MEASURES AGAINST WATER POLLUTION IN BEET SUGAR PROCESSING INDUSTRIES

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ABSTRACT

In an introduction to the process the three principal steps are first mentioned: preparation of juice by extraction, purifying this juice and crystallizing sugar from the purified juice. A more complete flow sheet is then given, considering water use and re-use and effluent production in every step. A completely open factory would produce between 100000 and 200000 population equivalents per 1000 metric tons daily capacity.

After the introduction of modern continuous extraction equipment, the recirculation of the hot water from the jet condensers and the elimination of all spill and overflow, the only remaining inevitable source of pollution is the loss of juice from wounded beets in the transport- and wash-waters. This loss is directly proportional to the injured beet surface. Undamaged beets would cause a loss of 0.025% sugar, and a pollution of 2500 population equivalents (1–2% of an open factory). Mechanization of beet harvest and transport, however, caused a rise in sugar losses to about 0.2% of the beet weight. At this level of injury practically no part of the beet surface remains undamaged. When we want to diminish pollution, a programme to minimize beet injury deserves priority.

A reduction of sugar losses by 0.1%, relative to the Dutch beet harvest, can be assessed at $1\frac{1}{2}$ million guilders per annum in the form of export sugar, apart from a pollution abatement of 600000 population equivalents.

A further decrease of pollution can be realized by lagooning and biological purification, the economic optimum depending on local conditions.

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1. INTRODUCTION

The problems of waste waters in sugar factories were excellently treated by my colleague J. Henry in 1963[1]. Since then the subject was reviewed extensively in English by G. W. Crane[2, 3], in German by F. Schneider and H. P. Hoffmann-Walbeck[4, 5], in French by P. Devillers[9] and in several other publications.

In treating the subject again on the occasion of this International Congress on Industrial Waste Water I will try to introduce the process and the generally known details of water re-use in sugar factories as concisely as is feasible to give a basic understanding to those unfamiliar with the sugar industry. After that it will be possible to pay more attention to some actual problems related to reduction of losses in the factory and to the treatment of inevitable waste waters.

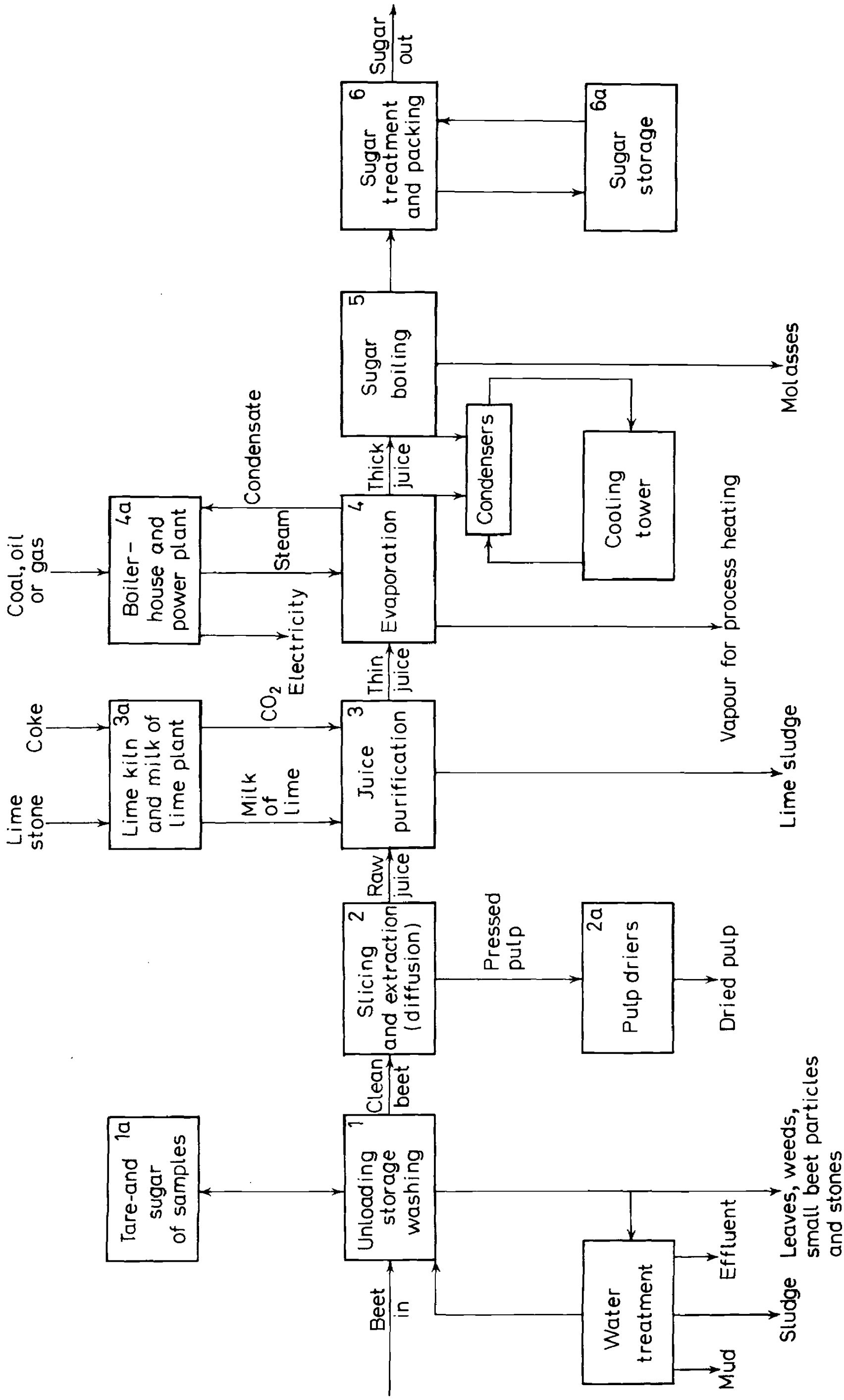
Beet in
Unloading storage washing 1
Tare-and sugar of samples 1a
Clean beet
Slicing and extraction (diffusion) 2
Pressed pulp
Pulp driers 2a
Dried pulp
Raw juice
Lime stone
Coke
Lime kiln and milk of lime plant 3a
Milk of lime
CO_2
Juice purification 3
Thin juice
Coal, oil or gas
Boiler– house and power plant 4a
Electricity
Steam
Condensate
Evaporation 4
Thick juice
Sugar boiling 5
Condensers
Cooling tower
Sugar treatment and packing 6
Sugar storage 6a
Sugar out
Water treatment
Mud
Sludge
Effluent
Leaves, weeds, small beet particles and stones
Lime sludge
Vapour for process heating
Molasses

Figure 1. Flow sheet of a beet sugar factory

1. The beets, after having arrived by lorry, barge or rail, are unloaded mechanically or hydraulically. They are floated to the factory, either directly or after temporary storage, and washed.

1a. Sugar and tare determinations are made in samples from every load.

2. The clean beets are sliced and extracted.

2a. The pulp, remaining after extraction, is used as a fodder or dried for long term use.

3. The raw juice is purified by lime and carbon dioxide. The precipitated calcium carbonate is filtered off and the lime-cake (sludge) is removed.

3a. Burned lime and carbon dioxide are prepared in factory-owned installations.

4. The function of the evaporation is not only to concentrate the juice, but also to distribute vapour of different pressures and temperatures.

4a. Energy comes from boiler house and power station.

5. The sugar in the thick juice is crystallized stepwise by continued concentration. Crystals and juice are separated in centrifugals.

6. The sugar is dried, screened and packed.

6a. Ample storage room is required because of the campaign way of manufacture.

2. FLOW SHEET OF A BEET SUGAR FACTORY AND THE USE OF WATER

Introduction to the process

Making sugar from beets is in its essence a simple process, unchanged in its principal steps for about a century. Three basic steps are needed for this task:

(i) making juice out of the beets
(ii) purifying this juice in order to make crystallization possible
(iii) crystallizing sugar from the juice.

In reality these three processes are the principal stations in a beet-sugar factory.

In the flow sheet of *Figure 1* a number of indispensable extra operations is added, the function of which will be clear from the accompanying text. On the photograph of *Figure 2* we recognize the corresponding parts of a real factory. In the next section more details will be given if necessary. Quantities are either given as percentages of the quantities of beet or they are related to a factory working a unit quantity of 1000 metric tons of beet a day. Most factories have daily working capacities varying from 2500 to 10 000 metric tons of beet. Sugar production is about 13 per cent of the quantity of beets worked. The factory of *Figure 2* is processing about 7000 tons of beet a day.

The water

Water is playing an important part in every step of the process. Following the flow sheet from left to right we subsequently meet the places where water may be polluted.

Transport and wash waters

Beets, when harvested, are lifted from the field by harvesting machines which leave a certain percentage of soil (tare) sticking to them. Tare percentages vary normally between 10 and 25 per cent but in some regions even 40 per cent is not unusual. Type of soil, weather and harvesting system, each of them have their own influence on the tare, which has to be washed off the beets before further processing is possible. Washing being unavoidable, it is convenient to transport the beets into the factory by water as well. In this way adhering soil is also softened before washing.

Beets can be either unloaded directly by high pressure water jets from the lorries and wagons into the factory or stored after unloading, and transported afterwards. In at least one point of their travel vertical transport is needed, for which a great variety of apparatuses is being used. Stones and weeds are caught by special installations, after which the beets arrive at the washer. The combined transport and wash waters form the first stream of effluent. Its quantity is usually 7 to 10 times the beet weight.

Juice extraction

Water is used to extract sugar from beets, but in contradiction to the old type of diffuser, no effluent is created in the modern continuous type of extraction equipment. All presswaters from the pulp are reintroduced into the extraction apparatus. The same procedure should and can be used in the case of the old

Figure 2. The various stations of a beet sugar factory (to be compared with *Figure 1*).

1. Unloading and storage of beets (barge and lorry)
1a. Tare laboratory
2. Extraction plant
2a. Pulp driers (with steam cloud)
3. Juice purification
3a. Lime kilns, with lime-stone in front
4. Evaporation
4a. Boiler house and power station
5. Crystallization
6. Sugar handling
6a. Silos

type battery-diffusers, which will otherwise form a serious source of water pollution.

Lime sludge

This is the filter-cake which forms during filtration of the calcium carbonate precipitate in juice purification. It contains about 50 per cent of dry substance and can be pumped undiluted to storage lagoons or removed by band conveyors. Factories removing their filter-cake together with the dirty water from the beet washing and transport considerably increase the pollution load, as the lime sludge contains the organic impurities, removed in juice purification.

Condensers

Vapours from the boiling station and evaporation are condensed in jet condensers. The hot condenser waters are the second stream of effluent. The quantity, depending on the outlet temperature of the condenser, is in the order of five times the beet weight.

Miscellaneous process waters

There are several other effluent streams of varying importance. We mention:

(i) Surplus condensate, originating from the water content of the beets.

(ii) Brine from ion-exchangers. Juice is often decalcified in order to prevent incrustations in the evaporator tubes. On regeneration, salt containing waste water is produced.

(iii) Spill, leakage, overflows, water for floor cleaning.

(iv) Wash water for filter cloths is becoming extinct because continuous filters are taking the place of filter presses.

(v) Cooling water, water for gas scrubbing, blow-off water from boilers.

(vi) Lavatories and rainwater.

Summarizing we have seen two important sources of waste water, *viz.* the transport and wash waters of the beets and the hot condenser water. Apart from that we have to take into account excess condensate, regeneration brine from ion exchangers, and leakage, spill and overflows.

3. NATURE OF THE WATER CONTAMINATION AND MEASUREMENT THEREOF

Kind of contaminants

The raw juice extracted from the beets contains about 90 per cent sugar on solids. The remaining 10 per cent is for about one quarter to one third of an inorganic nature. We can conclude that sugar is the principal component of all process streams so that most of the organic pollution of a sugar factory really is sugar.

For the measurement of pollution, sugar, COD or BOD_5 determinations are used. In some cases organic carbon analyses are preferred. For sugar, COD and BOD_5 we use some rough-and-ready rules which are reproduced in *Table 1.*

Table 1. Rough-and-ready rules for loss and water pollution

$$C_{12}H_{22}O_{11} + 12\,O_2 \rightarrow 12\,CO_2 + 11\,H_2O$$

1 gram of sugar needs 1.122 g of oxygen
Apart from sugar we must take into account 20% other contaminants. Therefore
1 g of sugar is equivalent to $1.2 \times 1.12 = 1.35$ g COD
1 g BOD_5 = 1.8 g COD

$$1 \text{ g of sugar} = \frac{1.35}{1.80} = 0.75 \text{ g } BOD_5$$

75 g BOD_5 = 135 g COD = 100 g sugar daily
is 1 population equivalent.

They enable us to keep an eye on water pollution when we make micro-sugar determinations for tracing sugar losses, and conversely we can make an estimate of the losses from COD measurements. By doing so we must be aware of two things we have neglected in *Table 1*:

(i) The role of nitrogen. The hot condenser waters may contain a fair amount of ammonia, which may cause an extra consumption of BOD up to 10 per cent.

(ii) Organic matter in suspension such as small beet particles, rootlets, humus from the soil, weeds, etc., can cause extra contamination in undecanted waste water.

Quantitative measurements

This subject is dealt with in another section of this Congress, but it is perhaps useful to mention here two methods we have successfully applied in our factories:

(i) Determination of water flow by salt injection. Brine is pumped with constant flow into the stream for a certain time. Salt concentration downstream can be analysed by flame photometer or specific ion electrodes and used to calculate flow.

(ii) Sugar concentration by the use of the colour reaction between sucrose, resorcinol and hydrochloric acid. This reaction can also be performed on the auto-analyser for large series or continuous registration.

Volume of pollution load

A factory using fresh water without any re-use, with battery-diffusers and washing away lime sludge causes a water pollution between 100000 and 200000 population equivalents for every 1000 tons daily capacity. In the next section we will show that a reduction to 10000 to 20000 population equivalents is possible without biological purification. A further reduction can be realized by minimizing damage to the beets and by waste water purification.

4. MEASURES TO REDUCE POLLUTION

For this purpose three means are at our disposal:

(i) reducing losses at the origin
(ii) re-use of water
(iii) water purification.

In this section we will deal with the different types of effluent mentioned in section 2, from these three points of view.

Regeneration of ion exchangers

The brine from juice decalcification should be practically free of organic matter. Good control can be achieved by partly or fully automating the operation of the valves. The disposal of the salt is a more serious problem. In some cases it may be pipelined to the sea.

Spill, leakage, overflows, water for floor cleaning

All these losses can and should be avoided. Glandless constructions are often possible, *e.g.* in pumps with vertical axes, and leakage may be collected in drains and re-circulated into the process. All this needs a good mentality and keen attention from the design-phase. One example: On the bottom of the scalding trough and press-water tanks of the Buckau diffusion sand may collect, which is sluiced by special valves entraining juice and press-water. We found out that the quantity thus separated is only a fraction of the total quantity of sand in the juices, and blowing off serves no useful purpose. Part of the press water tanks could be left out and the remaining valves blended off without harmful effects.

Unexpected mechanical or technological difficulties during campaign may still cause unavoidable overflows which should be collected in special buffer containers.

Surplus condensate

When all water flows are recirculated, no fresh water is needed for the factory. The incoming beets still contain about 78 per cent ot water, causing a surplus. *Table 2* shows that from these 78 per cent, 50 per cent is condensed after evaporation in the process. About 20–30 per cent of this goes to the jet condensers, the remaining 20–30 per cent leaving the factory as excess condensate. Though containing some ammonia, it is relatively pure water and could be sent to drain after cooling in many cases. In the next sections we will see that surplus condensate usually serves as a source of fresh water for the partial renewal of the re-circulation systems.

Table 2 (a). Composition of the beet

Sugar	16%
Unsoluble cell constituents	4%
Soluble cel constituents	2%
Water	78%

Table 2 (b). Distribution of the water from the beet during processing

Evaporation in pulp dryers	22%
In dried pulp	0.5%
In lime sludge	3.5%
In molasses	1%
In boiler-blow off and regeneration of ion-exchangers	1%
Remains to be evaporated from the juice	50%
Total	78%

Hot water from the jet condensers

In rivers where only heavily polluted water is giving trouble, the wasting of the water from the jet condensers, containing 20–50 ppm BOD_5 can be tolerated. We must, however, realize that this water has a relatively high content of ammonia nitrogen (about 10 ppm), it has a temperature of about 25 °C above that of the river, it contains very little oxygen, and that in special cases an appreciable entrainment of juice droplets may take place. Entrainment separators of a suitable construction (some are really unsuitable) will catch the droplets but the ammonia will pass undisturbed.

The hot water can be recirculated after it has been cooled down in ponds or cooling towers. When the excess condensate is simultaneously cooled down, the circuit will have a surplus of about 20 per cent of the beet weight. During the cooling stage part of the volatile compounds such as ammonia will be removed. Algae growth can be prevented by dosing hypochlorite. The efficiency of the cooling towers can be improved by using special condenser constructions consuming less water with a higher outlet temperature[23, 24].

Transport and wash water

Up to this point for every effluent problem a solution could be given, offering the possibility of a practically complete elimination of pollution. The case of the transport and wash waters is principally different and causes more difficulties.

Beets are topped when harvested, that is to say, the upper disk, with the leaves is cut off. From field to factory the beets are treated rather roughly: mechanized harvesting, intermediate transport and storage at the farm, loading on lorries, sometimes transfer to barges by dumpers, unloading at the factory, transport on the yard, washing in the beet washer. In the old days there was a lot of manual handling, but mechanization has been introduced here as well.

Every time a beet is damaged, cells and vascular bundles are opened, contents of which will leak out into the transport and wash water. Two German investigations[26, 27] showed that the loss of sugar in the muddy water, which was determined at the end of last century to be 0.02 to 0.03 per cent sugar on beet, has risen to about 0.07–0.11 per cent in 1937. In our times 0.2 per cent is quite a normal figure. The magnitude of this loss is more clearly illustrated when we realize that 2000 kg of sugar daily flow into the river for every 1000 tons working capacity of the factory. According to our rough-and-ready rules this effluent is equivalent to 20000 people, which, however, is only 10 to 20 per cent of the original pollution.

The increased loss of 0.1 per cent due to mechanization, applied to the Dutch beet crop stands for an annual 5000 tons of sugar, worth $1\frac{1}{2}$ million guilders at the present world market price. The cost of the increased pollution has yet to be added.

All this sugar is present in the muddy water in a very diluted form so that regaining is out of the question. Of course we can recirculate the water, but the concentration rises according to the number of recirculations, the loss remaining constant.

As long as the circuit is not completely closed, the total amount of organic pollution does not change. Three means for reduction remain at our disposal:

(i) Putting down losses by minimizing damage to the beet
(ii) Use of a completely closed circuit
(iii) Treating the effluent by biological purification.

We have seen now that in a well managed sugar factory the inevitable water pollution is caused by the leakage of juice from the beets into the transport and wash water. The three possibilities just mentioned to reduce this pollution need to be considered further.

Cutting down losses in transport and wash waters by minimizing damage to the beets

The literature on this subject is rather limited. In 1937 Radbruch[26] and Bielitzer[27] treated the subject, answering a prize question. They could refer to three articles, published between 1890 and 1900 and to a short communication from Kryz[25] about the loss per cm^2 wounded beet surface. Becker[28] treated the losses from frost-damaged beets and Evi Swietlicka[29] reported about healing of wounds and frost damage to beets, showing very illustrative drawings after microscopic preparations by Birgitta Olofsson. Very recently Stiemerling[30] drew our attention once more to this important subject. *Figure 3* shows curves representing the extraction of sugar from beet, gently brought into contact with water. The two lines of Radbruch[26] fit in with those of our own experiments.

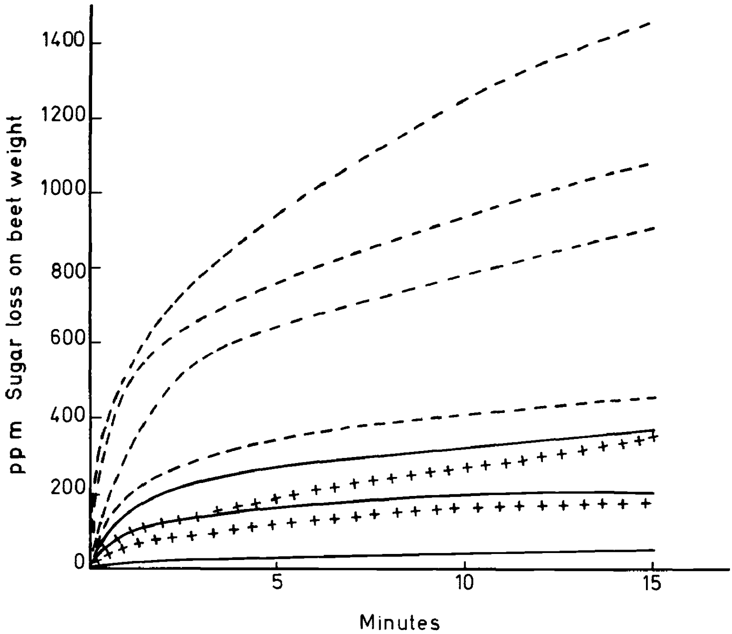

Figure 3. Loss of sugar from beets in transport water according to model experiments. When beets are brought into contact with water (as is done during the hydraulic transport at the factory yard) sugar is leached from the wounded surfaces. After a normal residence time of four minutes the loss hardly rises any more, except when the beets are heavily damaged by frost or severe mechanical handling. —— normal beets after unloading at the factory; + + + the same according to Radbruch[26]; – – – heavily damaged beets.

These two lines are the only ones I could find in literature and we must be grateful to Radbruch because a lot of time and skill were required in those days for measurements which are easily carried out in our age of automation.

We can see that the velocity of sugar extraction slows down rapidly and is very low after four minutes. Beets seldom remain in the transport water longer than four minutes and we therefore adopted this as a standard time in order to make comparisons between losses under different circumstances.

It will be clear that the loss is proportional to the damaged surface. Kryz[25] found 3.5 to 4.5 mg/cm² in half an hour in cold water. Our figures for four minutes are situated between 2 and 3 mg/cm² in water of 10 to 20°C. Temperature appears not to be so important as we would perhaps expect. A rise in loss of any importance only begins to take place between 40 and 50°C, temperatures which are never used in practice. Some of the cells in the beet tissue are already killed then. To our astonishment we found a minimum in the extraction rate in the range between 20 and 35°C which we could reproduce many times, but which we could not explain.

Old wounds are healed by cork formation (Swietlicka[29]) which may explain the rather wide range in *Figure 3*. If beets are frost damaged, the tissues are destroyed[29] and losses can rise unlimited. Becker[28] reported about a loss of 1 per cent of sugar on beet and we found lower as well as higher figures according to the degree of damage. Washing the beets is a separate problem. The sticky clay cannot be removed without some mechanical damage. Whether the customary 'cudgel' washers are the optimum solution is an open question.

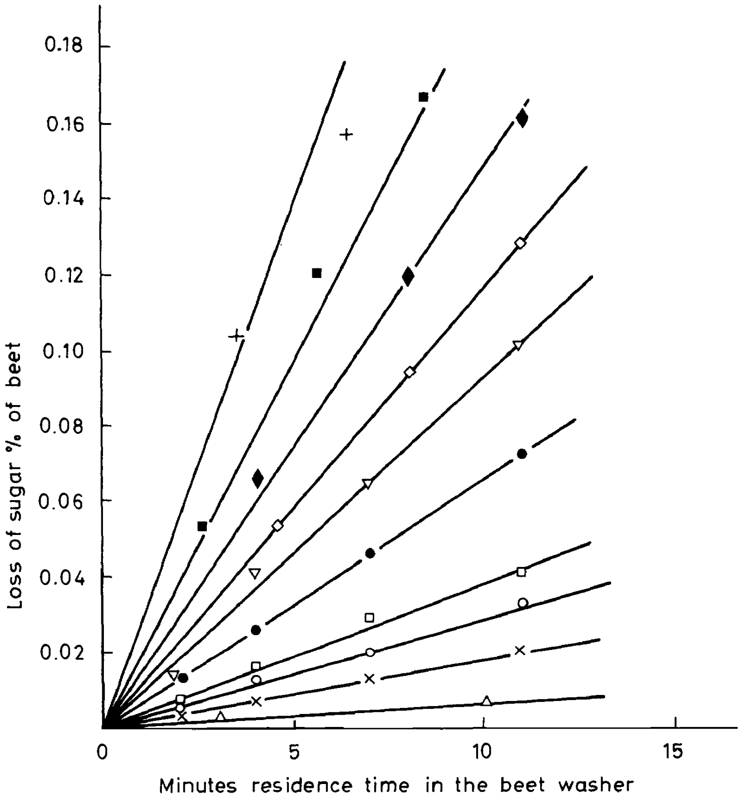

Figure 4. Loss of sugar from beets in the beet-washer according to model experiments. During the washing operation the beets are constantly bruised by the mechanical action of the washer. The resulting loss is proportional to the residence time. Steeper curves indicate more severe treatments or beets weakened by frost. The individual points are only given to indicate the reproducibility of the method. Quantitative interpretation of the treatment severity was unavailable during preparation of this paper.

Beets remain in the washer for a period between about 3 and 12 minutes. During that time the surface is constantly bruised, resulting in a loss which is proportional to the residence time. *Figure 4* shows some results of model experiments in the laboratory. The beets were gently soaked beforehand, imitating the residence time in the transport water.

The slope of the lines, representing the loss per minute residence time in the washer, depends on the degree of mechanical damage, exercised on the beets. In the customary washers we calculated this to be proportional to the third power of the speed of rotation. Other types of washers use high-pressure nozzles, the beets being transported underneath by a vibrating screen or a roller table screen. We are planning to make comparative experiments during this beet campaign. The effect of temperature of the wash water is similar to that described for transport water.

Frost-damaged beets are much more sensitive to the mechanics of beet washing and unfortunately the factory will have a lower working capacity with these beets, caused by badly filtrating juices, so that the residence time in the washer is prolonged accordingly. A useful measure might be to lower the speed of rotation to spare the beets.

Between the transport trough and the washer we find one of the many types of lifting conveyers. Some types may badly damage the beets. In our works we are installing mammoth pumps, the driving force of which is formed by air bubbles. The low efficiency must be taken for granted.

Samples of the beets received are analysed for sugar content in a special laboratory where they pass through multiple saw machines. The remainder are often dumped into the transport troughs where the large wounded surfaces give rise to substantial sugar losses. Dry transport would be preferable.

To conclude this section we may put the question how much of the beet surface is ultimately damaged, when the loss during transport and washing totals to 0.2 per cent. To answer this question we use the following model. A normal beet has a weight of 900 grams. Suppose it to be a cone with a height of 25 cm and a diameter of the basic circle of 11.2 cm. Its volume is 818 cm^3, its weight at a density of 1.1 is 900 g. The conical surface is 450 cm^2, the surface of the basic circle 98 cm^2, total surface 548 cm^2. When the total surface would be wounded, the loss according to Kryz[25] would be 548 $\times$ 3.5 to 4.5, that is 1.9 to 2.5 grams of sugar or 0.21 to 0.28 per cent of the beet weight. Our losses of 0.2 per cent are therefore very near to a beet without any undamaged part of its surface!

Reducing losses due to mechanical damage may be possible by scrutinizing the complete transport and wash system from harvest up to the factory. Beet handling should be minimized, and where necessary, we could be better inspired by installations handling peaches, than by those provided for ore and coal.

Use of a completely closed circuit

Re-use of transport and wash water through a mechanical thickener is customary in most sugar factories now. Suspended organic particles are previously removed, *e.g.* by means of a slit-screen with 2 mm slits. The quantity thus removed may vary between 1 and 6 per cent of the beet processed and a special apparatus is developed to separate and return beet particles. The rest may be sold directly or dried together with the pulp. The decanted mud, suspended in a small proportion of the recirculating water (say 10 per cent) is pumped to settling ponds or sludge beds. The clarified water may be recirculated, making the circuit completely closed. The water balance depends on rainfall, water content of decanted mud compared to the beet tare, evaporation and drainage. Such a fully closed circuit was described by Blankenbach and Willison[11].

The usual procedure, however, is to use the surplus condensate as a source of fresh water on the beet washer, resulting in an effluent quantity of 20 per cent of the beet weight. The pollution load is not reduced in this case, but merely concentrated into a small volume, which opens the very important opportunity to store the waste water in lagoons.

When the sugar loss in transport and wash water is reduced to 0.1 per cent on beet, the organic load in the effluent water still rises to 6000 or 7000 ppm COD corresponding to 3500 or 4000 ppm BOD_5. These figures, of course, vary according to the height of the sugar losses and the volume of effluent.

Without special precautions the circuit will soon become septic, smelling of H_2S and foaming badly. It is customary to add lime to combat these phenomena. A quantity of 0.03 per cent on beet can be sufficient but in many cases much more is used (0.05 to 0.25 per cent) enabling us to reach a pH between 10 and 11 in the complete circuit, reducing the amount of bacteria to a level where the sugar is conserved. The sugar concentration in the circuit may rise to several tenths of a per cent in that case. Lime additions may cause scale formation in pumps and pipelines and on screens, which in turn must be combated by specific measures.

In addition to lime other chemicals are sometimes used: chlorine or hypochlorite for sterilization, anti-foam oil, and flocculents to accelerate sedimentation. In periods of frost the temperature can be raised by passing part of the recirculating water through one or more of the jet condensers.

Storage of all effluent in lagoons offers two important possibilities, first to level out the quantity of waste water over the whole year, secondly to make use of the natural purification in the ponds. This method which is successfully used in many countries has two obvious disadvantages, *viz.* the surface required amounts to several hectares per 1000 tons daily capacity and the stored water causes an odour problem in spring and early summer. The latter disadvantage may be prevented by surface aeration.

All this is still in course of development. The economic optimum is dependent on local conditions. In small and densely populated countries like Switzerland and the Netherlands finding adequate places for the disposal of the mud (some 4 ha may be needed per 1000 tons daily capacity) is already a problem, but the arrangement of large storage lagoons, temporarily giving rise to atmospheric pollution, is absolutely impossible. Water storage should be separated from the mud ponds; otherwise deposited organic material would go into solution and add to the pollution (Schneider and Hoffmann-Walbeck[5]).

Treating the effluent by biological purification

Most efficient is to make optimum use of the natural purification in the lagoons. Studies by Schneider[4,5] and Engelbart[12] in Germany, Crane[2,3] in England, Devillers[18] in France, and others showed that in the course of spring and summer series of biological populations follow each other, breaking down the organic matter from an original BOD_5 of many thousands to below a hundred in August or September. The water may ultimately contain a high concentration of green algae.

In some cases this water can be disposed of without any treatment or used to start the next campaign. Part of the water may drain away or evaporate. Tsugita[22] are developing a system of anaerobic and aerobic lagoons forming a complete continuous system of water treatment. If the water from the lagoon has to be purified, the installation can be much smaller as Langen and Hoeppner[16] and Meyer[17] showed in practice. Devillers[18] made a computation about the waterflow in the course of the year, giving a constant BOD load on the purification. It turns out that in August this rate can be ten times, in September twenty times the rate which can be tolerated in the campaign. Instead of installing a purification plant, the water may pass to a municipal sewer and be purified together with the effluent of the local population.

From all these studies the requirement emerges to use shallow ponds, with a maximum depth of 1 to 1.2 metres. Greater depths cause longer anaerobic periods and slower purification. Natural purification can be accelerated by surface aeration. In our Breda factory we are attempting to solve the problem of both tare disposal and of wash water by passing the decanted mud–waste water mixture directly to a sand pit, filled with water, with floating surface aerators of about 40 hp per 1000 tons daily capacity. A similar treatment is described for an Australian sugar refinery (Bevan[20]).

The direct treatment of carbohydrate-containing waste water in an activated sludge plant may give difficulties caused by 'bulking' of the sludge. This phenomenon exhaustively described in the literature on waste water, can be combated either by temporary storage (several days to several weeks) to ferment the sugars, or by using special modifications of the activated sludge process, such as 'contact stabilization'. The first-mentioned process was described by Kollatsch[15], the second by Gaudy[21] for waste water from a sugar refinery.

Table 3. Some figures on the cost of installations for the biological purification of sugar factory waste water

Installation at:	*Ameln Germany*	*Aarberg Switzerland*	*Halfweg the Netherlands*
Literature ref. no	16, 17	19	—
Built in	1963	1967–1969	planned for 1971
kg BOD_5 a day	860	8400	8250
aerator kW	30	165	150
stage	second	first	first
total cost	DM. 240000	Sw. fr. 1.25 mill.	Rough estimates: *f* 800000
Running cost per kg BOD_5. Interest and depreciation not included	DM. 0.15	Sw. fr. 0.11	*f* 0.10

In Aarberg (Switzerland) the waste water is also treated directly in an activated sludge plant (Roennefahrt[19]). The purification attained in one step is about 75–85 per cent, the final purification being done in a municipal sewage plant.

Activated sludge plants used to have a disposal problem for the surplus sludge produced, but a sugar factory can pass it on to the mudponds together with the beet tare. For the growth of the activated sludge, the addition of some phosphorus and nitrogen is needed.

Summarizing the experiences reported in the literature we may state that the highly contaminated carbohydrate-containing waste water from a sugar factory needs a two-step purification. One or both steps may be executed in lagoons, but the execution of one or both in activated sludge plants is also possible. In *Table 3* some figures about the cost of such installations are summarized.

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