bibliography 16.

OECD countries

Except in the south of Spain, there are no cane sugar factories in OECD countries. For sugar refineries, the effluent limitations are different for each OECD country.

The OECD legislation introduces the notion of industrial waste water similar to urban waste effluent for all agro-food industries. It contains the following effluent standards:

- BOD_5: 25 mg/l or 70 to 90% reduction
- COD: 100 mg/l or 75% reduction
- SS: 30 mg/l

Developing countries

Legislation varies from one country to another. The main problem is not the standards but the enforcement of them. This problem is accentuated when sugar factories are isolated and far from urban centres.

In China, the maximum allowed concentration of effluent discharges is dependent on the raw material (cane or beet), the age of the plant (new or old) and the location of the province. The effluent limitations are expressed in concentration for a given volume of waste water per tonne of raw material.

Table 10: National Integrated Control Standard in China. Maximum Allowed Concentration of Sewage Discharges

Type of production	Old or New/ reconstructed plant	Maximum volume of waste water plant plant	Maximum allowed concentration of sewage discharges					
			BOD_5 Class		COD Class		Soluble Solids Class	
			I	II	I	II	I	II
Cane sugar factory	New	$10 m^3$/t cane		100		160		150
	Old	$14 m^3$/t cane	100	120	160	200	150	200
Beet sugar factory	New	$4 m^3$/t beet		140		250		200
	Old	$6 m^3$/t beet	150	250	250	400	200	300
Alcohol from molasses	New	$70 m^3$/t alcohol		200		350		200
	Old	$80 m^3$/t alcohol	200	300	350	450	200	300

Source: Bibliography 2, (GB89 78-88 UDC 628.391 628.54).

Table 11: Integrated Control Standard of Guangdong Province. Maximum Allowed Concentrations of Sewage Discharges

Type of production	Old or New/ reconstructed plant	Maximum volume of waste water plant plant	Maximum allowed concentration of sewage discharges					
			BOD_5 Class		COD Class		Soluble Solids Class	
			II&III	IV	II&III	IV	II&III	IV
Cane sugar factory	unclassified	$17m^3$/t cane			100	120		
Alcohol and other products from molasses	unclassified	$70m^3$/t alcohol $600m^3$/t gourmet powder	150	200	300	350		
Alcohol and other products from molasses	New	$70m^3$/t alcohol		200		350		200
	Old	$80m^3$/t alcohol	200	300	350	450	200	300

Source: Bibliography 2, (GB89 78-88 UDC 628.391 628.54).

In India and Taiwan, discharge standards for sugar industries are as described in Table 12.

Table 12: Discharge Standards for Sugar Industries in India and Taiwan

PARAMETER	INDIA	TAIWAN
BOD mg/l	100a) (30b))	80
TSS mg/l	100a) (30b))	200
COD mg/l	-	300

a) Disposal on land
b) Discharge in surface waters

Sources: Environmental Protection Rule. Ministry of Environment and Forests. 1986; and Effluent standards under Water Pollution Control Law, section 9.2 - Environmental Protection Laws in Taiwan. 1991.

Required emission standards [7]

The following standards must be met in all projects financed by the World Bank.[8] The requirements are expressed as considerations to facilitate monitoring. Dilution of effluents to achieve these requirements is unacceptable.

Air emissions

Particulate matter and sulphur oxide emissions should be less than 50 mg/Nm3 (in some cases, 150 mg and 2,000 mg/Nm3 respectively.

Nitrogen Oxide emissions should be less that 260 ng/J (750 mg/Nm3) for solid fuels and 130 ng/J (460 mg/Nm3) for liquid fuels. Odour controls should be implemented where necessary to achieve acceptable odour quality for nearby residents.

Liquid Effluents

EFFLUENTS FROM SUGAR MANUFACTURING

PARAMETER	MAXIMUM VALUE
pH	6-9
BOD_5	50 mg/1
COD	250 mg/1
Total suspended solids	50 mg/1
Oil and grease	10 mg/1
Temperature increase	less than or equal to 3°[9]

The following effluent levels should be achieved:
Biocides should not be present above detection levels or should be less than 0.05 mg/i.

Noise Abatement

Noise abatement measures should achieve the following levels, measured at noise receptors located outside the project property boundary, with an increase in existing ambient level of less than 5dBa.

7 From: *Pollution Prevention and Abatement Handbook - Part III Sugar Manufacturing*, October 30, 1996

8 This technical guideline is part of the World Bank Group's *Pollution Prevention and Abatements Handbook* and should be read in conjunction with the Introduction as well as Parts I and II which spell out important policy and procedural considerations. The information is intended for use by the World Bank staff and consultants in carrying out the policies set out in the *Operational Policy on Environmental Assessment* (OP4.01) and related documents.

9 Subject to the Environmental Assessment (see OP 4.01).

Permitted levels of noise

RECEPTOR AREA	LIMIT IN dBA	
	Day time	Night time
Residential	55	45
Commercial	65	55
Industrial	70	65

The emission requirements given here can be consistently achieved by well-designed, well-operated and well-maintained pollution control systems

Monitoring and reporting

Monitoring of air emissions should be on an annual basis with continuous monitoring of the fuel used. Only fuels with acceptable levels of ash and sulphur should be used. Monitoring of the final effluent for the parameters listed above should be carried out at least on a daily basis, or more frequently if the flows vary significantly. Effluents should be annually sampled for biocides to ensure that they are not present at significant levels.

Monitoring data should be analysed and reviewed at regular intervals and compared with the operating standards so that the necessary corrective actions can be taken. Records of monitoring results should be kept in acceptable format. These should be reported to the responsible authorities and relevant parties, as required.

Key Issues

The following points summarize the key production and control practices that will lead to compliance with emission requirements:

- Monitor key production parameters to reduce product losses to less than 10 percent;
- Design and operate the production system to achieve recommended waste water loads;
- Recirculate cooling water; and
- Collect waste for use in low-grade products.

Monitoring requirements

Monitoring of COD and SS content of the effluent can and should be checked in every factory. It requires only a minimum of training of laboratory personnel.

Effective management of final effluents

There are three basic ways to effectively manage final effluents:

- Reuse;
- Valorization; and
- Treatment and discharge

Reuse of final water effluents from sugar factories

The reuse of residual waters for the purpose of irrigation does require special precautions. An effective guideline to this process is outlined in the previous pages of this Booklet II in *Pollution Prevention and Abatement Guidelines for Cane Sugar Processing and Refining.*[10]

Treatment

In a well-managed sugar factory, effluent water should be limited to excesses from the condensate stream, wash cleaning water, and cooling water from the sulphitation and other stations.

Wash cleaning water is the main source of pollution. By using a dry cleaning system and adopting all other recommendations, the total pollution load should be less than 180 mg/l of COD. When some special attention is applied to laboratory and sanitary waste water, then according to specific country states regulations, there is usually no need for a treatment plant.

Reluctance to introduce a no-cost, dry cleaning system into a factory may mean legislation regarding waste water disposal is being infringed. In this case the installation of a water treatment plan may prove unavoidable.

10 UNIDO, 1995, reference 5.3.2.5

The method used to calculate and install an efficient double lagooning system - possible to realise with in-house resources - is described below:

Basic data:

- Capacity of the cane sugar factory: 4 000 tcd

- Factory effluents:
  - effluent flow: 110 m^3/hour
  - BOD_5 load = 800 to 1 200 mg O_2/litre
  - COD load = 1 360 to 2 050 mg O_2/litre
  - S.S = 500 mg/litre
  - Presence of mineral oil and grease

- Domestic waters:
  - effluent flow: 6 m^3/hour
  - BOD_5 load = 350 mg O_2/litre
  - COD load = 600 mg O_2/litre

- Environmental data:

DATA	UNITS	MAX.	MIN.	AVERAGE
Ambient temperature	**°C**	**31**	**22**	**26**
Humidity	**%**	**90**	**81**	**86**
sunshine hours	**hours/day**			**6.5**

Proposed system of treatment:

a) Inability to segregate water in the following categories:

- Cleaning water from tubular heat exchangers;
- Water from laboratory; and
- Water from boiler bleedings.

Water coming from these sources should be first neutralised, then released – in limited quantities – into the final collector. It DOES NOT need to be processed by the waste water treatment plant.

b) Normal, every-day effluents require the following three-stage biological treatment:

- Pre-treatment: screening, sedimentation and degreasing
- Anaerobic treatment in a bacterial pond (microphytes)
- Aerobic treatment in a macrophytes pond

It will be useful to recirculate water from the aerobic pond to the anaerobic pond (recirculation rate = 15%). This allows the return and activation of inlet waters rich in oxygen and helps eliminate bad odours.

Calculations

Anaerobic lagoon

The COD degradation is an exponential function of time: $y = y_0\ e^{-kt}$ in which k is a factor dependant on temperature and climatic conditions. For usual tropical conditions $0.02<k.<0.03$

The elements of the pond are calculated in three steps:

- Surface of the pond: $S = F\ (C_1 - C_2)/L$, in which:
  S = surface of the pond in ha
  F = effluent flow in m^3/day
  C_1 = inlet COD load in mg O_2 /litre
  C_2 = required outlet COD load in mg O_2 /litre
  L = admissible COD load of anaerobic pond in kg /ha/day
  For usual tropical conditions $350 < L < 600$ (From Mara experimentations in Brazil)

- Retention time T is calculated from the degradation formula $y = y_0\ e^{-kt}$
  $T(day) = (Log\ C_2 - Log\ C_1)/k$

- Theoretical volume of the pond and water level:
  $V\ (m^3) = F\ T$ and $h\ (m) = V\ (m^3)/\ 10^4\ S\ (ha)$

Aerobic lagoon

The COD degradation is an homographic function of time: $y = y_0/(1+\lambda t)$ in which λ is a factor depending on temperature θ and climatic conditions. For cane sugar factories:

$\lambda = 0.181 \times (1.084)^{(\theta-16)}$

All other calculations follow the same sequence set out above, the admissible load of an aerobic pond L (in kg/ha/day) ranges $100<L<350$.

Calculation results

	ANAEROBIC POND	AEROBIC POND
Surface (ha)	3.7	1.6
Water level (m)	3.5	1
Height of the pond (m)	4	1.5
Retention time (days)	41	6

Each pond is calculated in order to obtain a pollution abatement rate of 70%. The total abatement rate during usual working conditions should be 90%. After treatment, BOD_5 load should not exceed 120 mg O_2/litre in final discharge and the COD load 200 mg O_2/litre.

Civil works and management requirements

Special precautions are required both during the construction and in follow-up management.

Although space limitations of this manual does not permit further descriptions, more detailed information can be obtained from:

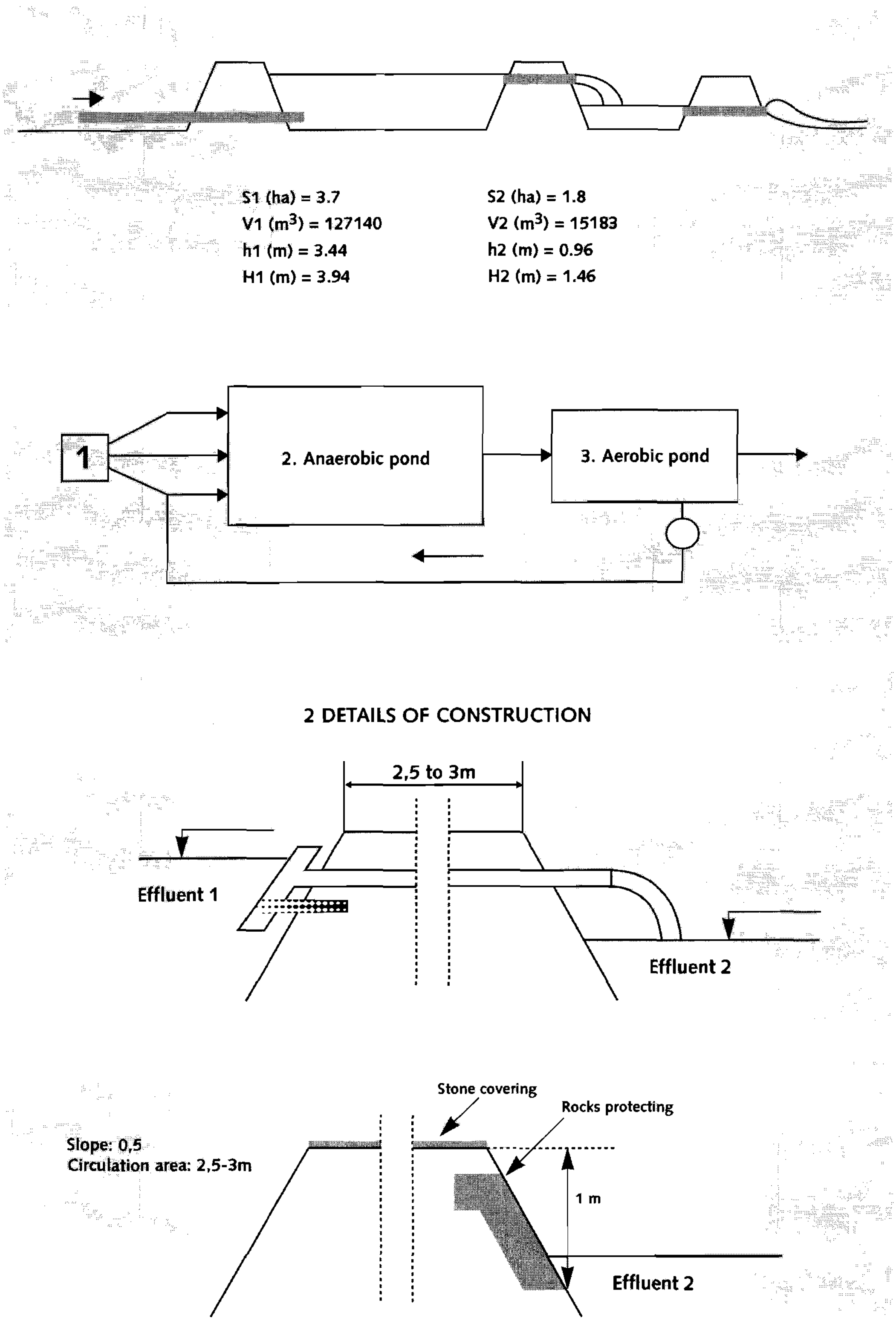
United Nations industrial Development Organization (UNIDO)
Agro-based Industries Branch
Industrial Sectors and Environment Division
P.O. Box 300
Vienna, Austria, A-1400
Fax +43 1 211 31 6349

Reuse of waste material from distilleries

Vinasses

Soil loses quantities of potassium, phosphorus and lime to the sugarcane during the growing season. It is possible, however, to recover these important soil elements in the sugar factory in the form of cinders, filter muds and final molasses. Their return to the soil is an important economic consideration. Filter mud is usually returned to the field, but the cinders may be overlooked. As the total amount of mineral nutrients encompassed in molasses is recovered in vinasses from the distillation process, it make sense to mix vinasses and filter mud and apply them to the fields in one spreading operation. This material will have the same consistency as a standard agricultural slurry.

Fig. 3: Scheme of the Double Lagooning System



This solution produces immediate advantages, including:

- The filter mud (and the ash cinders) neutralises the acidity of the spent wash;
- Only one transport system for the combined slurry is required;
- Spreading the combined material in the form of 15,000 litres per hectare (filter mud 2,600 l/ha + vinasses 12,000 kg/ha) will ensure the equal distribution of all the fertiliser compounds over the complete surface. It is practically impossible to obtain this equal distribution by spreading filter mud alone. The technique permits the homogeneous spreading of filter mud over the entire surface instead of increased doses on specific pieces of land.
- Using this slurry liquid is far easier than storing chemical fertilisers, or spreading them in the field.

A good solution is to build a facility close to the factory where the vinasses, filter mud and ash cinders can be combined. This mixture can be maintained in a homogeneous manner by using floating agitators. By a judicious blending of the vinasse and the filter mud, it is possible to obtain a syrup-like liquid that is very suitable for spreading on land.

Spreading the fields can be carried out using slurry tankers (approximate size 7.5 tonnes), pulled by four wheel drive tractors with an engine capacity of about 80 horse power. Spreading of 15,000 litres per hectare – two full slurry tanker loads of 7.5 tonnes each – will prove less expensive than spreading of 2.6 tonnes of filter mud and 4 tonnes of vinasses per hectare.

Treatment and methane production

The treatment of vinasses and the production of methane through an aerobic digest remains out of the scope of a DO-IT-YOURSELF installation, however it is of special interest to an autonomous distillery because it combines three advantages:

- Treatment of stillage effluents;
- Economic use of energy; and
- Preserving molasses mineral content in the bio-digestor slurries for possible field application

Descriptions here will only cover calculations for the production of methane and for economic use of energy.

Production of methane
After determining the COD load in vinasses it is possible to assume that 100 kg COD results from the production of 100 litres of alcohol (usual value).

With a usual elimination rate of 68% and a production of .0.35m^3 per Kg of COD, methane production will be:

100 x 68% x 0.35 = 24 m^3/hl of alcohol

If the net calorific value is compared:

- methane = 8 570 kcal/kg (35 860 k J/kg)
- heavy fuel oil n°2 = 9 350 kcal/kg (39 140 k J/kg)

Then:

240m^3 of methane is equivalent to 22 kg of fuel oil n°2.

Fuel economy for an independent distillery: (classic process, wine fermentation: 7.5° G.L)

For the production of one hectolitre of alcohol

PRODUCTION	STEAM	FUEL OIL	ECONOMY
Rum at 65° GL	**235**	**19**	**>100%**
Rectified alcohol 96° GL	**290**	**23**	**95%**
Refined alcohol (double rectification)	**500**	**40**	**55%**

Added expenses:

- water: 2 to 3.5 m^3/hl of alcohol
- electricity: 1.2 to 1.4 kW/hl of alcohol

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