OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

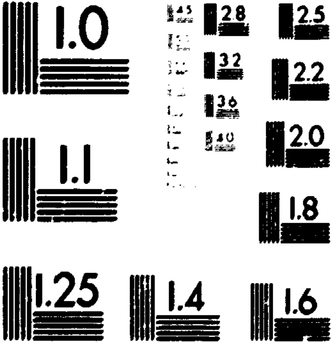
FAIR USE POLICY

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org


1.0
2.8
2.5
3.2
2.2
3.6
4.0
2.0
1.1
1.8
1.25
1.4
1.6

RESTRICTED

DP/ID/SER.A/559
9 January 1985
ENGLISH

NATIONAL CANE SUGAR INDUSTRY RESEARCH CENTRE

DP/CPR/82/005

CHINA

14348

Technical report: Treatment of Effluent from an Alcohol Distillery and Utilization of Molasses*

Prepared for the Government of China
by the United Nations Industrial Development Organization
acting as executing agency for the United Nations Development Programme

Based on the work of R.B. Brooks
Expert in the Treatment of Effluent from an Alcohol Distillery
and Utilization of Molasses

3124

United Nations Industrial Development Organization
Vienna

* This document has been reproduced without formal editing.

V.85-20359

TABLE OF CONTENTS

1. INTRODUCTION

This report describes the activities carried out by Dr. R.B. Brooks under the short term consultancy DP/CPR/82/005/11-02/31.7.C. This consultancy was to advise, lecture and present information on effluent treatment in alcohol distilleries and to discuss other related areas of technology where appropriate. The job description varied slightly during the lead up to the visit, both by UNIDO and the National Cane Sugar Industry Research Centre (NCIRC) but during the briefing session by Mr. Sissingh (UNDP) this was clarified in an explanation of the whole advisory programme between UNIDO and NCIRC. The task as described was to have a flexible approach to the lectures and seminars on the broad subject of distillery waste and fermentation, and to pass on as much written and reference material as possible. Two literature searches were carried out prior to arrival in China.

. stillage analysis, treatment, usage and disposal;
. immobilised enzymes and cells.

These literature reviews are included in Appendix 1 and 2. Copies of various other papers were handed over including material which has yet to be published as also were copies of the overhead projector slides, Appendix 3 (Figs. 1-62).

The programme as devised by NCIRC within the time constraint set by UNIDO ıded on 27 October, Appendix 4 and included only one factory/distillery visit.

The NCIRC had been unable to find a visiting expert to give lectures on:

. the Australian Cane Payment System
. the Australian Sugar Industry Structure
. other Asian Cane Payment Systems

The author volunteered to give this series of talks by extending the programme another eight days. This series of talks could be presented to UNIDO in a separate report. This amended programme, Appendix 5, allowed two more factory visits.

Apart from the main task of the expert, some observations were made about the sugar industry in China, factory operation, and the NCIRC. These have been included in Appendix 6.

2. STILLAGE DISPOSAL

There are a number of streams of waste water leaving a distillery particularly the fermenter and condenser cooling waters, the fermenter wash water, and the stillage. In China, effluent is only considered polluting i.e. it is only penalised financially, if the COD is greater than 100 mg/l - irrespective of the volume to be disposed of! Thus, with care, stillage is the only waste stream leaving a distillery which is considered polluting by the regulations of China. When a waste stream has a COD greater than 100 mg/l it is penalised financially on a daily basis only. The penalty is Y1000 per day for each day there is a discharge greater than 100 mg/l concentration with no regard for volume or total concentration. Of course, stillage is also considered polluting because it is dark brown whereas liquid condensate from the bottom of the rectifying column is often disposed of without penalty because it is like water in colour (but probably greater than 100 mg/l COD).

2.1 General

It is often said that there is no widespread agreement on the "best" disposal method for stillage. The reasons are obvious.

- stillage characteristics vary widely depending on how and where it is produced.
- the environmental considerations are different at different sites
- the economics of disposal techniques vary widely.

It is unfortunate that most scientific papers neglect some of these factors in presenting case histories and solutions. Distillery still bottoms have many names, Fig. 1. Some of them give an indication of the country of origin or the type of feed material that may have been fermented. The molasses may have been pretreated, Fig 2, by acid addition (increasing stillage ash), sterilization (reducing by-product formation), stillage recycling (reducing total stillage volume but marginally increasing ash). Nitrogen and phosphate nutrients may have been added to the molasses to improve fermentation (increasing stillage ash). The type of sugar cane and the way it is grown will affect the molasses analysis as will the degree of exhaustion of the molasses.

There are many different stillages, Fig 3, depending on the feed material to be fermented. Even if the crop is sugar cane, the actual distillery feed may be juice, syrup, molasses or pieces of cane. Even if the actual feed is cane molasses the product may be alcohol, citric acid, yeast, or some other product.

It can be clearly shown, Fig 4, that stillages are different and so solutions to disposal problems will be different. Stillage from a cane molasses distillery in Australia has six times the COD and 14 times the ash content of a cassava starch distillery in Brazil-yet these extra facts are often not reported. Molasses varies widely between beet and cane, cane molasses varies widely between countries and even within a country, and from year to year, Fig 6. Chinese cane molasses stillage seems to have a much higher nitrogen and potassium level than Brazil but a much lower lime and phosphate level, Fig. 7. This, as will be seen later can mean it will produce different results in irrigation, cattle feeding etc.

Cane sugar factories in different countries process different quality cane but also operate with different efficiencies, Fig.8,9, leaving the final molasses with different amounts of sugar, ash, non fermentables etc. This implies that factories within a country will have a variable analysis stillage to dispose of dependent on the geographical location of the factory in that country, the time of the year (cane maturity), the boiling system in the factory (which may change with mixed juice purity). This is particularly so in China where each factory usually ferments its own molasses within weeks of production compared to larger distilleries which collect molasses from various factories and may have 6-12 months storage capacity with the inherent smoothing out of differences.

A simple change to the distillery operation such as slopping back, Fig.10, can radically change the stillage analysis. It is also clear why distilleries operating with a cereal feed e.g. rice, sorghum, wheat or corn can recycle a large amount of stillage before the ash rises to the level at which it will begin to slow down fermentation,but cane molasses stillage can only be recycled a small amount or none at all. This can explain why some distilleries claim recycling of stillage is very useful in saving dilution water, reducing stillage volume and concentrating stillage without using evaporation, others claim they cannot recycle stillage as it slows down fermentation. As can be seen, Fig 10, a cane molasses of 12% ash needs a dilution of three times its volume of water to produce a substrate of the correct sugar concentration to ferment to alcohol. It will produce a stillage of four times the volume of molasses at 3% ash. However, with a cereal molasses distillery, the output of stillage can be reduced by a factor of 2.5 times using stillage recycle without unduly raising the ash in the fermenting medium.

If the stillage is recycled correctly, using a settling tank and flocculant, a precipitate can be induced,reducing the scaling in the distillery and reducing the ash in the fermentation medium, Fig. 11.

Stillage is no different to any other effluent, it must be disposed of by land, water or air. However the constituents in the stillage are changed, they must still eventually recycle back into the environment. The duty of an environmental engineer is to recycle the effluent in such a way that no permanent damage is done to any part of the ecosystem.

There are a very large number of treatment/disposal systems for stillage, Fig. 13, most of which have some role to play in the correct situation. There is no uniquely best way, and often a combination of systems is better than just one method.

Stillage has two polluting factors, Fig. 14,

- inorganic
- organic

and nearly all of the treatment methods are concerned with reducing the organic material whereas many of the problems caused by disposing of stillage into the river or on land are because of the inorganic constituents. Remember, the stillage can have a salts concentration equal to sea water and this alone may cause pollution in a small fresh water river even if all of the organic material has been removed.

The organic matter in stillage can be analysed by the BOD_5, COD, TOC, or PV, Fig. 15. The most appropriate for stillage analysis is the COD. The BOD_5 has a number of disadvantages,

- it is difficult to reproduce accurately
- it does not measure the total polluting load inflicted on the environment.
- it only gives historic data as the analysis method takes five days (COD only 4 hrs).
- incubation equipment is expensive.

2.2 Irrigation

Stillage contains valuable inorganic constituents, Fig. 16.
The proportion of N,P,K,Ca and Mg will vary depending on all the previously discussed factors. However, the "Manual of Cane Growing" N.J. King (1965) has the following quotation with regard to irrigation of stillage and molasses.

"It is unfortunate that no provision exists for the recovery of plant nutrients from the distillery residues which run to waste and are lost to the industry".

"74% of the potash entering the factory in the cane crop is eventually concentrated in the molasses. In addition, a quarter of the phosphoric acid in the cane is located in the molasses".

"Molasses is the most valuable byproduct from the farmers point of view".

He was a world recognised authority on cane agronomy and he considered that irrigation of molasses on to cane was good for it. Yet, it can be seen that molasses has a COD twelve times greater than stillage and an ash level four times greater, Fig. 15.

The best answer for stillage disposal would appear to be to irrigate it back on to the cane it originally came from. To do this, it can be seen, Fig. 17, that stillage in Australia may have to be irrigated at 4.9 m^3/ha/yr. There have been papers written on the problems caused by irrigation. However, a literature search, Fig. 17, shows that irrigation rates in these cases have been excessive. The very high irrigation rates used by Dubey in the U.K. were with a much lower ash level beet molasses stillage, again showing that a full understanding of each situation must precede using any successful disposal system.

Many countries use large central distilleries many hundreds of miles from cane growing areas. This may give economies of scale but removes the possibility of disposing of the stillage back on the cane fields. However, if it is concentrated to the same volume as the original molasses then it may be back loaded in the same tankers that carried the molasses. A small distillery, annexed to the sugar factory is in an ideal situation to recycle its stillage back to the cane fields. It is wise to irrigate fields after they have been ploughed out or immediately following ratoon harvesting.

The best way of classifying the hazardous nature of any irrigation water is shown, Fig. 19. Although the salinity hazard of stillage is high C3 or C4, the SAR is S1.

In 1981, John Warner was hosted by the Ministry of Light Industry to tour Guandong Province and make recommendations for sugar cane agriculture. His major finding was that cane soils in China are deficient in potash. Stillage is very rich in potash.

2.3 Biostil

The Biostil process has caught the imagination of the technical people in China because it claims to use less equipment than a conventional system and it virtually eliminates stillage. This is not the best way of describing the Biostil process, particularly when discussing sugar cane molasses stillage, Fig. 20.

Instead of claiming virtual elimination of effluent it is more scientifically correct to say there is no elimination of inorganic material, no elimination of non fermentable organic material and perhaps a 10% reduction in BOD_5. The stillage volume is lower because stillage is recycled, reducing the need for some dilution water. The concentration of all the components, both organic and inorganic, are much higher in the stillage from Biostil.

If a conventional system uses stillage recycle, particularly if it also uses the stillage from the rectifying column for molasses dilution, and an osmotolerant yeast is used as is used in the Biostil process, then stillage volume will also be reduced. Biostil will achieve a stillage with 30% dry solids while conventional will achieve perhaps 13-14% dry solids. If the disposal system is irrigation, anaerobic digestion, aerobic purification, pumping to river or sea, use as cattle feed or biomass production then there is no advantage in concentrating the stillage and thus no advantage in the Biostil process. In fact, there is a disadvantage as the energy demand for the conventional process is lower and equipment costs for the conventional process are lower than Biostil.

The process is shown, Fig. 21, with a few minor additions to the flowsheet normally published. Biostil will use a few percent less energy than conventional systems if the stillage is to be incinerated but equipment cost could be higher.

2.4 Disposal within the Sugar Factory

Advantage can be taken of the situation where a distillery is located adjacent to the sugar factory, Fig. 22. The stillage can be poured on to the bagasse or coal going into the sugar mill boiler. This has been tried successfully on a trial basis in Australia, and in China where smaller non-suspension fired boilers are used it will be even more successful. With Chinese factories claiming very low final baggase moistures, stillage which has been concentrated a little by recycling may be disposed of in this way. The point must be reiterated, that the solution to a stillage disposal problem may be to dispose of some one way and some another.

The stillage could be disposed of completely by spraying into a boiler chimney prior to the ash scrubbers in some countries that have high stack flue gas temperatures (500-600°C). China claim flue gas temperatures of only 150-200°C which would be too low. However, a method was discussed where they could use the flue gas to concentrate the stillage, using stillage to sluice ash from the boilers and scrubbing the flue gas at the same time.

Direct spraying of stillage into flue gas leaving the stack would increase the solids in the gas from 0.1 up to 2.0 grains per standard cubic foot which would not be tolerable under Australian air pollution regulations but may be quite acceptable in China.

Filter cake is usually used in China as a fish food in ponds adjacent to cane blocks. In Australia and many other countries it is a valuable cane soil additive. It can be seen, Fig. 23, that stillage and filter cake are similar in analysis and so stillage can be a good substitute for filter cake either in fish ponds or in the field.

There is potential for filter cake and stillage to be disposed of together and improve sugar production at the same time. We have found in Australia that a batch basket centrifuge of the type used for sugar can reduce the moisture content of filter cake from 74% down to 40%. This can give up to an extra 0.5% extra factory sugar production, Fig. 24, which would pay for the cost of the centrifuge. Stillage can then be added to the filter cake to increase its moisture level back to 74%. This combined mix can be belt conveyed, shovelled and transported by open truck without dripping stillage. These calculations and trials should be repeated by the Chinese to find out how their filter cake will centrifuge with their fugals. Again, it may be a partial solution which can be used with another method to dispose of all the stillage.

2.5 Anaerobic Digestion

There is a great deal of skill and experience of anaerobic digestors in China, particularly with regard to the domestic production of digestor gas from animal/human waste. Biological purification of stillage whether aerobic, anaerobic or a combination of the two is only doing what would happen in nature but it is carried out more intensively and in such a way that any release to the outside environment is controlled so that nature is not unduly disturbed.

There are many ways of purifying stillage biologically, Fig. 25 and of course they all work technically. The task is to choose a method or methods which are economic in terms of resource use (man, money, materials). It is essential to realise that biological treatment only affects the organic material, the inorganic constituents in the stillage do not change and these are the one's that often cause most trouble. Not only that, but much of the soluble organic carbon in the stillage is converted to insoluble organic carbon (cell growth) which must still be separated and disposed of. This solid will amount to 10%-15% of the weight of the chemical oxygen demand removed. It must be disposed of on land.

Digestor gas of 50% methane and 50% carbon dioxide has a high calorific value, about equal to ethanol and coal on a weight basis, Fig. 26. The yield of gas can be theoretically up to 830 litres/kg of starch or protein, Fig. 27. One cubic metre of biogas can run a 0.2 kW engine for 5.5 hrs.

However, a factory cannot be built soley dependent on biogas for power. It must have an alternative energy source because of the instability in the production of biogas and the need for a factory to keep operating. Thus, extra capital must always be spent on two alternative power sources, biogas and a conventional. This can often prove uneconomic.

Traditional digestor systems operate on 30-40 day residence times. This would be uneconomic with the large volumes of stillage produced daily. If digestion is to be chosen for reduction of COD in the stillage then it is essential that a system is used which can fully complete the digestion in 1-2 days. There is no point experimenting with systems which are known to take 30-40 days. A small Chinese distillery producing 10 million litres per year of ethanol would require a traditional digestor of 30,000 to 40,000m^3 capacity and would have to have the ability to be shut down for 240 days each year yet start up and run at the start of the next crushing season - a difficult task for a biological system. Only 1-2 day residence time systems are worth experimenting with because at least if the tests succeed technically the system stands some chance of succeeding economically.

The first of the modern systems which has been commercially operated at short residence time is the Upflow Anaerobic Sludge Blanket, Fig. 30. It can operate at loadings of 12 kg COD/m^3/day reducing a 60,000 mg/l to 300-600 mg/l and produce 0.35m^3 methane per kg COD loaded. It is worth pointing out that this excellent achievement would under the present Chinese regulations still result in the distillery being fined the same penalty as if no COD reduction had taken place. A UASB digestor flowsheet is shown, Fig. 31, together with a number of important references on results that have been achieved todate, Fig. 32.

A modern development which has proved of great interest to Chinese technical workers is the Tower digestor (Upflow Flocculated Digestor), Fig. 33. It is very similar to the UASB but it has never operated on full scale and never had a cane molasses stillage feed. Although it was called a <u>tower</u> digestor, recent results have shown that on full scale, because it is scaled up on diameter not height, it will be a sqat, fully mixed, tank Fig. 33. Its original design comes from the tower fermenter first made popular in the 1960's which has never created much demand. The main difference between the UASB and the UFFD,

Fig. 35, is that the UFFD uses flocculent to promote sludge blanket formation. Sulphide problems produced in pilot scale experiments were overcome by ferric chloride addition. Anaerobic digestors may be operated at 30-35°C (mesophilic) Fig. 37 or 50-55°C (thermophilic), Fig. 38. The results from a wide range of workers show that there is little difference in general performance between those two temperature regimes. All of the references given in Fig. 37 & 38 can be found in the very complete literature review given in Appendix 1. With stillage feed available at such a high temperature (100°C), and the high ambient temperatures of the tropics, there is the opportunity to operate at thermophilic temperatures. However, as the general evidence is that there is no real advantage,and certainly thermophilic operation is more temperamental,it would be advisable to concentrate on digestion in the mesophilic range.

The Chinese have been concentrating research on a two-stage process though no reasons were given. Perhaps a system of two mixed tanks in series would give better kinetics than one mixed tank, or they could optimise the hydrolytic step in the first tank and optimise the methanogens in the second step. However, once the pH in the first tank drops below 5.5 methanogen growth would stop totally and nothing would control the hydrolytic step so the pH would continue to drop until the hydrolytic bacteria were inhibited. A recycle would not improve matters as the methanogens in the second stage would not survive the low pH. It would be better to have a single mixed tank with a large recycle. One Chinese system had been set up using three tanks in series but loadings were low, removal rate very low and pH in the first tank very low. I suggested it would operate better if the three tanks were put in parallel and a recycle was used.

There are other high rate, intense systems such as anaerobic filters which are fully described in references given which could be researched.

Lagoon treatment of stillage is an attractive alternative in terms of capital and operating costs provided the land is available and inexpensive. However, land is not a cheap resource in China particularly near sugar/distillery factories.

Digestors cannot reduce the COD of stillage to below 100 mg/l so the financial penalty would still be exactly the same as if the stillage was discharged without treatment. The effluent would also still contain all the inorganics, so it would still have the same conductivity as seawater. A solid sludge, which would quickly start to smell, would be produced of about 5-10% of the volume of original stillage. This would have to be mixed into soil quickly before it encouraged fly breeding etc.

It is essential in China to have a second aerobic stage to purify the effluent from the anaerobic digestors to below 100 mg/l COD.

2.6 Aerobic Treatment

Aerobic biological treatment of waste is well documented. The higner intensity processes use more power and less area than the low rate processes, Fig. 38. Activated sludge systems Fig. 39, and trickling filters, Fig. 40 can both be used to produce effluents of COD less than 100 mg/l. It would be uneconomic to treat raw stillage because of the very large power demand but anaerobically digested stillage of 500-1000 mg/l COD could be purified to below 100 mg/l COD. It would still have a high colour, still have a high inorganic content and in China would also have a high ammonia (or nitrate/nitrite) content. Biological sludge production would be 0.3 - 0.6 kgs cells per kg COD removed and this dry weight of cells would be produced as a 2-4% dry weight gelatinous sludge. This sludge must be disposed of by digestion or by immediately mixing in with soil. Again, the point is made that organic carbonaceous material does not just disappear. It is often converted into another form which still has to be disposed of.

There is a process called the ANAMET process which has had one application on beet molasses stillage, Fig. 41. It is a combination anaerobic/aerobic system. It has an optional additional ammonia stripping system (Type 2) which helps the aerobic part of the process reduce the BOD_5 much lower than normally is the case.

2.7 Incineration

Stillage has been disposed of by incineration by a very few factories in the world, notable in Japan and Europe. The European experience was with sugar beet molasses stillage. Beet stillage has a very low melting point (approx. 650°C) and so furnace deashing is no problem as the ash runs out of the specially designed furnace bottom. This slagging (melting) characteristic caused a great deal of concern to sugar cane people when they considered disposing of concentrated sugar cane molasses stillage in boilers used for burning bagasse. However, we found from laboratory trials in 1974 that sugar cane derived ash had a much higher melting point (1300-1500°C) than sugar beet derived ash. Preliminary tests on burning the stillage in a suspension fired bagasse boiler were satisfactory. It is known that the higher the silica ratio in the ash, the higher the melting point but in practice we did not find any effect of mixing bagasse with stillage before burning.

The possibility exists with incineration that the organic material in stillage will burn with sufficient heat release to provide enough energy to evaporate dilute stillage to a syrup concentrated enough to burn and have excess heat left over to help power the distillery. Again, only the organic pollutants are removed by incineration, the inorganics are still all present. There has been a good deal of talk about recovering crude potash, or just concentrated ash to use as a cheap fertiliser from the residual liquor after incineration. Of course, if the distillery is close to the cane fields then the fertiliser value can be obtained by irrigating the dilute stillage before incineration.

Autothermal conditions can exist with stillage having a total dry solids of as low as 35%. However, the flame temperature would be too low because of the water present, and unrecoverable latent heat would be lost from the stack that could be recovered by an extra stage in a multieffect evaporator, evaporating that 35% stillage to 60%.

Stillage varies widely in its elemental analysis, particularly with regard to the amount of K,Ca and Mg and these are the elements which affect the melting point of the ash the most. A Distillery adjacent to a sugar factory may choose to combine concentrated stillage with bagasse and burn the combination resulting in a different elemental mix. China, because of coal pricing policy and the need for wood fibre for paper pulp, burns little bagasse in sugar factory boilers but mainly coal. Again, this will result in a different ash and different melting characteristics. The advice given to China in this regard was to team up with the local University in their incineration studies. A local Professor of Physical Chemistry would be an invaluable team member in trials on melting characteristics of various inorganic components.

In January 1982, the first large scale modern sugar cane molasses stillage incinerator started up in Thailand. Engineers from the National Cane Sugar Research Institute had an extended visit of many months at that factory recently. I also visited the factory recently. Unfortunately, this factory does not analyse its molasses feed and its two major problems are scaling in evaporators and the high melting point of the stillage ash necessitating shut downs each shift to manually deash the furnaces. There are claims that this second problem will be overcome in any new design but it is unfortunate that lack of detailed data on the molasses being fermented makes it difficult to automatically transfer useful information to a different country, (different molasses = different stillage = different ash).

This distillery in Thailand is a large stand alone factory a long way from any sugar factory and the cane fields which sourced the cane/sugar/molasses. It is adjacent to a relatively small river which it could not discharge into without causing a major polluting nuisance. The situation is very different to any in China. Incineration was chosen as the only potential solution.

Burning the concentrated stillage raises 39 tph of steam of which 18 tph is needed for evaporating dilute stillage to produce the concentrate. The residual 21 tph is supplemented by a 19 tph fuel oil steam package boiler which together provides all the energy for the 180,000 litre/day distillery. This distillery actually ferments a mixture of molasses and sticky rice, again altering the stillage characteristics.
When burning the concentrated stillage as a supplementary fuel, the energy saving amounts to $1.5-2 million each year but as the stillage disposal section cost $25 million it certainly is not worthwhile economically. A second problem is that the condensate from the stillage evaporators has a pH of 3.3, a COD of 3,500 mg/l, and 84% of the total volume of the original stillage. Thus, although the claim is total removal of all polluting character from the stillage, the reality appears to be a reduction of 16% in volume, a removal of about 95% of the COD, a process which is not very economic, and still leaves all of the inorganic content to dispose of. However, for a large stand-alone distillery, it may be the only way. The Chinese engineers who spent a great deal of time at this incineration facility thought that all of the COD was getting in to the condensate because of entrainment of stillage in the water vapour. I believed some of it would have been because of volatile organic matter. This should be investigated further as under the Chinese legislation, a distillery discharging this condensate would be fined as much as if it was discharging untreated stillage.

A multinozzle burner, Fig. 43, is a good idea for burning waste such as concentrated stillage, as fuel oil, waste oil and other materials can be burned at the same time.

There are Chinese experiments going on at present on burning stillage in admixture with coal. This should work well as stillage ash would stay on the grate, fused with the coal and cause no fly ash problem. When burning a spray of stillage in a suspension fired bagasse boiler a large amount of fly ash is produced.

Under the incineration heading, the Zimpro (or Zimmerman) process should be discussed. This was a new idea to China. The Zimpro process is a wet air oxidation process which has been used for more than 45 years. It operates on the principal that aqueous suspensions or solutions of organic matter can react with the oxygen in air or pure oxygen at elevated temperature and pressure. This reaction is exothermic and because the "burning" takes place in the liquid phase, no latent heat is lost nor the heat of stack discharge gases. The system has been used particularly with sewage sludges and many difficult to oxidise organic molecules. Theoretically, once the waste has a COD greater than 1,050 mg/l, with normal heat losses, the reaction becomes autothermal. Certainly, with dilute stillage of COD greater than 20,000-30,000 mg/l the reaction will generate a great deal of extra energy which could be used to run a distillery. There is certainly more potential to raise energy by using the Zimpro process on dilute stillage at the 10-12% concentration it normally leaves the bottom of a conventional distillation tower than can be raised from incineration of a stillage concentrated to 60% solids. However, the Zimpro process is expensive in capital cost, with most of the equipment needing to be imported from overseas. The stainless steel reactor would need to be many cms. thick. The Zimpro section for a factory the size of the Thailand distillery (180,000 litres/day) would cost $15-$25 million. The Zimpro people have a great deal of laboratory experience on this type of stillage waste but no experience on full scale.

In a comparison of anaerobic digestion and incineration it is difficult to determine which process may be better, Fig. 44.

- neither process has an operating plant on full scale anywhere in the world which produces an effluent of less than 100 mg/l, but it is potentially possible with incineration.

- neither process treats the inorganic part of the stillage which can be a problem affecting discharge to small streams or on land, but incineration gives the possibility of further processing to concentrated crude potash fertiliser.

- incineration will give twice the recoverable energy of anaerobic digestion by a more reliable method (biological processes are notoriously unstable)

- incineration will work at full efficiency immediately after start-up, whereas biological anaerobic digestion will take weeks and perhaps months to reach full efficiency. Chinese distilleries only operate for 6-8 months each year.

- digestion produces a secondary pollutant of 240-360 tpd of wet microbiological sludge which must be disposed of on land - it has good fertilising value but then so does the stillage before anaerobic digestion.

2.8 Growth of Protein

The Chinese scientists were very interested in the production of protein from stillage either by growing micro-organisms or by feeding animals.

Animal feed

We have had experience feeding stillage to cattle as have a few other people in the world. The most important point to be made is that the amount that can be fed in an animal ration is dependent primarily on the potassium content of the stillage causing diahorrea and to some extent on the overall salts content. These two factors limit the amount of stillage which can be incorporated in an animal diet to below 5% with Australian stillage. The main 95% of the animal feed in a lot feeding situation must be made up of protein, fat, fibre, carbohydrate. There has been very limited reporting of "factors" in stillage which assist in an animals diet, probably dependent on whether the yeast is hydrolysed by leaving it in fermented molasses going to distillation, or whether it is removed for alternative disposal. Certainly in a lot feeding situation, feeding stillage at below 5% of the animals diet, the feed lot would generate infinitely more pollution than the untreated stillage.

Biomass/Microbial Protein

It is important to realise that in growing protein, the stillage provides very little of the nitrogen, it only provides the carbon source. There are references to a number of workers that have grown, candida utilis, "yeasts", chlorella vulgaris, trichospora, "fungi" and "fodder yeasts" on stillage, Fig. 45. Generally, the stillage is first sterilised, then ammonium salts, urea, phosphates, yeast extract and other minor constituents are added. Molasses is also often added to improve cell growth sometimes by adding up to 50%, but this is not truly growing biomass on exhausted stillage.

It may not be possible to get the same results as other workers in this field. The biomass is growing on the organic constituents left in the stillage. The amount of sugars, fusel oils, organic acids and esters furfural, and glycerol etc. left in or produced by the original yeast fermentation will vary depending on the efficiency of fermentation, the degree of infection, the type of fermentation used, the staleness of sugar cane (polysuccharides).

The standard way of approaching this type of work is to try and grow all the "standard" type microbial growths on the waste - in this case, the stillage, and proceed with what seems to grow best. I advocated a different route with the Chinese technologists. The stillage should be analysed by HPLC, GLC and thin layer chromatography to find out what organic species are available as the major carbon sources. There will be carbon compounds which are non fermentable by the alcohol producing yeasts used in China, residual sugars which are not fermented during the standard fermentation and there will be all the byproducts of the EMP glycolytic pathway such as glycerol, fusel oils, acetaldehyde, acetic acid, lactic acid, butanediol etc.

Most yeasts can ferment glucose, galactose, maltose, melibiose, trehalose, but very few can ferment cellobiose. Saccharomyces pombe can use pentose (xylose, ribose) as can Candida/Torula under aerobic but not fermentative conditions. Some yeasts have high tolerance to salts,and the inorganic salts content will vary between countries. There may be some use in adding specific enzymes to breakdown the residual polysaccharides into fermentable sugars.

One major drawback is that all of the relatively easy to metabolise organic constituents will be used up, leaving difficult to biologically attack molecules, no nitrogen and no phosphate, Fig. 46. This partially biologically oxidised stillage will still contain a residual COD of 50% of the original.

There is little use of stillage as a raw material for biomass production and the reasons are clear. The economics for producing feed or food yeast are favourable in few places in the world. The stillage only provides carbon with a very small amount of nitrogen yet biomass is 46% protein, so the nitrogen to carbon ratio should be 15:100, i.e. some nitrogen source acceptable to the microbes should be added. Phosphate must also be added. The fermentation will have an optimum of 30-32^{o}C and as fermentation is exothermic (3870 cals/gm yeast growth) the fermentation must be cooled. Cooling is no problem in Europe where surface waters are usually below 20^{o}C but in the tropics it is a major problem. There is a large electricity demand as growing biomass is aerobic, using 400 volumes of air per volume of stillage. This air should be sterilised as should the stillage, to ensure only the chosen strain is the one growing. The centrifuged biomass will not be first quality as cane molasses stillage is full of ash and dark brown in colour, imparting high colour and flavour to the biomass.

The major problem is what to do with the waste from the biomass production system. It will still have 50% of the original organic strength, a higher salts content than originally and the "easiest" organics have been removed. If incineration is contemplated, only half the heat can be generated which means it is no longer thermally self sufficient, and only half the methane gas would be produced by anaerobic digestion.

3. FERMENTATION OPTIONS

The Chinese technologists were very interested in improving the fermentation section of the distillery, particularly to discuss ways of reducing the capital cost of the equipment by changing to other technology. This section discusses the value in investigating fermentation.

The total cost of equipment delivered to site of a normal cane molasses distillery is only 29% of the overall fully operational cost of the factory, Fig. 49. The fermentation section equipment would only be 25% of this i.e. 7% of the overall operational factory cost.

In a 10 year financial analysis of an ethanol distillery, the capital cost amounts to only 28% of the factory gate price of ethanol, Fig. 51. Thus, a 25% saving in the fermentation equipment cost will result in only a 1.5% saving in the overall distillery and only result in a 0.4% saving in the factory gate price of ethanol (say 0.2 cents in 50 cents). It is difficult to see how scientific papers can state that ethanol cost can be reduced by 25-50% by reducing the cost of "expensive" batch fermenters. It is worth noting, Fig. 52, that the same 0.4% saving in ethanol cost can be achieved with a 0.8% extra yield from the molasses say, producing 252 litres/tonne rather than 250 litres per tonne. While it is not easy to simply lift yield, it is certainly easy to lose yield

- by having a small amount of infection in a continuous fermentation which is perhaps not seen to be important enough to shut down the production line for

- by losing a small amount of yield by not fully completing the fermentation due to carry over in a stirred tank reactor.

The value in batch fermentation is that each yeast pitching can be fresh ensuring no loss of product through contamination and each fermentation can be left until fermentation really is complete.

4. IMMOBILISATION

There are two types of immobilisation, immobilised enzymes and immobilised cells (yeast or bacteria) - to produce ethanol.

Firstly, to consider the use of immobilised enzymes. Extracellular enzymes are generally stable while intracellular enzymes are unstable (or need closely defined conditions to operate well). The technique of immobilisation stabilises intracellular enzymes to allow them to be used outside of the cell. Intracellular enzymes are also expensive to manufacture because of their instability and the fact that cells must be ruptured to release them. Normally, enzymes are soluble and so are lost with the product. This is not acceptable with expensive enzymes. The concept of immobilising enzymes to hold them within a reactor is therefore a good one for unstable, expensive enzymes. The cost of such enzymes would be prohibitive for the production of such a cheap final product as ethanol, Fig. 53. There are twelve different enzymes which convert glucose to ethanol. Most of them have not been isolated on anything other than very small scale. They would all have different rates of reaction, different pH and other environmental optima.

Now let us consider immobilised yeast or bacterial cells for ethanol production. In a batch fermentation system, the cells are all held within the reactor (fermentor) so no immobilisation technique is required. The advantage of immobilised cells is in the operation of a continuous stirred tank reactor or a tubular plug flow reactor.

One benefit often quoted in the literature is that the cells are held by immobilisation thus removing the need for equipment to separate the new cell growth from the finished product i.e. no settling tank or centrifuge is required. This is not true as ethanol production is growth linked and an immobilised system would be operated in such a way that cells sloughed off the immobilised cell granules would just equal new cell growth.

These discarded cells would constitute most of the total cells produced during fermentation, and would still need to be separated A second benefit often quoted in the literature is that the system can be operated at a high flow rate, one that would give wash out if the cells were freely suspended. However, at a high dilution rate, certainly productivity is higher but yield drops. As discussed earlier in the fermentation section, maximum yield is critical to the economics of ethanol production.

Certainly, one potential use of immobilised cells is in a tubular plug flow reactor system, Fig. 54. The fermentation tanks can be replaced by a simple tubular converter which will give very high conversion efficiency and by using a few columns in series (as with active carbon columns or on exchange columns), the exhausted section can be replaced at regular intervals.

Most work in immobilised cells has been carried out with clean liquids, defined media, filtered solutions. Molasses is a very dirty syrup. Dilute molasses would soon foul up any packed column. Attempts to prefilter dilute molasses would result in having to discard fermentable sugar with the gums, waxes and other insoluble solids.

It has been said that fermenting more completely with such a system would have the dual benefit of producing more ethanol and at the same time reducing the COD of the effluent. Certainly, with pure glucose, an increase of substrate removal from 96% to 99% reduces the subsequent effluent by a factor of 4 i.e. from 4% down to 1%. However, with the large amount of non fermentable organic material in molasses, there is only a very small reduction of COD (less than 1,000 mg/l) for a similar improvement in fermentation efficiency.

There are many ways of immobilising cells using adsorption, entrapment and coupling systems, Fig. 55. Although there appears little possibility of practical application of such systems, it was of great interest to the Chinese technologists and so was discussed in detail, Fig. 57. A number of scientific papers of major importance in this area were handed over and a special literature search was completed, Appendix 2.

One area which is usually not discussed in scientific papers is the actual cost of producing the immobilised cells. We took one of the simpler gel immobilisation systems and designed a large scale production flow sheet, Fig. 59. A large number of assumptions have to be made as there is no published information on this topic. Assuming the gel beads have to be stored under sterile conditions in a moist condition with a limited life until immersed in a growth medium, we have estimated that the gel bead production unit of a 10 million litre per year distillery would have a capital cost of $450,000 per year and running cost of $55,000 per year, Fig. 60, and would still need the same yeast culture system. The fully erected batch fermentation system for such a distillery would be only $1.8 million. Thus, any continuous system using immobilised gel beads would have to be less than $1.3 million and in general, it is found that continuous systems are more expensive than batch systems.

The advantages and disadvantages of immobilisation are fully listed, Fig. 61. As economics finally dictate any decision, it would seem that immobilisation will not have any future in ethanol production.

5. CONCLUSIONS

The primary task of this project was not to reach conclusions but to pass on as many ideas as possible which have been established, tried or perhaps only talked about in other countries. The team at the NCIRC are all very dedicated applied researchers who although they have some pieces of very modern equipment are limited by budget restraints more so than they would be in an Institute of comparable standing in many developed countries.

However, there were signs that some individual workers thought the answer to problems was simply to buy scientific equipment.

During discussions with the NCIRC it was apparent that their teams would be strengthened by using a more multi-disciplinary approach. Particularly, any work involving stillage should have agriculturalists involved in equal representation with technologists, as the ultimate site for disposal of either stillage, biologically purified stillage, inorganic salts in the stillage, or biological sludge grown during anaerobic or aerobic purification will be on land. Hopefully, this land will be used for growing cane, rice or some other important crop, and the valuable fertiliser constituents will not be lost.

The NCIRC should also combine with other learned Institutions such as the South China Institute of Technology. While resources of money, materials and men are in short supply in China there should be no duplication of work.

The question of why do research is often asked, and there are a number of equally valid answers, Fig. 62.

China particularly wants to improve productivity in sugar production with the long term goal of producing 10 million tonnes in 15 years time compared to 3.8 million tonnes now. Davy Agro analyses of factory data we have been given suggests that there are improvements to overall factory recovery that can be made using up-to-date Australian technology i.e. operating techniques (knowledge). This would certainly be economic but would only result in about 5% extra sugar recovery. While the percentage is small, a 5% improvement in just the larger factories is the equivalent of 2 extra sugar factories. This work should be left to others who already have the experience in this area.

The major advances in improved productivity will be in cane breeding, cane growing, cane harvesting and scheduling so that much larger crops of cane are grown per hectare, they are harvested at maturity and the better quality cane that is grown, is delivered to the factory in good condition. Paying for cane on quality rather than simply weight was the subject of a separate series of lectures and may be reported on at some future date.

Another research goal is to reduce costs of production. This can often best be done by actually working at the factory, rather than in the isolated atmosphere of a research institute. It was apparent that most of the NCIRC technologists had great appreciation of the practicalities of applied research as applied to sugar factories, but it would be worthwhile forming a review team including an economic manager which could assess the economic value in pursuing some research goals. What can be done and what should be done are not necessarily the same.

Often the only thought in research technologists heads is to educate themselves, they do the work because they would like to do it. This role can be taken by Universities but should not be the role of an industry dedicated Institute. At this stage in the development of the NCIRC, with allocation of resources spread thin, the luxury of research for its own sake should be left to peoples free time. Much of the work done at the Institute should be the investigation and application of other peoples findings. The Institute should see itself as a funnel to gather information from all over the world and to apply to the Chinese situation those developments which are most relevant. It should not blindly follow the conclusions of others. Conditions are different in different countries. General scientific reporting often excludes those things that are taken for granted i.e. an intimate knowledge of their own countries sugar industry, which of course is not known by other countries workers.

The Institute is in a better position that the individual sugar factory to sift the information from overseas but it is important always to acknowledge the work of others, to quote the original reference.

These thoughts influenced the lectures and answers to questions. The task was to try and pass on as much information and experience as possible in terms of photocopies of papers and references rather than give simple conclusions. In two weeks it is not possible to understand the Chinese situation.

Some things stand out however, with respect to stillage handling. The technologist will take the approach with stillage -

"How can we get more out of it?"

and will think of:

- energy (incinceration, digestion).
- other by-products (animal feed, biomass).

A multidisciplinary team including agriculturalists would consider the wider question:

"Where is stillage of most use?"

and as:

- the major productivity increases are in the field,
- Chinese soils are deficient in potash,
- potash is a major component of stillage,
- the distilleries are all located in cane growing areas,
- there can be no cheaper disposal system than irrigating stillage on cane,
- even the water in the stillage is then of some value,
- no disposal system other than irrigation purifies the organic matter to below COD = 100 mg/l,
- no disposal system other than irrigation uses up the inorganic salts in the stillage.

the conclusion could be reached that disposal of stillage on to cane is the best solution to the problem. The major advances in productivity, to meet the target of 10 million tonnes sugar by 2000 will be in the field, including the installation of a payment for cane on quality system.

6. RECOMMENDATIONS

These suggested recommendations should not be read in isolation from the main report as is sometimes the situation with people wishing to obtain a quick review.

1) The pollution control regulations must be altered. At present, a fine is imposed on a daily basis for any volume of effluent which exceeds 100 mg/l COD. It is no simple matter to regulate on volume and concentration because for that to be done, these parameters must be regularly measured. Perhaps a system of penalties could be introduced based on the process and equipment installed to treat the waste, with occasional measurements made by one appointed officer from the Institute who's job is to travel around the industry taking snap samples.

2) A great deal more analyses of molasses and stillage must be made. There is little point in instituting a number of stillage disposal programmes before a few seasons of regular, careful analyses on both molasses and stillage. The range of individual inorganic and organic omponents should be known first to make comparisons with other workers overseas e.g. Acceptable irrigation rates will be directly proportional to total inorganic salts, incineration heat release will be proportional to COD yet problems with scaling of evaporators and deashing problems in the boiler will be dependent on the amount and type of inorganic salts etc.

3) Although a waste of a valuable resource, stillage can be acceptably disposed of in a river if the river has a sufficient flowrate, aeration rate, and width to accept it. If there is a situation where a factory is discharging to a river and believes it is doing no environmental damage because the river can adequately purify the load, then it is suggested that the

factory fund an independent postgraduate study of the problem - considerably cheaper than the pollution fine and a more constructive use of the money. It would make an excellent MSc thesis, provide money to the University, and provide extra funds to employ the postgraduate. It would be totally independent.

4) During discussions on the measurement of pollution using BOD, COD and TOC, it was apparent that the BOD_5 method being used relied on chance contamination to seed the dilute stillage with bacteria. This is normally not acceptable with any effluent and is particularly unsound practice with an effluent which has effectively been sterilised during production. As there is no way that the Institute can obtain a fresh daily sample of seed without running their own laboratory activated sludge effluent treatment pilot plant it is suggested they discontinue measuring BOD_5. There is no point in measuring BOD_5 knowing it is the wrong method because it will still be reported and will then be accepted as correct. The COD is a more meaningful measurement of stillage polluting value even if the BOD_5 method is done in the correct manner.

5) In discussions with microbiologists, there was a great desire to study thermotolerant yeasts as "the fermentation temperature often rose above 35-40^{o}C". At the three distilleries visited, they had no problem keeping the temperature below 35^{o}C. It would be worth considering studying osmotolerant yeasts rather than thermotolerant ones. There is some evidence, that osmotolerant yeasts produce a smaller amount of glycerol i.e. a higher yield of alcohol, molasses fermentation speed is affected by the ash content of the molasses and this limits the degree to which stillage can be recylced. Recycling of stillage can help in many ways,

- reduce distillery water use
- improve exhaustion of sugars in stillage
- reduce the volume of stillage to be disposed of.

6) It is worth trying to use stillage instead of water to scrub flue gas and as a long term project, to use the hot flue gas to evaporate stillage to a concentrate by direct contact. This was discussed in detail, but it is not done on full scale.

7) One of the most useful ways of disposing of stillage is by fugalling filter mud and then re-adding stillage to produce a cake of similar wettness to that prior to fugalling. This was suggested to the NCIRC, discussed in detail with them and received enthusiastic response. The author tried this method in 1974 on pilot scale with some success. The Chinese have promised to try it. The liquid centrifuged off contains valuable sugar. Its recovery can pay for the entire process and the stillage gets "free" transport to the cane fields - or perhaps in China to the fish ponds.

Davy Agro

APPENDIX 1

STILLAGE LITERATURE REVIEW

STILLAGE LITERATURE REVIEW

ABRIGO Jr., C. - Crystallizer, Los Banos, Philippines, 1980, vol. 3 (2, Sep.-Oct.), 12, 16, E.
"Determination of optimum conditions for biogas generation from distillery slop" (82-1391)

ACCORSI, C.A. and F. ZAMA - Ind. Sac. Ital., 1977, 70 (6, Nov.-Dec.), 150-151. I, e
"Experimental Contribution to the Study of the Problems of Pollution by Distillery Effluents" (78-568)

AGARWAL, M.L. and S.P. DUA - Seminar on Treatment & Disposal of Effluents from Sugar and Distillery Industries, Bangalore, 24 July 1976, (publ. Sugar Technologists' Association of India), Distillery Section 26-29. E
"Nutritive Value of Distillery Effluent and its Effect on Soil Properties" (78-702)

AKAKI, Morio, Tsutomu TAKAHASHI and Kazuhiko ISHIGURO - Mie Daigaku Nogakubu Gakujutsu Hokoku, 1981, vol. 62, 155-161, J, e
"Studies on microbiological treatment and utilization of cane molasses distillery wastes. 1. Screening of useful yeast strains" (83-180)

ALLEN, J.E. - In Sugar's Future, Rep. Hawaii, Sugar Technol. 40th Annu. Conf., 1981 (1982), 127-131. E.
"Ethanol feasibility study for Hilo Coast Processing Company" (83-450)

ALMAZAN, O. (1968)
"Use of residual stillage for the production of fodder yeast" (Torula). Sobre Deriv. Cana Azucar. 2. 17-26.

ALMEIDA, J.R., RANZINI, G. & VASECHI, O. (1950)
Piracicaba-SP. Instituto Zimotecnico da Escola Superior de Agricultura "Luiz de Queiroz" 1950 Trab apres ao 8th Congresso Internacional das Industriaa agricolas. Bruelas.

ANDERSON, G.K., T. DONNELLY and K.J. McKEOWN - Process Biochem., 1982, vol. 17 (4, July-Aug.), 28-32, 41, E.
"Identification and control of inhibition in the anaerobic treatment of industrial waste waters" (83-178)

ANON - Ann. Rpt. Mauritius Sugar Ind. Research Inst., 1974, 57-58
"By-products research in Mauritius"

ANON - Phosphorus & Potassium, 1975, No. 78 (July-Aug.), 37-38. E
"Potassium Fertilizers from Molasses Waste Liquors (Review)" (79-369)

ANON - Practical Biotechnology, 1982, Vol. 2 (2, June), 12-13, E.
"Biostil's yield details" (82-1059)

ANON - Technology Update, 1982, vol. 38 (42, Oct.), 4, E.
"Bacardi (Puerto Rico) has used an anaerobic waste treatment process to solve a serious discharge problem and save energy" (83-179)

ANON - Zimbabwe Sugar Ass. Exp. Station, Rep. for 1980 and 1981, 24-27, E.
"Distillery effluent" (83-184)

ANON - Zuckerind., 1983, 108, 144-147 (German)
"A pilot project for ethanol and biogas manufacture in association with Ochsenfurt sugar factory"

ANON, ERSTE HESSISCHE PRESSHEFFE FABRIK UND DAMPFBRENNEREI. INH. JOSEF PLESER SOHNE - Ger. OLS 2539383. Appl. 4 Sept. 75. Publ. 10 Mar. 77. 10 pp.
"Process for Eliminating Waste Waters" (79-56P)

ANON, K.T.I., S.A. - FR 2 442 798, A 29 Nov. 78. no. 78-33769, P 27 June 80, 6 pp.
"Process for the elimination of waste liquids" (82-1072P)

ANON. (1969)
"Molasses vinasse as fodder" Z. Zuckerind 19. 550.

ANON. (1970)
"Value of vinasse albumin for dairy cows" Voolichtingsblad 266. 4256-4264.

ANTONIE, R.L. (1976)
"Fixed Biological Surfaces - Wastewater Treatment" p.109 CRC Press. Cleveland.

ARAUJO, J.A. de, H.A.M. de SOUZA, M.J.G. PONTES and H.A. GERMEK - Brasil Acuc., 1982, 100, 155-157 (Portuguese)
"Profiting from distillery bottoms"

ARBATTI, S.V. - Seminar on Treatment & Disposal of Effluents from Sugar and Distillery Industries, Bangalore, 24 July 1976, (publ. Sugar Technologists' Association of India), Distillery Section 59-64. E
"Some Considerations About Spent Water Disposal and its Processing" (78-851)

BAKER, B.P. - In: Problems with Molasses in the Yeast Industry (see SIA 81-520), 113-127, E.
"The Availability, Composition and Properties of Cane Molasses" (81-509)

BAKR, M.Y., A.A. ZATOUT and M.A. ZAYED - Chem. Age India, 1977, 28 (9), 773-776. E
"Potassium Fertilizers from Molasses Waste Liquors. 1. Literature and Short Discussion" (79-1019)

BAKR, M.Y., A.A. ZATOUT and M.A. ZAYED - Phosphorus & Potassium, 1976, No. 81 (Jan.-Feb.), 40-42. E
"Potassium Sulphate From Egyptian Molasses Waste Liquors" (79-370)

BALABANOVA, A.M., RUDNITSKI, P.V. & SHCHERBAK, N.S. (1969)
"Molasses slops as cattle feed" Ferment. Spirit. Prom. 35, 24-26

BAN, S. and M. GLANSER - Krmiva (Zagreb), 1976, 18 (7), 145-151. Cr
"Manufacture of Single-Cell Protein From Waste Water of the Food and Fermentation Industries with Particular Emphasis on its Economics" (79-55)

BASS, H.H. (Invr.) Unisearch Ltd. (1974).
"Preparation of fertilizer and animal feed from molasses fermentation residue" U.S.P. 3983 255.

BASU, A.K. & LECLERC, E. (1972)
"Mesophilic digestion of beet molasses distillery wastewater" Adv. Water Pollut. Res., Proc. Sixth Int. Conf. Jerusalem, pp. 581-590. Pergamon. Oxford.

BASU, A.K. & LECLERC, E. (1973)
"Comparative studies on treatment of beet molassses distillery waste by thermophilic and mesophilic digestion" Water Res. 9. 103-109.

BASU, A.K. (1970)
"Treatment of distillery wastewaters" Trib CEBEDEAU 23, 316. 127.

BASU, A.K. (1975)
"Characteristics of distillery wastewater" J. Water Pollut. Control Fed. 47, 2184-2190

BATALLONES, E.D. & CASTRO, A. (1974)
"Feasibility study on the biotreatability of industrial waste waters" Southeast Asian J. Trop. Med. Public Health 5. 290-298.

BEEK, Invr. E.H. van de, Hollandse Constructie Groep B.V. - EP 48 061. A 8 Sep. 81. no. 812010023, P 24 Mar. 82. 14 pp., E. Designated states AT BE CH DE FR GB IT LI LU NL SE PR NL 12 Sep. 80. no. 8005147.
"Method and apparatus for processing vinasse" (83-461P)

BEHR, W. - Branntweinsirtschaft, 1980, Vol. 120(15 , Aug.), 246-248, D.
"Obtaining Methane Gas from Distillery Vinasse. 1. Basic Principles of Methane Fermentation" (81-534)

BEHR, W. - Branntweinwirtschaft, 1980, Vol. 120 (17, Sep.), 291-292, D.
"Obtaining methane gas from distillery vinasse. 2. Purification of distillery effluents by methane fermentation" (81-535)

BENJES, Invrs. H.H., V.N. WAHBEH and J.R. STUKENBERG, Bacardi Corporation - US 4 311 593, A 15 Sep. 80, no. 187 551, P 19 Jan. 82, 9 pp.
"Process for treatment of waste water" (83-186P)

BEVAN, D. (1972)
"Problems in the disposal of sugar mill effluents" Prod. Rev. November 25-36

BHANDARI, H.C., A.K. MITRA and V.K. MALIK - Proc. Annu. Conv. Sugar Technol. Ass. India, 1979, 43, G65-G72. E
"Treatment of Distillery Effluent" (80-787)

BIAGGI, N. (1956)
"Studies of rum distillery wastes in Puerto Rico" PhD Thesis, University of Michigan, University Microfilms No. 58-883.

BIESKE, G.C. (1979)
"Agricultural Use of Dunder" Proc. of A.S.S.C.T. 1. 1979

BIROLAUD, P. (1973)
"Animal feed product" Fr. P. Sole Publn. 2 165 034

BITTENCOURT, V.C., L.J.B. de CASTRO, A.A.M. FIGUEIREDO et al. - Brasil Acucareiro, 1978, (Oct.), 25-36; 92 (4), 217-228. Pt
"Composition of Vinasse" (79-525)

BODE, G. (1933)
Vom. Wasser 7, 259

BOLTON, D.H., BOUCHARD, J.P. & HINES, D.A. (1976)
"The application of the ICI Deep Shaft Process to industrial effluents" Proc. 31st Ind. Waste Conf., Purdue University, Lafayette, Ind, Preprint pp. 1-12

BORUFF, C.S. & BUSWELL, A.M. (1932)
"Power and fuel gas from distillery wastes" Ind. Eng. Chem. 24, 33-36

BRAUN, R. and S. HUSS - Process Biochem., 1982, vol. 17 (4, July-Aug.), 25-27, E.
"Anaerobic digestion of distillery effluents" (83-177)

BRAZIL, Proc. 4th Int. Symposium on Alcohol Fuels Technol. 1980, 119-122.
"Development of technology for improvement in the energy balance in production of ethyl alcohol from sugar cane molasses"

BRIEGER, F. - Brasil Acucareiro, 1977 (Nov.), 23-30, 90 (5), 307-314. Pt
"Observations on the Distribution of Vinasse or Distillery Juice in Sao Paulo State" (78-423)

BRIEGER, F.O. - Sugar Azucar, 1979, 74 (1), 42-43, 46-47, 49, E; 69-72, 74, S
"Distribution of Distillery Slops in Sao Paulo, Brazil" (79-694)

BURKHEAD, C.E., LESSIG, C.A. Jr. & RICHARDSON, T.R. (1968)
"Biological Treatment of a Distillery Waste" Proc. 23rd Ind. Waste Conf., Purdue University, Lafayette, Ind, 520-527.

BURNETT, W.E. (1973)
"Rum distillery wastes: laboratory studies on aerobic treatment" Water Sewage Works 120, 107-111

BUSWELL, A.M. & LE BOSQUET, M. (1936)
"Complete treatment of distillery wastes" Ind. Eng. Chem. 28, 795-797

CABRERA, C., GONZALEZ, E., ALVAREZ, E. & PORTUONDO, Y. (1976)
"Vinasse as a corrosion inhibitor" Cuba Azucar, July-Sept. 20-26

CALAMARI, L. and G. BERTONI - Ann. della Facolta di Agraria, Univ. Cattolica del Sacro Cuore, Milan, 1979, Vol. 19(2), 141-151, I, e.
"Research on the use of dried depotassified molasses slops in dairy rations" (81-879)

CALLELY, A.G., FORSTER, C.F. & STAFFORD, D.A. (eds.) (1977)
"Treatment of Industrial Effluents" pp. 251-254, Hodder & Stoughton, London

CAMHI, J.D. - Brasil Acucareiro, 1979, (July), 94 (1), 18-23. Pt; e
"Treatment of Vinasse, By-Product of Alcohol Distillation" (79-1518)

CAMPBELL, W. (1977)
"Wastewater treatment in brewing and distilling. Proc. Biochem. June 6,7,8,32

CAMPOS, M.P. de and D. de V.F. GONCALVES - Brasil Acucareiro, 1981 (July) 47-53 and (Aug.) 15-29 vol. 98 (1 and 2), 47-53, 103-117, Pt.
"Biogas production by anaerobic digestion of vinasse. 1 and 2" (82-805)

CARDOSO, M.B. and J.R. NICOLI - Nutr. Rep. Int., 1981. Vol. 24 (2, Aug.), 237-248, 249-256, E.
"Single-cell protein from the thermotolerant fungus Phanerochaete chrysosporium grown in vinasse. 1. Production and composition. 2. Nutritive value" (82-514)

CASTELLO BRANCO, J.R., P.A. LACAZ and C. COSTA RIBEIRO - Proc. Int. Soc. Sugar Cane Technol., 17th Congr., 1980 (1981) (see SIA 81-1605), Vol. 3, 2662-2685, E, s.
"Economics of in-natura stillage utilization as fertilizer" (82-215)

CAVANI, C. and M. MANFREDINI - Zootecnica e Nutrizione Animale, 1979, Vol. 5 (3-4, June-Aug.), 455-462, I, e.
"Distillery effluents as animal feed: condensed cane molasses slop (CCMS) in lamb feeding" (81-556)

CESAR, M.A.A., A.A. DELGADO and L.C. GABAN - Brasil Acucareiro, 1978, (July), 92 (1), 24-29. Pt, e
"Increase of the Level of Starch and Potassium in Cane Juice, due to Systematic Application of Vinasse to the Soil" (79-200)

CHAKRABARTHY, R.N. - Indian Chem. J., Annual Number, 1977, Proc. of the Seminar on Recovery and Re-Use of Useful Materials from Pollutants, held Bombay 3rd Mar. 1977, 101-105, discn. 106. E
"Recovery of Useful By-Products from Distillery Wastes" (79-1018)

CHAKRABARTY, R.N. (1963)
"Potash recovery - A method of disposal of distillery wastes and saving foreign exchange" Symp. on Ethyl Alcohol Production Technique. New Delhi. India, pp.93-97. Publ. Noyes Development Corp. N.Y. USA. (1964)

CHANG, C.T. & YANG, W.L. (1973)
"Study on feed yeast production from molasses distillery stillage" Taiwan Sugar 20. 200-203, 205

CHARRET, E.P. (1978)
"Purification of industrial liquid wastes and by-product recovery" Science Technol 16. 10-13

CHATTERJEE, A.C., B.M. DUTT and A.P. LAD - Chemical Age of India, 1976, 27 (12), 1036-1038. E
"Potash Fertilizer from Distillery Waste" (78-569)

CHENU, P. - Anais do IV SEMINARIO COPERSUCAR da Agroindustria Acucareira, see S.I.A. 78-1421, 123-125. Pt
"Concentration of Vinasse" (78-1470)

CHIAN, E.S.K. & DeWALLE, F.B. (1977)
"Treatment of high strength acidic wastewater with a completely mixed anaerobic filter" Water Res. 11. 295-304

CHING-LIANG Lai, Hsi-lin Cheng (Shi-ling Cheng) and Hsin-I Hsueh (Hsin-I) Shieu - Tai-Wan Tang Yeh Yen Chiu So Yen Chiu Hui Pao (Rep. Taiwan Sugar Res. Inst.). 1981 (no. 94, Dec.), 41-53, Ch, e.
"Some undesirable factors affecting ethanol fermentation in cane molasses from carbonation process" (82-1061)

CHIPPERFIELD, P.N.J., ASKEW, M.W., & BENTON, J.H. (1972)
"Multiple-stage plastic-media treatment plants" J. Wat. Pollut. Control Fed. 44. 1955

CHOPIK, V.I. - Ferment, Spirt, Prom., 1977, (6), 8-9, R
"Replacement of Potassium by Ammonium in Molasses Slops with Precipitation of the Double Salt $K_2SO_4.CaSO_4H_2O$" (78-1180)

CHUANG, Y.T, LAI, C.L. & SANG, S.L. (1977)
"Treatment of concentrated yeast waste" Taiwan Sugar 24, 268-272

CHUANG, Y.T. and C.L. LAI - Water Pollution Control in Developing Countries, Proc. Int. Conf., held Bangkok, Thailand, 21-25 Feb. 1978, ed. F.A.R. Ouano, B.N. Lohani and N.C. Thanh, publ. Asian Institute of Technology, 1978, 475-480, E.
"Studies on treatment and utilization of molasses alcohol slop" (82-1067)

CILLIE, G.G., HENZEN, M.R., STANDER, G.J. & BAILLIE, R.D. (1969)
"Anaerobic digestion - IV. The application of the process of waste purification"
Water Res. 3.623-643

CLARKE, M.A. and M.A. BRANNAN - Proc. 1978 Tech. Sess. Cane Sugar Refining Res., (see S.I.A. 79-949), 136-145; discn. 145-148. E
"Sugars in Molasses" (79-1078)

COLETI, J.T. - Brasil Acucareiro, 1978, (Nov.), 38-59, 92 (5), 294-306. Pt
"Fertilizing (Cane) with Vinasse From Santa Adelaide Factory (In Sao Paulo State)" (79-695)

COOK, R. - Proc. Bio-Energy '80 (see SIA 82-1373), 396-397, E.
"BIOSTIL - a process for the production of ethanol from concentrated substrates" (82-1378)

COOPER, B.R. - Annu. Rep. of Res., Caroni Res. Station, Trinidad, Year Ending 30th June 1976, 47-53. E
"Use of Distillery Waste as a Fertiliser" (79-51)

DAHIYA, D.S. & PRABHU, K.A. (1972)
"Environmental factors affecting the activity of ammonifying micro-organisms in the treatment of distillery waste" Proc. 38th Ann. Conc. Sugar Technol. Assoc. India. G35-G39.

DAHIYA, D.S., BHATT, C.S., PRABHU, K.A. & VISWANATHAN, L. (1975)
"Trials of the ammonification process for distillery effluent treatment" Proc. 5th Joint Conc. Sugar Technol. Assoc. India, Deccan Sugar Technol. Assoc. and S. Indian Sugar Cane Technol. Assoc., G39-G75.

DAHIYA, D.S., M. KOSHY, S.S. DHAMIJA et al. - Int. Sugar J., 1982, vol. 84 (no. 1004, Aug.), 232-235, E, f, d, s.
"Spent wash recycling for molasses fermentation" (82-1388)

DAS, K.R. - Seminar on Treatment & Disposal of Effluents from Sugar and Distillery Industries, Bangalore, 24 July 1976, (publ. Sugar Technologists' Association of India), Distillery Section 30-44. E
"Plastic Media Bio-Filters in Distillery Waste Treatment" (78-848)

DAVIDSON, A.B. & BANKS, J.F. (1949)
Proc. 4th Ind. Waste Conf. Purdue University, Lafayette, Ind. 94.

DAVIDSON, A.B. & BROWN, H.B. (1952)
Proc. 7th Ind. Waste Conf. Purdue University, Lafayette, Ind. 142

DAVIDSON, A.B. (1950)
Sew. Ind. Works 22, 654

DE, S.B., RADHAKRISHNAM, L. & NATH, B. (1969)
"A critical appraisal of the loading parameters in anaerobic digestion" 1st I.I.T. Symp. on Ind. Wastes. Indian Insititute of Technology., Kanpur

DETROY, R.W. and C.W. HESSELTINE - Process Biochem., 1978, 13 (9), 2-8, 31. E
"Availability and Utilization of Agricultural and Agro-Industrial Wastes" (79-208)

DONCOEUR, A. - FR 2 473 502. A 11 Jan. 80. no. 80-00609. P 17 July 81. 10 pp. Also EP 33 254.
"Process for the preparation of a thixotropic liquid fertilizer based on vinasse, and product obtained" (82-1071P)

DUBEY, R.S. (1974)
"Distillery effluents - treatment and disposal" Sugar News Ann. Number 6. 9-26

DUBEY, R.S., N.C. VARMA, M.K. PATIL and S.N.G. RAO - Proc. 6th Joint Conv. Sugar Technol. Ass. India, Deccan Sugar Technol. Ass. and S. Indian Sugar-cane Sugar Technol. Ass., 1977, G1-G6. E
"Scheme for the Disposal of Distillery Spent Wash (78-571)

DUVAL, P. (1976)
"New process for pretreating organic wastes from distilleries or other sources without catalyst addition" Ind. Aliment. Agric. 93. 1351.

ECKENFELDER, W.W. Jr. (1971)
"Water quality management in the brewing industry" Paper presented at Instituto de Ing. Quimicos De Puerto Rico. San Juan. Puerto Rico.

FILGUEIRAS, G., - Proc. Int. Soc. Sugar Cane Technol, 17th Congr., 1980 (1981) (see SIA 81-1605), vol. 3, 2607-2611, E, s.
"Energetic conception for distilleries of ethylic, anhydrous or potable alcohol, with simultaneous production of liquid carburant, biofertilizer and electrical energy" (82-194)

GAEVSKAYA, L.V. - Ferment. Spirt. Prom., 1979, (1), 30-33. R
"Fractional Study of the Qualitative Change of Molasses Slops During Fodder Yeast Culture" (80-789)

GAEVSKAYA, L.V., A.I. SKIRSTYMONSKII, A.U. MAMUNYA and A.B. BUTNIK-SIVERSKII - Fermentnaya i Spirtovaya Prom. 1979(8), 10-12, R.
"Corrosion testing of steels in media of the evaporator station of molasses-alcohol factories" (82-1698)

GAEVSKAYA, L.V., A.U. MAMUNYA and V.G. STEPANSKAYA - Fermentnaya i Spirtovaya Prom., 1980 (3), 8-10, R.
"Corrosion of steels in fodder yeast manufacture on molasses spent wash" (82-1699)

GHOSE, T.K. & RAO, B.K. (1959)
"Anaerobic fermentation of distillery waste by enriched methane cultures" J. Sci. Ind. Res. 180, 176-178

GLORIA, N.A. Da - 32 pp. (Portuguese)
"Use of vinasse as fertilizer"

GLORIA, N.A. Da - Brasil Acucareiro, 1975, 86 (5, Nov.), 11-17. Pt - Cf. S.I.A. 74-74, 74-75.
"Agricultural Use of Vinasse" (76-1480)

GLORIA, N.A. da (1977)
"Use of Stillage as a Fertiliser" Codistil internal publication, Dedini, Sao Paulo, Brazil

GONZALEZ, I.M. and N.F. MURPHY - J. Agr. Univ. P.R., 1979, Vol. 63 (3, July), 325-329, 330-335, E, s.
"Potential use of rum distillery slops as animal feed supplement. 1. Mould growth in slops. 2. Nitrogen content of mycelial growth in slops" (81-867)

GOTTLASZ, O. - Szeszipar, 1980, Vol. 28(3), 99-102, Hu. - e abstr. in FSTA. 1981, Vol. 13 (9), 9 E 430.
"Purification of effluent in the alcohol industry" (82-216)

GRAY, R.M. - Paper at UNEP/FAO joint seminar on Residue Utilization "Management of Agricultural and Agro-Industrial Wastes" Rome 18-21 Jan. 1977 FAO Assec No. 34665, 16 pps English S.I.A. - Vol. 40 - No. 5 - 67
"Recovery and Utilization of Residues from Brewing and Other Fermentation Processes (78-572)

GRBA, S. and J. BIJELE - Prehrambeno-technoloska revija - Food Technol. Rev., Zagreb, 1979, Vol. 17(4), 165-168, Cr, e.
"Production of single-cell proteins by Candida utilis on molasses slop" (81-531)

GUIMARAES, E., BETKE, E.G. & BASSINELLO, J.L. (1968)
"Determination of economic dose of vinasse as sugar cane fertilizer" O. Solo 60, 87-91

GUPTA, S.C., SHUKLA, J.P. & SHUKLA, N.P. (1968)
"Recovery of crude potassium salts from spent wash of molasses distilleries by fluidized incineration" Proc. 36th ann. Conc. Sugar Technol. Assoc. India. XXXXIII-1-XXXXIII-7

GURNHAM, C.F. (1955)
"Principles of Industrial Waste Treatment" J. Wiley, New York

HALBERT, E.J. and C.S. BARNES - Proc. Conv. Inst of Brewing (Australian and NZ Section), 1980, Vol. 17, 219-225, E.
"Anaerobic digestion of waste from an alcohol distillery" (82-1066)

HANG, Y.D., SPLITTSTOESSER, D.F., WOODAMS, E.E. & SHERMAN, R.M. (1977)
"Citric acid fermentation of brewery waste" J. Food Sci. 42, 383-384

HANUMANULU, V. and P.V.R. SUBRAHMANYAM - Seminar on Treatment & Disposal of Effluents from Sugar and Distillery Industries, Bangalore, 24 July 1976, (publ. Sugar Technolgists' Association of India), Distillery Section 1-10. E
"Econmics of Treatment and Disposal of Distillery Wastes" (78-700)

HAURY, M. (1958)
Darmstadts Abwassersorgen und Durchgefuhrte Mabnahmen, Stadtehygiene 9, 209-216.

HIATT, W.C., CARR, A.D. & ANDREWS, J.F. (1973)
"Anaerobic digestion of rum distillery wastes" Engineering Bulletin. Purdue University. Engineering Extension Series 142, 966-976

HODGE, H.M. & HILDEBRANDT, F.M. (1954)
"Alcoholic Fermentation of Molasses in Industrial Fermentations" (Edited by Underkoffer, L.A & Hickey, R.J.), pp. 73-89. Chemical Publishing Co., New York

IL'INA, L.D. & EVSEICHIK, B.L. (1976)
"Expediency of growing food yeasts on spent wash from alcoholic fermentation" Nauk. Pre-Udr Sil's Kogospod. Akad. USSR 191,129

IL'INA, L.D. and L.I. BRATCHENKO - Mikrobiologichnyi Zh. (Kiev), 1977, 39 (4), 422-426. Uk, e
"Changes in Nitrogen Substances of Molasses Stillage in the process of Candida Utilis L-35 Development" (79-1522)

IL'INA, L.D., N.G. SITNIK, E.I. PODGURSKAYA et al. - Ferment. Spirt. Prom., 1974, (8), 30-34. R
"Research on Chemical Composition of Molasses Slop with Evaluation of its Degree of Purification" (77-452)

IL'INA, L.D., OSOVIK, A.N., ZABRODSKII, A.G. et al. (1969)
"Selection of the most productive yeast-like fungi for culture on molasses distillery residue" Ferment. Spirt. Prom. 35, 18-21

ISIK, H. (1977)
"Production of fodder yeast from vinasse" Seker 103. 1-11

IWUGO, K.O. - Effluent and Water Treatment J., 1981, 21, (1), 8-10, 12-16, 18; through S.I.A., 1982, 44, ABS. 82-1674
"Mechanical aeration versus hydrogen peroxide in stabilization pond treatment"

JACKMAN, E.A. (1977)
"Distillery effluent treatment in the Brazilian National Alcohol Programme" Chem. Eng. (London) 319. 239-242

JACKSON, C.J. & LINES, G.T. (1970)
"Measures against water pollution in the fermentation industries" Int. Cong. on Indust. Waste Water. Stockholm. Sweden (Edited by Goransson, B.) pp. 381-393. Butterworths, London.

JACKSON, C.J. (1960)
"The treatment of distillery and anti-biotic wastes" Proc. 2nd Symp. on the Treatment of Waste Waters (Edited by Isaac, P.C.) pp. 226-239. Pergamon, Oxford.

JACKSON, C.J. (1966)
"Fermentation waste disposal in Great Britain" Proc. 21st Ind. Waste Conf. Purdue University, Lafayette. Ind. 19-32

JADHAV, H.D. and N.K. SAVANT - Indian J. Agr. Chem., 1975, 8 (1-2), 73-84. E - Abstr. in Chem. Abstr., 1977, 87 (15), 116874p. e
"Influence of Added Spent Wash (Distillery Waste) on Chemical and Physical Properties of Soil"

JAPANESE FERMENTATION RESEARCH INSTITUTE
Biological treatment of industrial waste. Agency of Industrial Science & Technology

JOHNSON, R.N. - Proc. Aust. Soc. Sugar Cane Technol., 1982, 311-315, E.
"Zimbabwe fuel ethanol industry - conception to production" (82-1377)

JUHASZ, B., M. GALANTAI, G. JECSAI and B. SZEGEDI - Szeszipar, 1977, 25 (3), 84-88.u, d, f
"Utilization of Distillery Vinasse in Animal Feeding. 1. The Nutrient Content of Vinasse" (79-1520)

JULSINGHA, VAN J. (Invr.), N.V. Centrale Suiker Maatshappij (1970)
"Process for removing potassium from molasses or vinasse in the form of its double salt K_2SO_4, $CaSO_4$, $1H_2O$, Ger OLS 1817550.

KALE, S.T. - Seminar on Treatment & Disposal of Effluents from Sugar and Distillery Industries, Bangalore, 24 July 1976, (publ. Sugar Technologists' Association of India), Distillery Section 11-18. E
"Studies in Treatment of Distillery Wastes" (78-701)

KAMPF, G., BEHRENS, U. & LEIBNITZ, E. (1965)
"Multiple growth-promoting effects in the efermentation of beet molasses slops" Monatsber. Deut. Akad. Wiss. Berlin 7, 878-882

KAPOOR, B.D., O.P. BHATIA and A.K. MISRA - Proc. 46th Annu. Conv. Sugar Technol. Ass. India, 1982, G63-G70, E.
"Mould protein from molasses distillery spent wash" (83-181)

KARALAZOS, A. & SWAN, H. (1977)
"Nutritional value for sheep of molasses and condensed molasses solubles" Animal Feed Sci. Technol. 1. 143-152

KARALAZOS, A. - Thesis for PhD, Univ. of Nottingham, May 1975. 326 pp. E
"Digestion of (Cane) Molasses (and Condensed Molasses Solubles) in the Ruminant (Sheep)" (79-188)

KAROVA, E. et al (1976)
"Possibilities of using vinasse in the production of feed yeast and l-sorbose" Priroda (Sofia) 25, 5, 58

KAROVA, E., Z. ROSHKOVA, M. MARINOV and N. K'OSEVA - Lozarstvo i Vinarstvo, 1976, 25 (5), 36-40. Bg
"Study of the Possibilities for Using Vinasse in Some Microbiological Industries. 1. Use of Vinasse for Cultivation of Acetic Acid Bacteria" (78-854)

KATO, R., MORINAGA, T. & GOTO, T. (1977)
"Alcohol fermentation" Japan, Kokai, Nov. 77. 143, 286

KATZ, G.M. and H.A. GERMEK - Saccharum STAB, Rev. Trimestral da Sociedade dos Tecnicos Acucareiros do Brasil, Sao Paulo, 1979, 2 (No. 6, Sep.), 47-48. Pt
"Vinasse : Conger Now Supplies Two Processes for its Drying" (80-336)

KEENAN, J.D. (1977)
"Methane fermentation of brewery by products" Biotechnol. Bioengr. 19. 867-878

KHRUSLOVA, T.N. & KOLOMIETS, D.M. (1974)
"Use of fodder yeasts slops from alcohol factories for irrigation and as fertilizer for seedlings" Ferment. Spirit. Prom 4. 40-42

KIRCHGESSNER, M. - Das Wirtschaftseigene Futter, 1980, Vol. 26(2), 150-162, D.
"Utilization of vinasse in pig fattening" (81-880)

KIRCHGESSNER, M. and E. WEIGAND - Archiv fur Geflugelkunde, 1980, Vol. 44, 119-123, D.
"Feeding test on battery chickens with vinasse and molasses, a unique feedstuff" (81-881)

KLIBANSKY, M., A. SAEZ and R. READIGOS - Sobre Deriv. Cana Azucar, 1981, vol. 15 (1), 29-39, S, e
"Study of the clarification of molasses for the production of biomass" (82-1394)

KOIKE, Takashi - Nikkakyo Geppo (Japan Chem. Ind. Ass. Monthly), 1977, 30 (11), 4-10. J - e abstr. in Chem. Abstr., 1978, 88 (24), 176582x.
"Treatment of Fermentatin Waste Water (Vinasse)" (79-1519)

KONDO, Ikuo, Itsuo NAKANE and Fukutaro ITAKURA - Aichiken Nogyo Sogo Shikenjo Kenkyu Hokoku, E, (Res. Bull. Aichi Agr. Res. Centre), 1978, E8, 14-21, J, e
"Studies on young steer fattening of Japanese cattle with special reference to the utlization of molasses - alcohol distiller's solubles" (81-552)

KOSHEL', M.I., A.I. SKYRSTYMONS'KII, L.A. DEMCHYNS'KA et al. - Mikrobiologichnyi Zh. (Kiev), 1977, 39 (2), 156-159. Uk, e
"Study of the Process of Methane Fermentation in Effluents From Fodder Yeast Manufacture" (79-1521)

KOSHEL, M.I., A.I. SKIRSTYMONSKII and A.A. DEMCHINSKA - Mikrobiolgichnyi Zh., Kiev, 1976, 38 (4), 443-448. Uk, e
"Study of a Two-Phase Method for Fermenting After-Yeast Molasses Slops with Methane-Forming Bacteria" (79-54)

KOSHY, M. and D.S. DAHIYA - Proc. 46th Annu. Conv. Sugar Technol. Ass. India, 1982, G85-G91, E.
"Further studies on recycling of spent wash in cane molasses distilleries" (83-175)

KOVAL, V.G., RUBCHENKO, M.E. & KOLODKINA, T.A. (1969)
"Research on chemical composition of fat obtained by microbial synthesis from vinasse" Tr., Ukr. Nauch-Issled. Inst. Spirit. Likero-Vodoch. Prom. 12. 93-105.

KRAVETS, Yu M., KATS, V.M. & KARANAV, Yu A. (1970)
"Partial recirculation of spent wash for molasses dilution" Ferment. Spirt. Prom. 36. 20-21

KUJALA, P., HALL, R., ENGESTROM, F. & JACKMAN, E. (1976)
"Alcohol from molasses as a possible fuel and economics of distillery effluent treatment" Sugar y. Arzuar. March, 28, 29, 32-39

KUMAR, S. and L. VISWANATHAN - Proc. 46th Ann. Conv. Sugar Tech. Assoc. India, 1982, G.71-G.83.
"Isolation of bacterial cultures for the treatment of distillery effluent"

KURANA, K.C. and A.K. MONGA - Chem. Age India, 1980, vol. 31 (7), 771-774, E.
"Disposal of spent was by incineration" (82-1389)

LAVRISHCHEVA, Invrs. T.N., A.S. EGOROV, E.I. STRIZH and Zh.I. PETRAVICHUS, UKRAINSKII NAUCHNO-ISSLEDOVATELSKII INSTITUTE SPIRTOVOI I LIKERO-VODOCHNOI PROMYSHLENNOSTI. - U.S.S.R. P. 526 658. Appl. 14 Mar. 75. Publ. 13 Oct. 76, 2 pp.
"Method of Pretreating Vinasse for Production of Nutrient Media" (79-372P)

LEME, E.J.A., U. ROSENFELD and J.R. BAPTISTELLA - Proc. IV Int. Symp. on Alcohol Fuels Technology (see SIA 82-489), 815-821. Pt.
"Use of vinasse by sprinkling with hydraulic gun" (82-515)

LEWICKI, M. - In : Melasses et Alcool Industriel, Compte rendu de la Reunion d'Experts organisee par le Centre de Developpement de l'OCDE, Paris, 1-3 Dec. 1976, 129-131. F - See S.I.A. 77-931.
"Utilization of Vinasse Arising from Molasses Fermentation" (79-690)

LEWICKI, W. - Kraftfutter, 1978, (9), 480-482. D - also : Inf. Bull. Belgian Beet Res. Inst., 1979, 14 (1), 14-15. E
"HPCV : Molasses Residues of High Protein Content, Partially Dealkalized and Enriched as Partial Substituent for Protein and Molasses in Ruminant Feedstuffs (Description and Uses of HPCV (High-Protein-Containing Vinasses) Using as Examples Proteinal and Viprotal)" (79-691)

LEWICKI, W. - Paper presented at UNIDO Fermentation Alcohol Workship, 1979, 7 pp.
"Production, application and marketing of concentrated molasses fermentation effluent (vinasses)"

LEWIKI, W. (1977)
"Introduction to the technology, application and marketing of concentrated vinasses from the molasses fermentation industry" Z. Zuckerind 27, 302-303

LEWIKI, W. (1978)
"Production, application and marketing of concentrated molasses-fermentation-effluent (vinasses)" Proc. Biochem. June 12-13

LIN, Shui-Fa (1970)
"Research on the cultivation of fodder yeast in vinasse" Rep. Taiwan Sugar Exp. Sta. 51, 1-7

LONDONG, D. (1969)
"Purification of wastes from a German yeast plant" Proc. 24th Ind. Waste Conf. Purdue University, Layfayette, Ind., 770-768

LURIE, J. - S. Afr. Food Rev., 1980, vol. 7 (1), 136-139, E. afrikaans.
"The fermentation industry in South Africa present and future" (82-1692)

MADELEY, J. - Mazingira (Tycooly International Publishing Ltd., Dublin, 1981. Vol. 5(3), 42-51. E.
"Ethanol production runs into environmental difficulties" (82-516)

MAGNY, J., MONTANT, C., RAYNAUD, P., GONTIER, C. & DARDENNE, J. (1977)
"Treating the distillation residues from white wine production" Ger. Offen. 2 630 680

MAGRO, J.A. - Brasil Acucareiro, 1978, (Oct.) 40-48, 92 (4), 232-240. Pt
"Use of Vinasse on Sugar Cane at Usina Da Pedra, Serrana" (79-526)

MAGRO, J.A. and N.A. da GLORIA - Brasil Acucareiro, 1977, (Dec.), 31-34, 90 (6) 363-366. Pt, e
"Fertilization of Sugar Cane Ratoons with Vinasse Complemented with Nitrogen and Phosphorus" (78-567)

MALANOWSKA, J., SKIBA, M., LEBENDZINSKY, S. & WOJCIESZAC P. (1967)
"Yeast cultivation on vinasse with addition of molasses" Prace Inst. Lab. Bad. Przem. Spoz. 17, 27-48

MANFREDINI, M. and C. CAVANI - Zootecnica e Nutrizione Animale, 1979, Vol. 5 (1, Feb.), 147-153, I, e.
"Zootechnical utilization of distillery effluents: concentrated vinasse from beet molasses (VCMB) in feeding lambs" (81-553)

MANFREDINI, M. and C. Cavani - Zootecnica e Nurizione Animale, 1979, Vo. 5 (1, Feb.), 155-164, I, e.
"Zootechnical utilization of distillery effluents: concentrated and depotassified vinasse from beet molasses (VCMB)" (81-554)

MATSUMOTO, J. et al (1971)
"Treatment of alcoholic distillery slops by activated sludge process" I. Kogyo Yoshi 153, 26.

MATTEUZZI, D., P. BRIGIDI, F. CROCIANI and P. SINA - Ind. Soc. Ital. 1982, vol. 75 (4, July-Aug.), 111-113, I, e.
"Preliminary study on the microbiological degradation of some hygroscopic substances present in distillery stillage" (82-1697)

MAZZONE, J. - Food Eng. Int., 1981, vol. 6 (9, Nov.), 50-52, E, d, s, f.
"Pollutant becomes an asset" (83-176)

MERKEL, W. (1959)
"Treatment of industrial wastewaters" Ber. Abwassertech. Ver. 10. 249-253

MONTANANI, F.N. (1954)
Ingenieria Sanitaria, Mexico, 8, 21-43

MONTEIRO, C.E. (1975)
"Brazilian experience with the disposal of waste water from the cane sugar and alcohol industry" Process Biochem. Nov. 33-41

MORENO, I.E. & CARDENAS, G.J. (1971)
"Finding the optimum conditions for the production of fodder yeast from vinasses from alcohol fermentation of sugar cane molasses" Arch. Bioquim. Quim. Farm. Tucuman 17, 145-157

MOSEY, F.E. (1978)
"Anaerobic filtration: A biological treatment process for warm industrial effluents" Water Pollut. Control 1978, 370-378

MULLER, Invrs. W.C. and F.D. MILLER, National Distillers & Chemical Corp. - US 4 310 629, A 3 Apr. 80, no. 137 074, P 12 Jan. 82, 6 pp.
"Continuous fermentation process for producing ethanol" (83-185P)

MUNOZ-CANDELARIO, R. M. PEDRAJA-SANTOS, A. RODRIGUEZ-RAMIREZ et al - NTIS Rep. PB80-224942, Feb. 1979, 29 pp., E.
"The wet-air oxid ation of rum distillery wastes"(82-521)

McNEIL, K.E., P.J. ANDERSON, H. BARTHOLOMEW and R.T. HUTCHINSON - Proc. Aust. Soc. Sugar Cane Technol., 1982, 301-310, E.
"Biological treatment of distillery waste" (82-1387)

NICOL, Invrs. R. and A. DEBRY, Degremont S.A. - FR 2 461 684, A 23 July 79, no. 79-18899, P 6 Feb. 81, 8 pp.
"Process for the purification of effluents with high organic loading and containing sulphates" (82-1070P)

NICOLAIEWSKY, E. - Brasil Acucareiro, 1981 (Oct), 23-30 vol. 98(4), 253-260, Pt
"Physiochemical treatment of vinasse: flocculation, sedimentation and filtration" (82-806)

OKUBA, H., TEZUKA, T. & TAKAO, K. (1967)
"Alcohol distillation wastes treatment by unicellular algae culture. II. Cultural conditions of Chlorella in flat flasks" Hakko Kyokaishi 25, 76

OKUBA, H., TEZUKA, T. & TAKAO, K. (1967)
"Treatment of alcohol distilled wastes by algae culture. III. Culturing conditions of Chlorella in a jar fermenter" Hakko Kyokaishi 25, 237.

OLDHAM, W.K. & NEMETH, L. (1973)
"Anaerobic lagoons for treatment of high strength organic wastes"

ONO, H. (1964)
"Formal discussion on paper by Bhaskaran" T.K. In Proc. 2nd Int. Conf. Tokyo (Edited Baars, J.K.), pp. 100-104. Pergamon, Oxford.

PAGAN-FONT, F.A., C. KOHLER and D. WEILER - J. Agr. Univ. Puerto Rico, 1980, vol. 64(2, Apr.), 1981-189, E, s
"Preliminary evaluation on the potential utilization of distiller's solubles (slops) for the culture of the blue tilapia (Tilapia aurea)" (82-1393)

PAINTER, H.A. (1960)
"Treatment of malt whisky distillery wastes by anaerobic fermentation" Brewers Guide (Br) August

PANNACH, H. & SCHULZE, G. (1968)
"Molasses vinasse, a still unexploited fodder for ruminants" Tierzucht, 22. 132-133

PARKHOMCHUK, M.A., ZABRODSKII, A.G. & PERERVA, P.K. et al (1969)
"Test of growing fodder yeast on vinasse" Tr. Ukr. Nauch-Issled. Inst. Spirt. Likero-Vodoch. Prom. 12, 74-80

PARKHOMCHUK, M.A., ZABRODSKII, A.G. & SOSHKO, G.F. (1969)
"Effect of acids and nutrients salts on yield of fodder yeast from vinasse" Tr. Ukr. Nauch-Issled. Inst. Spirt. Likero-Vodoch. Prom. 12, 67-74

PARTHASARTHY, T., THANGADURAI, D. & BASHEER, Ahmed N. (1967)
"Anaerobic stablization of distillery waste from cane sugar industry" Environ. Health (Nagpur) 9, 110-117

PAUL, B.B. - Chemical Age of India, 1976, 27 (12), 1039-1041. E
"Poultry Feed and Mixed Fertilizers from Distillery Waste" (78-570)

PAZ, H.A. & LOPEZ, HERNANDEZ J.A. (1973)
"Utilization of raw material by products and wastes of the sugar industry in preparation of fodder yeast" Revista Agronomica del Noroeste Argentino 10, 205-214

PETTET, A.E., TOMLINSON, T.G. & HEMENS, J. (1959)
"The treatment of strong organic wastes by anaerobic digestion" J. Inst. Pub. Health Eng. 170

PLAKSVA, V.D., A.I. SKIRSTYMONSKII, M.I. KOSHEL and I.I. SAGAN- Pishch. Prom., N.P. Sb. Kiev, 1981(4, Oct.-Dec.), 48-50, R.
"Utilization of vinasse from molasses-based yeast manufacture" (83-455)

POPESCU, V. et al (1967)
"Treatment of waste water from manufacture of alcohol and compressed yeast factory" Studii de Protectia Si Epuranea Apelor, Bucarest IX, 269

PRABHU, K.A. & PRAKASH, G. (1972)
"Treatment of distillery waste by nitrifying bacteria" Proc. 38th Ann. Conc. Sugar Technol. Assoc. India, G57-G60.

PROGREBNAYA, V.F., ZABRODSKII, A.G., KRAVETS, E.N. et al (1971)
"Biosynthesis of fat by yeast and yeast-like fungi cultured on vinasse" (3rd communication) Tr. Ukr. Nauch-Issled. Inst. Spirt. Likero-Vodoch. Prom. 13, 55-62

PUSHPARAJ, B., CAROPPO, S. SIU, C. & MICHLAUS, N. (1976)
"Preliminary tests for wastewater purification by algae filters" Nuovi, Ann. Ig. Microbiol. 25, 407-417

QUEIROZ ARAUJO, N. de, A.S. VISCONTI, H.F. de CASTRO et al. - Brasil Acucareiro, 1976, (Dec.), 35-45, 88 (6), 479-489. Pt, e
"Production of Fungal Biomass from Vinasse" (78-1204)

RADHAKRISHNAN, I. De, S.B. & NATH, B. (1969)
"Evaluation of the loading parameters for anaerobic digestion of cane molasses distillery waste" J. Wat. Pollut. Control Fed. 41, R431-R440.

RAFFINERI TIRLEMONTOISE (1973)
"Process for preparing a proteinized concentrate and the concentrate so obtained" Belg. P. 793, 960

RAMIREZ ZARZOSA, J.C. and E. AVILA GONZALEZ - Chapingo Nueva Epoca, 1977, No. 6, (July-Aug.), 38-45, S.
"Use of molasses treated and not treated with sodium benzoate in practical diets for fattening chickens" (81-557)

RAMIREZ, M. and R.P. PLANT - J. Agr. Univ. Puerto Rico. 1982, vol. 66 (3 July), 235-238, E.
"Characterization of slops of high-test molasses alcoholic fermentation" (83-453)

RAO, B.S. (1972)
"A low cost waste treatment method for the disposal of distillery waste (spent wash)" Water Res. 6, 1275-1282

RAO, B.S. - Seminar on Treatment & Disposal of Effluents from Sugar and Distillery Industries, Bangalore, 24 July 1976, (publ. Sugar Technologists' Association of India), Distillery Section 45-50. E
"Disposal of Distillery Waste by Anaerobic Lagoon Method, Design and Operation" (78-849)

RAO, B.S. - Tech. Annu., Indian Ass. Water Pollution Control, 1980, vol. 6-7, 83-90, E.
"Distillery effluent treatment" (82-1390)

RAO, C.E.S. - Seminar on Treatment & Disposal of Effluents from Sugar and Distillery Industries, Bangalore, 24 July 1976, (publ. Sugar Technologists' Association of India), Distillery Section 51-58. E
"Treatment of Spent Wash by Anaerobic Digestion and Recovery of Methane Gas" (78-850)

RAO, P.J.M. - Proc. Int. Soc. Sugar Cane Technol., 18th Congr., 1983, held Havana, Cuba, 18-26 Feb. 1983, Product Commission, 325-342, E, f, s.
"Production of methane gas from stillage on commercial scale in India" (83-1040)

RASTOGI, M.K. & KRISHNA, Murti C.R. (1963)
"Preparation and properties of a protein digest made from distillery sludge" Symp. of Ethyl Alcohol Production Technque, New Delhi, India. pp. 98-104. Publ. Noyes Development Corp. N.Y. USA (1964)

REICH, G.T. (1945)
"Production of carbon and potash from molasses distillers' stillage" Trans. Amer. Inst. Chem. Engrs 41, 233-251

REMBOWSKI, E., ZDZIENNICKI, A., STACHOWICZ, K.J. & LABERCKI, M. (1974)
"Investigations on the application of reverse osmosis for the treatment and utilization of wastes from the yeast industry" Proc. IV Int. Cong. Food Science & Technol. Madrid. 4, 306-312

RIBEIRO, C.C., J.R.C. BRANCO and P.A. LACAZ - Petro & Quimica, Sao Paulo, Brazil, 1979, Vol. 2 (No. 8, Apr.), 55-60, Pt. e.
"Vinasse: a national programme for its utilization" (82-1064)

RIECHE, A., MARTINI, A. & LOHENZ, M. (1966)
"Microbial-technical synthesis of cell substance 13. Fermentation of beet molasses slops" Monatsber Deut. Akad. Wiss. Berlin 8, 457-460.

RIMY, J.C., L. ORSINI and A. MARIN-LAFLECHF. - Hautes Etudes Betterav. Agric., 1975, 7, (31), 17-21
"The agronomic importance of certain by-products of use in large-scale farming"

RIPLEY, P. (1979)
"Process Engineering aspects of the treatment and disposal of distillery effluent" Proc. Biochem. 14, 8-10

ROBERTIELLO, A. - Agr. Wastes, 1982. vol. 4 (5, Sept), 387-395, E.
"Upgrading of agricultural and agro-industrial wastes: the treatment of distillery effluents (vinasses) in Italy" (83-1042)

ROBERTIELLO, A., L. ANGELINI and E. D'ADDARIO - Agr. Wastes, 1982, vol. 4(5, Sep.), 397-405, E.
"Upgrading of agricultural and agroindustrial wastes: the desalification of concentrated beet vinasses" (83-1043)

ROBERTS, N. & HARDWICK, J.B. (1951)
"High rate trickling filter pilot plant studies on distillery waste" Proc. 6th Ind. Waste Conf. Purdue University, Lafayette, Ind. 80-87

RODELLA, A.A. and S.E. FERRARI - Brasil Acucareiro, 1977, (July), 90 (1), 6-13. Pt, e
"Composition of Vinasse and Effects of its Use as Fertilizer for Sugar Cane" (78-421)

RODELLA, A.A., E. ZAMBELLO Jr. and J.O. FRANCISCO - Proc. Int. Soc. Sugar Cane Technol. 18th Congr., 1983, held Havana, Cuba, 18-26 Feb. 1983, Agricultural Commission, vol. 1, 189-214, E, f, s.
"Effects of vinasse added to soil on pH and exchangeable aluminium content" (83-753)

ROLZ, C., DE CABBERA, S., ESPINOSA, R., MALDONADO, O. & MENCHU, J.F. (1975)
"Growth of filamentous fungi on rum distilling slops" Ann. Technolgie Agricole 24, 445-451

ROSEN, K. - Process Biochem., 1977, 12 (3, Apr.), 10-12. E
"Production of Baker's Yeast" (77-1075)

ROSS, P. & DE PROBERVILLE (1938)
Inst. Sugar J. 376

ROTENBERG, B. L.D. ANTONACCIO and A. JACHAN - Informativo do INT, Rio de Janeiro, Brazil, 1979, Vol. 12 (no. 23, Sep.-Dec.), 25-28, Pt, e
"Determination of the chemical constitution of vinasse from sugar cane molasses. 1. Organic acids and glycerol" (82-517)

ROTH, L.A. and C.P. LENTZ - Can. Inst. Food Sci. Technol. J., 1977, 10 (2, Apr.), 105-108. E, f
"Anaerobic Digestion of Rum Stillage" (78-228)

RUDOLFS, W. & TRUBNICK, E.H. (1948)
Sewage Works J. 20, 1084

RYBAROVA, J., F. STROS and J. NOVATNA - Biologizace a Chemizace Zivocisne Vyroby Veterinaria, 1982, vol. 18 (5), 451-458, Cs, r, e, d, f, s.
"The quality of fodder yeast obtained from various saccharic raw materials by wasteless technology" (83-463)

SA, Invrs. A. de and J.M. LUKSENBERG, Versa Consultoria Technica Ltda. CGC. - US 4 337 123, A 29 Aug. 80, no. 182 361, P 29 June 82, 6 pp. PR BR 31 Aug. 79 and 30 May 80. no. 7905624.
"Process for the production of fuel alcohol, without vinasse" (83-458P)

SAKAKIBARA, Invrs. Mikio, Sadao NOGUCHI and Toshio FUJISAWA, Kyowa Hakko Kogyo KK - GB 2 100 749 A, A 28 May 82, no. 8215746, P 6 Jan. 83, 6 pp. PR JP 29 May 81, no. 56/080991.
"Treating molasses" (83-444P)

SAMEJIMA, Hirotoshi, Takashi KOIKE, Sadao NOGUCHI and Minoru NAGASHIMA - In: Recent Developments in Separation Science, ed. N.N. LI, publ. CRC Press Inc., Cleveland, Ohio, U.S., 1977, 3 (B), 313-341. E
"Treatment of Fermentation Waste Waters, its Problems and Practices" (80-786)

SAMUELS, G. - J. Amer. Soc. Sugar Cane Technol., 1980 (1982), vol. 1, 62-67, E.
"Possible agricultural and industrial uses of distillery wastes in Puerto Rico" (82-1695)

SANCHEZ RIERA, F., S. VALZ-GIANINET, D. CALLIERI and F. SINERIZ - Biotechnology Letters, 1982, Vol. 4(2), 17-132, E.
"Use of a packed-bed reactor for anaerobic treatment of stillage of sugar cane molasses" (82-519)

SANDERS, M.C. (1977)
"Determination of the kinetic constants for the anaerobic treatment of wine stillage" 7th Fed. Conv. Aust. Water & Wastewater Assoc., Canberra. 479-513

SANG, S.L., L.H. WANGE, P.T. HWANG et al. - Proc. IV Int. Symp. on Alcohol Fuels Technology (see SIA 82-489), 797-800, E.
"Some notes on studies of alcohol slops treatment in Taiwan" (82-518)

SASTRY, C.A. & MOHANRAO, G.J. (1964)
"Treatment and disposal of distillery wastes" Symp. on Ethyl Alcohol Production Technique, New Delhi, India, pp. 88-92. Publ. Noyes Development Corp. N.Y., USA (1964)

SAVALAPPAN, K.N. - J. Institution of Engineers, India, Part EN, 1979, Vol. 59 (3, June), 93-96, E.
"Environmental pollution problem" (82-520)

SAVANT, N.K., J.D. PATIL and A.N. Deshmane - J. Maharashtra Agr. Univ., 1982, vol. 7 (1). 1-4, E.
"Chemical nature of a spent wash (distillery waste)" (83-1041)

SAWYER, C.N. & ANDERSON, E.J. (1949)
"Aerobic treatment of rum wastes" Water Sewage Works 96, 112-114

SCIPIONI, R., M. MANFREDINI and D. FIUMANA - Zootecnica e Nutrizione Animale, 1979, Vol. 5 (1, Feb.), 181-189, I, e.
"Zootechnical utilization of distillery effluents, determination of the metabolizable energy and digestibility of broiler diets containing concentrated beet molasses slop (CBMS)" (81-555)

SEN, B.P. & BHASKARAN, T.R. (1962)
Anaerobic digestion of liquid molasses distillery wastes" J. Wat. Pollut. Control Fed. 34, 1015-1025

SEYFRIED, C.F. (1969)
"Experiences with brewery sewage treatment plants" Muenchner Beitr. Abwasser-Fisch-Flussbiol. 16, 258.

SHCHERBAK, N.S. & RUDNITSKII, P.V. (1967)
"Question of efficiency of feeding vinasse to cattle (2nd communication) Tr. Nauch-Issled. Inst. Spirt. Likero-vodoch, Prom. 11, 138-145

SHEA, T.G., E. RAMOS, J. RODRIQUEZ and G.H. DORTON - In: Proceedings 5th National Symposium on Food Processing Wastes, Monterey, California, Apr. 17-19, 1974. Publ. Pacific Northwest Environmental Research Laboratory, Environmental Protection Agency, Corvallis, Oregon, EPA-660 2-74-058, PB 237 520, June 1974, 155-198. E
"Investigation of Rum Distillery Slops Treatment by Anaerobic Contact Process" (78-227)

SHEA, T.G., RAMOS, E., RODRIGUES, J. & DORIAN, G.H. (1974)
"Rum distillery slops treatment by anaerobic contact process" Envir. Prot. Tech. Series EPA 660/2-74-074, 1-99

SHEEHAN, G.J. and P.F. GREENFIELD - Water Res. 1980. Vol. 14(3), 257-277, E.
"Utilization, treatment and disposal of distillery waste water" (82-1063)

SHVETS, V.N. and A.N. OGORODNIKOVA - Izv. VUZ, Pishch. Tekhnol., 1981 (3), 71-74, R. - e abstr. in Int. Sugar J., 1982, vol. 84 (no. 1004, Aug.), 254.
"Conditions for removing volatile organic acids from molasses during heat treatment" (82-1384)

SHVETS, V.N., M.Ya. SAVCHUK, A.N. OGORODNIKOVA et al. - Ferment. Spirt. Prom., 1976, (7), 5-8. R
"Recycling of Primary Molasses Slops into Alcohol Manufacture" (79-692)

SILVA, G.M. de A., L.J. POZZI de CASTRO and J.A. MAGRO - Anais do IV SEMINARIO COPERSUCAR da Agroindustria Acucareira, (see S.I.A. 78-1421), 107-122. Pt
"Agroindustrial Behaviour of Sugar Cane in Soil Irrigated with Vinasse or not Irrigated" (78-1471)

SILVA, G.M.A. - Brasil Acuc., 1981, 98, 417-422 (Portuguese).
"Treatment and agroindustrial utilization of vinasse. II. A new focus"

SILVA, G.M.A., L.J.P. de CASTRO, A.C. SANCHES et al. - Bol. Tec. Copersucar, Sao Paulo, 1978, No. 7-78 (Nov.), 9-14, Pt; 16, e
"Effects of the Use of Vinasse as Fertilizer for Sugar Cane" (79-1021)

SILVA, L.C.F. da, O. ALONSO, J. ORLANDO, F. and E. ZAMBELLO Jr. - Brasil Acucareiro, 1981 (Nov.), 59-65 vol. 98 (5) 375-381, Pt, e.
"Nitrogen complementation of vinasse, 2. Forms of application to soil TE (structured dark red earch)" (83-183)

SINGH, R., N.T. SINGH and Y. ARORA - J. Indian Soc. Soil Sci., 1980, vol. 28 (1), 38-41, E.
"The use of spent wash for the reclamation of sodic soils" (82-1392)

SKIBA, J. & ILLNICKA-OLEJNACZAK, O. (1968)
"Selection of food yeast strains for the utilization of vinasse alone and with molasses added. 1. Batch yeast cultivation" Prace Inst. Lab. Badaw. Przem. Spaz. 18, 79-91

SKIBA, J. & ILLNICKA-OLEJNAICZAK, O. (1968)
"Selection of food yeast strains for the ulitization of vinasse alone and with molasses added. 3. Use of the strains" Candida tropicalis c.t./3 and c.t. 2 for the industrial production of food yeast" Pract Inst. Lab. Badaw. Przem. Spoz. 18. 93-102

SKIRSTYMONSKII, A.I., SHUSHII, M.S., LEVCHENKO, V.I. & BALATSKII, O.T. (1973)
"Preparing granular fodder from vinasse" Kharchova Prom. Nauk-Vyrob. Zb. 29-31

SKIRSTYMONSKII, A.S. - Pishch. Prom. N.P. Sb., Tekhnika, Kiev, 1977, (3), 24-27. R
"Use of Wastes in the Alcohol Industry" (80-788)

SKOGMAN, H. - Process Biochem., 1979, 14 (1), 5-6,, 25. E
"Effluent Treatment of Molasses-Based Fermentation Wastes" (79-527)

SOBRAL, A.F., D.A. CORDEIRO and M.A.C. dos SANTOS - Brasil Acucareiro, 1981 (Nov.) 52-58 vol. 98(5) 368-374, Pt, e.
"Effects of vinasse application to sugar cane ratoons" (83-182)

SONODA, Y. & TANAKA, M. (1968)
"Anaerobic digestion of low concentration wastes 1. Continuous digestion tests of some industrial wastes" J. Ferment. Technol. 46, 789-795

SOSHKO, G.F., PARKHOMCHUK, M.A. & ZABRODSKII, A.G. (1968)
"Research on the possibility of increasing the yield of food yeasts from vinasse by adding growth substances" Invest. VUZ Pishch Tekhnol 56-58

SPRUYTENBURG, G.P. - Int. Sugar J., 1982, vol. 84 (no. 999. Mar.), 73-74, E, f, d, s.
"Vinasse pollution elimination and energy recovery" (82-807)

SRIVASTAVA, C.P., RAVIKUMAR and S.J. LAGARE - Seminar on treatment & Disposal of Effluents from Sugar and Distillery Industries, Bangalore, 24 July 1976, (publ. Sugar Technologists' Association of India), Distillery Section 65-72. E
"Treatment of Distillery Waste: Pilot Plant Study at Somaiya Organo-Chemicals Ltd., Sakarwadi" (78-852)

STANDER, G.J. (1950)
"Effluents from fermentation industries" Parts 1-4, Instit. Sewage Purific. 286-312, 438-458

STOJSAVLJEVIC, T., R. CURCIC, S. STOJANOVIC and P. PLAVSIC - Krmiva, Zagreb, 1976, 18 (5), 975-102. Cr
"Possibilities of Using Evaporated Molasses Slops from Alcohol and Yeast Manufacture in Cattle Feeding" (79-52)

STUPIELLO, P., C.A. PEXE, H. MONTEIRO and L.H. SILVA - Brasil Acucareiro, 1977, (Sep.), 41-50 (90 (3), 185-194). Pt, e
"Effects of the Use of Vinasse as Fertilizer on the Quality of Sugar Cane" (78-422)

SVETS, V.N., M. Ya SAVCHUK, and A.A. EGOROV - Fermentnaya i Spirtovaya Prom., 1981 (7), 13-16, R.
"Unit for continuous heat treatment of molasses" (83-168)

TANAKA, M., KASAHARA, A. & ONO, H. (1960)
"Methane fermentation of distillery waste of alcoholic fermentation. XIII. Influence of the quantity of nitrogen on the thermophilic digestion" Kogyo Gijutsuin Hakko Kenkyusho Kenkyu Hokuku 18, 111-122

TARARYKOV, Invrs. G.M. and A.N. CHAYANOV, VORONEZHSKII TEKHNOLOGICHESKII INSTITUT - U.S.S.R.P. 461 943, Appl. 24 July 73. Publ. 12 Aug. 75. 3 pp.
"Arrangement for Dewatering of Molasses Vinasse" (79-528P)

TAUK, S.M. - Revista de Microbiolgia (Sao Paulo), 1976, 7 (4), 92-97. Pt, e
"Preliminary Study of Vinasse as a Substrate for Yeast Growth" (79-693)

TAUK, S.M. and V. GAMBALE - Rev. de Microbiolgia, 1982, vol. 13 (1, Jan.-Mar.), 12-21, Pt, e.
"Effect of agitation, pH, time and nutrients on biomass production of Candida guilliermondii in vinasse and molasses media" (83-464)

TAVERNER, M.R. & KARUNAJEEWA, H. (1976)
"Use of single cell protein in diets for livestock and poultry" J. Aust. Inst. Agric. Sci. March, 20-22

TAYGUN, N., R. OZDEMIR, G. ULKU and H. ISIK - Seker, 1978, No. 106 (Jan.), 1-16. Tr, e, d, f
"Recycling of Vinasse in Alcohol Plants" (78-1469)

TEIXEIRA, A. da S. - anales Asociacion Brasil Quimica, 1979, vol. 30 (3-4), 95-102, Pt, e.
"Stillage recycling" (83-174)

THOMAS, J.L. & KOEHRSEN, L.G. (1974)
"Activated sludge bio-disc treatment of distillery wastewater, EPA Report EPA-660/2-74-014, 1-101

TOMCZYNSKA, J. (1971)
"Analysis of effluent from fodder yeast production using molasses distillery slops" Prace Inst. Badaw. Przem. Spoz. 21, 319-327

TROITSKII, A.S. et al (1976)
"Production of protein biomass from viniculture discharge" Sadovod, Vinograd. Vinodel, Mold. 31, 28

USHER, J.F. & WILLINGTON, I.P. (1979)
"The potential of distillery waste as sugar cane fertiliser" Proc. ASSCT 1. 143.

UTIKAL, H. - DE-OS 2 919 518, A 15 May 79, P 20 Nov. 80, 12 pp.
"Process for the production of ethanol from sugar cane" (82-1068P)

VASSARD, O. - Ind. Aliment. Agr., 1982, vol. 99 (7-8), 525-528, F, e, d.
"Recycling of beet vinasse" (82-1696)

VERMA, S.R. & DALALA, R.C. (1976)
"Toxicity of distillery waste to Puntius sophore (Ham and Mystus vittatus (Bloch) (Pisces: Cyprinidae: Bagridae) Part 3. Bioassay studies and TL determination" Acta Hydrochim. Hydrobiol 4, 547

VILLEN, R.A., A.M. CRAVEIRO, B.M. ROCHA and W.S. NETTO - Energia, 1981, Vol. 3 (No. 15, July-Aug.), 22-24, Pt. e.
"Treatment of vinasse by anaerobic digestion - upflow system" (82-1065)

VITKOVSKAYA, V.A., Yu.M. KRAVETS, E.S. ADAMENKO et al. - Mikrobiogicheskie Metody Bor'by s Zagryazneniem Okruzhayushchei Sredy, Tezisy dokladov konferentsii, Pushchino, 1975, 24-26. R - Cf. S.I.A. 78-507.
"Biochemical Purification of Highly Concentrated Effluents from Molasses - Alcohol Factories" (78-703)

VITKOVSKAYA, V.A., Yu.M. KRAVETS, E.S. ADAMENKO et al. - Mikrobiologich. Metody Bor'by s Zagryazn. Okruzhayushchei Sredy, 1975, 24-26; through S.I.A., 1978, 40, Abs. 78-703.
"Biochemical purification of highly concentrated effluents from molasses-alcohol factories"

VUYST, de A., MOREEB, A. & ARNOULD, R. (1971)
"Value at vinasse in feeding livestock during growth" Centre de Rech. Zootechn. de L'Universite de Louvain, Publ. No.8, 1-12

WANG, L.H., Y.C. KUO and C.Y. CHANG - Rpt. Taiwan Sugar Research Inst., 1977, (78), 71-80 (Chinese)
"Distribution of organic matter during molasses alcohol fermentation and feed yeast cultivation on the slop"

WANG, L.H., Y.C. KUO and S.L. SANG - Rpt. Taiwan Sugar Research Inst., 1975, (70), 37-44 (Chinese)
"Treatment of the waste stream from a yeast plant. II. Experiment on re-using the waste stream on a jar fermenter scale"

WANG, Long-huei (Lung-hui WANG), Yung-chun KUO and Chien-yu CHANG (Ch'ien-yu CHANG) - Tai-Wan Tang Yeh Yen Chiu So Yen Chiu Hui Pao (Taiwan Sugar Res. Inst.), 1977, No. 78 (Dec.), 71-80. Ch, e
"Distribution of Organic Matters During Molasses Alcohol Fermentation and Feed Yeast Cultivation of the Slop" (78-1177)

WILLINGTON, I.P. and G.G. MARTEN - Resources and Conservation, 1982, vol. 8 (2, Sep.), 111-130, E.
"Options for handling stillage waste from sugar-based fuel ethanol production" (83-454)

WU, Yeun C. and Chiao F. KAO - J. Water Pollution Control Federation, 1976, 48 (11), 2609-2618. E
"Activated Sludge Treatment of Yeast Industry Waste Water" (78-2[illegible]6)

YADAV, B.S., D.S. DAHIYA and P. TAURO - Proc. 46th Annu. Conv. Sugar Technol. Ass. India, 1982, G41-G52, E.
"Studies on fermentation of sugar cane juice for the production of ethanol" (83-169)

YAMAUCHI, T. et al (1977)
"Waste water treatment in fermentation" Japan Kokai 77, 72, 365

YARCHUK, Invrs. I.L., L.E. AIZIKOVICH, N.V. ROMANYUKOV and B.S. GNIDYUK, DNEPROPETROVSKII SELSKOKHOZYAISTVENNYI INSTITUT. - U.S.S.R. P. 451 678. Appl. 24 No. 72. Publ. 3 Apr. 75. 1 p.
"Method for Improving the Fertilizing Properties of Molasses Slops" (77-458P)

YAROVENKO, Invrs. V.L., B.A. USTINNIKOV, D.M. MAKEEV et al., Vsesoyuznyi Nauchno-Issledovatel'skii Institut Produktov Brozheniya - SU 800 186, A 26 Apr. 79, P 2 Feb. 81, 3 pp.
"Method for utilizing molasses vinasse" (82-1069P)

ZABRODSKII, A.G. - A booklet, publ. Tekhnika, Kiev, 1977, 119 pp. R
"Obtainment of Fodder Yeast From Molasses Slops" (79-53)

ZABRODSKII, A.G., A.N. OSOVIK, L.E. GRIDINA et al. - Ferment. Spirt. Prom., 1977, (8), 14-16. R
"Preventing the Death of Yeast During its Growth on Vinasse" (78-1181)

ZABRODSKII, A.G., OSOVIK, A.N., POLYANSKAYA, E.A. & STRIZKENYUK, E.V. (1973)
"Possibility of getting higher yields of fodder yeasts from vinasse" Ferment. Spirt. Prom. 40-43

ZABRODSKII, A.G., PARKHOMCHUK, M.A. & SOSHKO, G.F. (1970)
"Precipitation of gypsum from molasses distillery residues prior to incubation of food yeasts" Ferment Spirt. Prom. 35, 17-19

ZABRODSKII, A.G., PARKHOMCHUK, M.A. & VASKO, T.P. (1967)
"Research on conditions for manufacturing fodder yeasts from vinasse" Tr. Nauch-issled. Inst. Spirt. Likero-vodoch. Prom. 11, 114-124

ZABRODSKII, A.G., POGREBNAYA, V.F., KRAVERTS, E.N. et al (1967)
"Biosynthesis of fat by the yeast Rhodotorula gracilis cultured on vinasse (1st communication)" Tr. Nauch-issled. Inst. Spirt. Likero-vodoch. Prom. 11, 133-137.

ZAJIC, J.E. (1971)
"Water Pollution Disposal and Reuse" Vol 2. pp. 573-589. Marcel Dekker, New York

Davy Agro

APPENDIX 2

IMMOBILIZED CELLS AND ENZYMES LITERATURE REVIEW

Davy Agro

IMMOBILIZED CELLS - R.B. BROOKS

ANON (1980) - Biotechnology and Bioengineering, Vol. XXII, 1489-1496
"Rapid ethanol fermentation in immobolized yeast cell reactor"

ATKINSON B. (1978) British Patent 38267/78

BLACK G.M., WEBB C., MATTHEWS T.M., ATKINSON B. (1983) - Biotechnology and Bioengineering, Vol. XXVI, July, 134-141
"Practical reactor systems for yeast cell immobilization using biomass support particles"

CHEUNG I.H.S., GHOSH P., PAMMENT N.B. (1984) - Private communication
"Factors affecting ethanol production in an immobilised whole cell reactor"

CHO G.H., CHOI C.Y. (1981) - Biotechnology Letters Vol. 3 No. 11, 667-671
"Continuous ethanol production by immobilized yeast in a fluidized reactor"

FUKUI S., TANAKA A. (1982) - Annual Review Microbiol, 145-173
"Immobilized microbial cells"

GENCER M.A., MUTHARASAN R. (1983) - Biotechnology and Bioengineering, Vol. XXV, 2243-2262
"Ethanol fermentation in a yeast immobilized tubular fermenter"

GROTE W., et al (1980) - Biotechnclogy Letters 2, 11, 481-466

HSIAO H.Y., CHIANG L.C., YANG C.M., CHEN L.F., TSAO G.T. (1983) - Biotechnology and Bioengineering, Vol. XXV, 363-375
"Preparation and performance of immobilized yeast cells in columns containing no inert carrier"

KENNEDY, J.F. (1976) - Nature 261, 242, 44

KING VAE, ZALL R.R. (1983) - Process Biochemistry, Dec, 17-20
"Ethanol fermentation of whey using calcium alginate entrapped yeasts."

Davy Agro

KLEIN J., KRESSDORF B. (1983) - Biotechnology Letters Vol, 5 No. 8, 497-502
"Improvement of productivity and efficiency in ethanol production with Ca-alginate immobolized Zymomonas mobilis"

KOLOT DR F.B. (1980) - Process Biochemistry, Oct/Nov., 2-8
"New trends in yeast technology-Immobilized cells"

KOLOT F.B (1984) - Process Biochemistry, Feb, 7-13
"Immobilized cells for solvent production"

KUU W.Y., POLACK J.A. (1983) - Biotechnology and Bioengineering, Vol. XXV, 1995-2006
"Improving immobilized biocatalysts by gel phase polymerization"

LEE J.M., POLLARD J.F., COULMAN G.A. (1983) - Biotechnology and Bioengineering, Vol. XXV, 497-511
"Ethanol fermentation with cell recycling:Computer simulation"

LEE, T.H., AHN J.C., RYU D.D.Y. (1982) - Enzyme Microb. Technol. Vol. 5, Jan, 41-45
"Performance of an immobilized yeast reactor system for ethanol production"

LINKO Y, et al, (1981) - Biotechnology Letters 3, 1, 21-26

MARGARITIS A., BAJPAI P.K., WALLACE J.B. (1981) - Biotechnology Letters, Vol.3 No. 11, 613-619
"High ethanol productivities using small Ca-alginate beads of immobilized cells of Zymomonas mobilis"

MOO-YOUNG M., LAMPTEY J., ROBINSON C.W. (1980) - Biotechnology Letters Vol. 2, No. 12. 541-549
"Immobilization of yeast cells on various supports for ethanol production"

McGHEE J.E., ST. JULIAN G., DETROY R.W. (1982) - Biotechnology and Bioengineering, Vol. XXIOV, 1155-1163
"Ethanol production by immobilized Saccharomyces cerevisiae, Saccharomyces uvarum, and Zymomonas mobilis"

Davy Agro

NAVARRO J.M., et al (1976) - Industries alimentaries et apricoles 6, 695

ODA G., et al (1983) - Proc. Biotechnology 83, 597

RAMAN H.S., RAO B.S., PUNDLE A.V., RAMAN C.S (1982) - Biotechnology Letters Vol. 4 No. 6. 359-365
"Continuous ethanol production by yeast cells immobilized in open pore gelatin matrix"

SITTON O.C, GADDY J.L. (1980) - Biotechnology and Bioengineering, Vol. XXII, 1735-1748
"Ethanol production in an immobilized-cell reactor"

TSAO G.T., FLICKINGER M.C., FINN R.K. (1980) - Annual reports on fermentation processes. Academic Press, Volume 4
"Immobilized microbes"

TYAGI R.D., GHOSE T.K. (1982) - Biotechnology and Bioengineering, Vol. XXIV, 781-815
"Studies on immobilized Saccharomyces cerevisiae"

WADA M., KATO J., CHIBATA I. (1981) - Europ. J. Appl. Microbiol Biotechnol, 11, 67-71
"Continuous production of ethanol in high concentration using immobilized growing yeast cells"

WADA M., et al (1980) - Eur. J. App. Microb Biotechnology 10, 275

WILLIAMS, D., MUNNECKE D.M. (1981) - Biotechnology and Bioengineering, Vol. XXIII 1813-1825
"The production of ethanol by immobilized yeast cells"

Davy Agro

APPENDIX 3

OVERHEAD PROJECTOR SLIDES

DISTILLERY STILL BOTTOMS

1. STILLAGE
2. DUNDER
3. DUNDAR
4. VINASSE
5. SLOP
6. VINHOTO
7. C.M.S. - CONDENSED MOLASSES SOLUBLES
8. F.E.L.
9. C.P.B.
10. BORLANDA CONCENTRADA
11. DICKSCHLEMPE
12. DICKLAUGE
13. D.M.S. - DRIED MOLASSES SOLUBLES

SUGAR CANE - MOLASSES - ETHANOL

1. WAS MOLASSES PRETREATED? e.g. STILLAGE RECYCLE
   H_2SO_4 ADDITION
   STERILIZATION

2. WERE NUTRIENTS ADDED? e.g. NITROGEN
   PHOSPHATE

3. COUNTRY OF ORIGIN? e.g. IS CANE FERTILISED
   IS MOLASSES EXHAUSTED.

Davy

MANY DIFFERENT TYPES OF STILLAGE

SUGAR BEET	JUICE	ENZYMES
GRAIN	SYRUP	AMINO ACIDS
RICE	MOLASSES	CITRIC ACID
SUGAR CANE	SOLID PHASE	BAKERS YEAST
		INDUSTRIAL ETHANOL
		DRINKING ETHANOL

STILLAGE ANALYSIS

	SUGAR BEET	AUSTRALIA MOLASSES	AUSTRALIA CANE JUICE	BRAZIL MOLASSES	BRAZIL CASSAVA	CHINA MOLASSES
DRY MATTER %	5.5	11.9	2.2	10	2.5	8.3
COD (mg/l)	48,000	110,000	27,000		18,000	68,000
BOD_5 (mg/l)		65,000	18,000		12,000	36,400
NITROGEN %	0.36	0.23	0.06	0.75	0.25	0.14
TOTAL SUGARS* %		1.33		1.3	0.68	1.5
GUMS %		3.33		1.0	0.6	
TOTAL ASH %		3.2	0.6	2.3	0.23	2.3
Na %		0.03	0.01			
K %		1.2	0.15			0.4
Ca %		0.28	0.05	0.65	0.009	
Mg %		0.17		0.32	0.008	
Fe %		0.04				
P %	0.01	0.004	0.008	0.02	0.02	0.04
Cl %		1.1		0.15	0.01	
SO_4 %	0.03	0.3				

* Reducing Sugar by Fehlings method – Furfural etc and other non-sugar organics

CAUTION 小心

YOUR STILLAGE MAY BE DIFFERENT

YOU MAY GET DIFFERENT RESULTS.

MOLASSES ANALYSIS.

	AUSTRALIA CANE	WORLD CANE	WORLD BEET	CUBA CANE	INDIA CANE	CHINA CANE
DRY MATTER	72-80	75	76	76	73	76
SUCROSE	30-39	30-40	48-52	33.9	41.8	34
REDUCING SUGARS	8.7-19.9	15-20	.2-1.2	16.6		20
NON FERMENTABLE		2-4	.5-2			
GUMS	11	4	6-9			
ORGANIC ACIDS		3	6-8			
PROTEIN (N x 6.25)	3-6	2-3	6-8	3.6	7.5	
TOTAL ASH	7.5-12.5	8-18	9-14	5.4	11	12-15
Na	.02-.17	.01-.7	.3-1.3			
K	2.6-5.1	1.2-6.4	2.3-4.4			
Ca	.7-1.2	.03-.95	.08-1			
Mg	.16-.74					
S	.3-1.1					
P	.04-.08	.4-2	.02-.07		.25	
Cl	1.3-3.9	.7-3	.3-1.5			
pH	5.5-6.5	5.1-6.0	6.5-9			

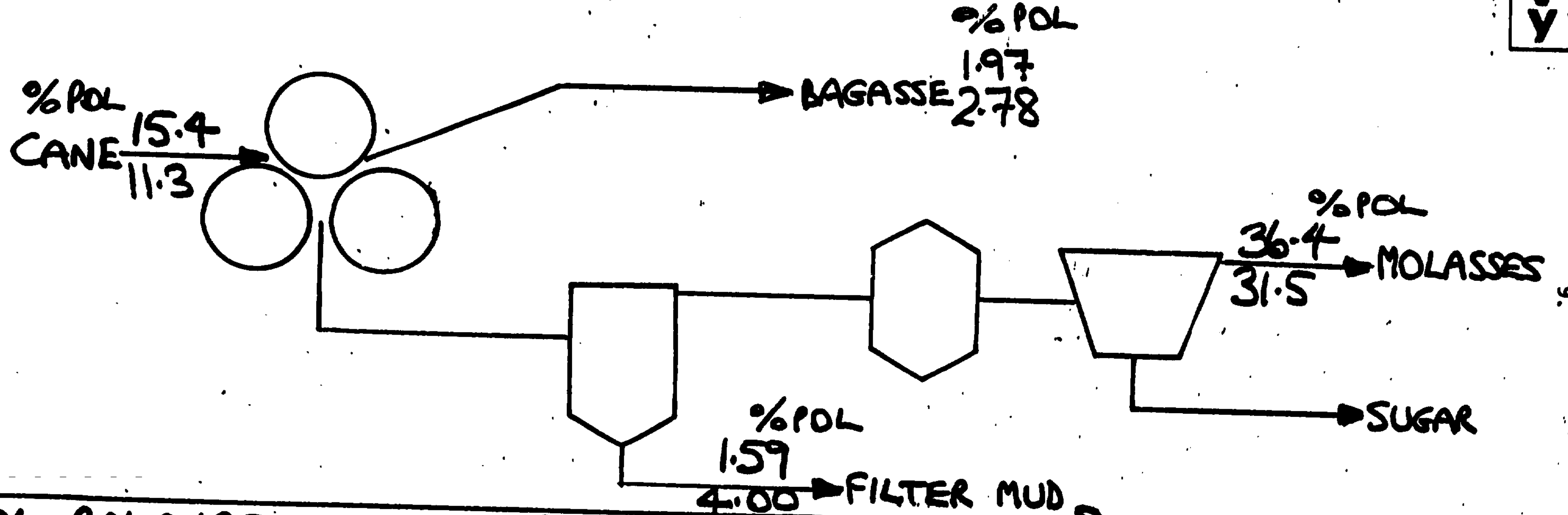
STILLAGE FROM VARIOUS FEEDS.

BRAZIL		CANE MOLASSES	CANE JUICE	CASSAVA STARCH	CHINA
ORGANIC MATTER		63.4	19.5	21.8	
TOTAL NITROGEN		1.2	0.3	0.4	3.4
SO_4	g/litre	84	0.6	0.1	
CaO	g/litre	3.6	0.7	0.1	2.2
P_2O_5	g/litre	0.2	0.2	0.2	0.05
MgO	g/litre	1.0	0.2	0.1	
K_2O	g/litre	7.8	1.2	1.1	11.1

SUGAR FACTORY DATA

		CHINA	AUSTRALIA	INDONESIA
MIXED JUICE	BRIX	15.5	17.0	12.6
	POL	12.6	15.0	9.48
	PURITY	81	88	75
POL % CANE		12.5	15.4	11.3
FIBRE % CANE		11.0	14.2	15.5
SUGAR ON CANE		11.0	14.38	9.12
MOLASSES ON CANE		3.2	2.9	3.5
MOLASSES	BRIX	92	87.3	92.4
	POL	27	31.9	32.1
	PURITY (APP)	29	36.5	34.7
	PURITY (TRUE)	37	46.6	
	SUCROSE	34	36.3	36.4
	DRY SUBSTANCE	–	78	79.5
	REDUCING SUGARS	20	11.9	17.0
	ASH	–	14.18	16.0
	R.S./ASH RATIO	–	0.84	1.06
FILTER CAKE ON CANE		3.0	5.55	4.04
	POL	3.0	1.59	3.95
	WATER	74	74.2	71.7
	ASH	–	8.6	

SUGAR FACTORY

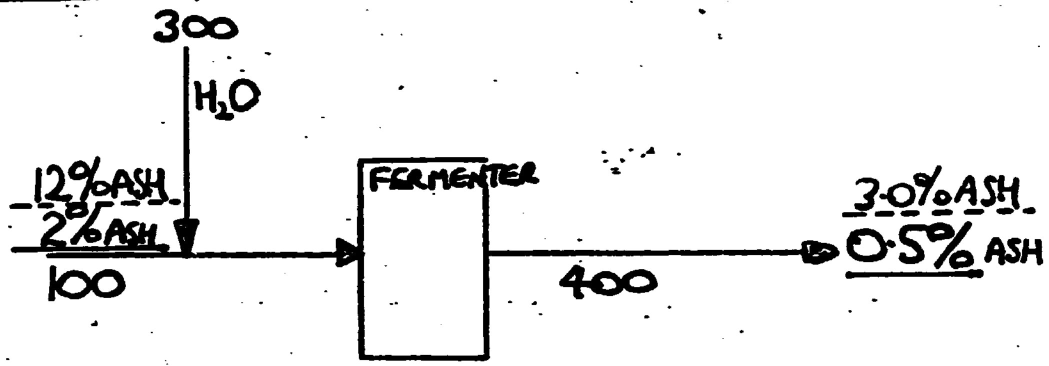


POL BALANCE		AUSTRALIA	CHINA?	INDONESIA
SUGAR	%	89.6	84.0	80.[illegible]
BAGASSE	%	3.7	7.0	8.[illegible]
MOLASSES	%	6.3	7.0	9.5
FILTER CAKE	%	0.6	0.6	1.0
UNDETERMINED	%	- 0.2	1.4	1.4

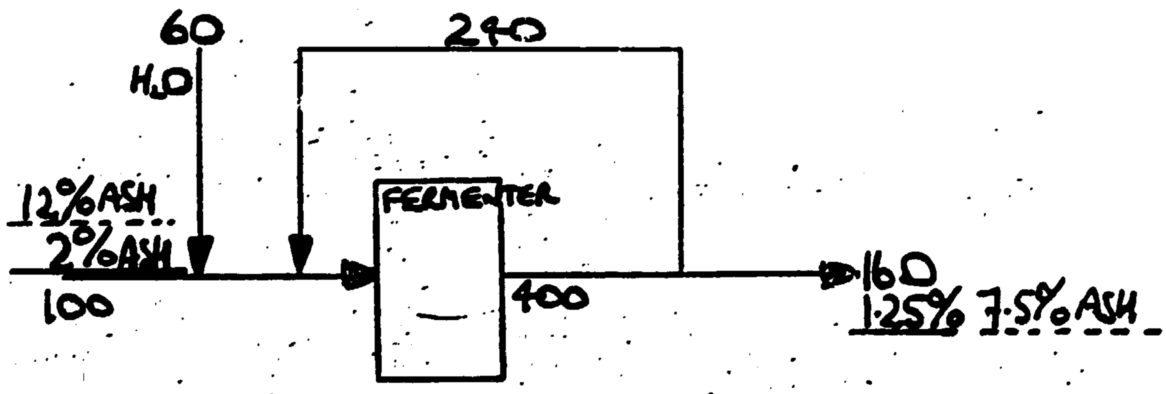
SLOPPING BACK.

PER 100 OF MOLASSES: CEREAL MOLASSES CANE MOLASSES

NIL RECYCLE



60% RECYCLE



CEREAL WITH RECYCLE OF 60% LESS THAN MOLASSES WITH NO RECYCLE.

DISTILLERY MOLASSES MUD

WATER %	60
ASH %	26*
ORGANICS %	14
K %	4.3
POL %	1.3
BOD_5 mg/l	100,000
TONNES/DAY	27.4

* MAINLY $CaSO_4 . K_2SO_4 . H_2O$
DOUBLE SALT

STILLAGE DISPOSAL

1. LAND
   - IRRIGATION ON SOIL
   - EVAPORATION

2. WATER
   - RIVER
   - OCEAN
   - UNDERGROUND

3. AIR
   - AS CH_4 OR CO_2
   - N AS NH_3

Davy

TREATMENT METHODS

1. IRRIGATION

2. MARINE DISPOSAL

3. MIX WITH FILTER CAKE

4. INCINERATION
   - 4.1. WITH BAGASSE
   - 4.2. SEPARATE FURNACE
   - 4.3. ZIMPRO

5. ANAEROBIC DIGESTION
   - 5.1. THERMOPHILIC
   - 5.2. MESOPHILIC
   - 5.3. UASB
   - 5.4. TOWER
   - 5.5. FLUIDISED BED
   - 5.6. FILTER

6. ANAEROBIC/AEROBIC
   - 6.1. ANAMET
   - 6.2. LAGOONS

7. AEROBIC
   - 7.1. BIOMASS
   - 7.2. ACTIVATED SLUDGE

8. ANIMAL FEED

9. PHYSICAL-CHEMICAL
   - 9.1. REVERSE OSMOSIS
   - 9.2. ELECTRODIALYSIS
   - 9.3. SEDIMENTATION.

STILLAGE HAS TWO POLLUTING FACTORS

1. ASH (INORGANICS, SALTS)
2. ORGANIC MATTER (BOD_5, COD)

ALL TREATMENT METHODS REMOVE ORGANIC MATTER

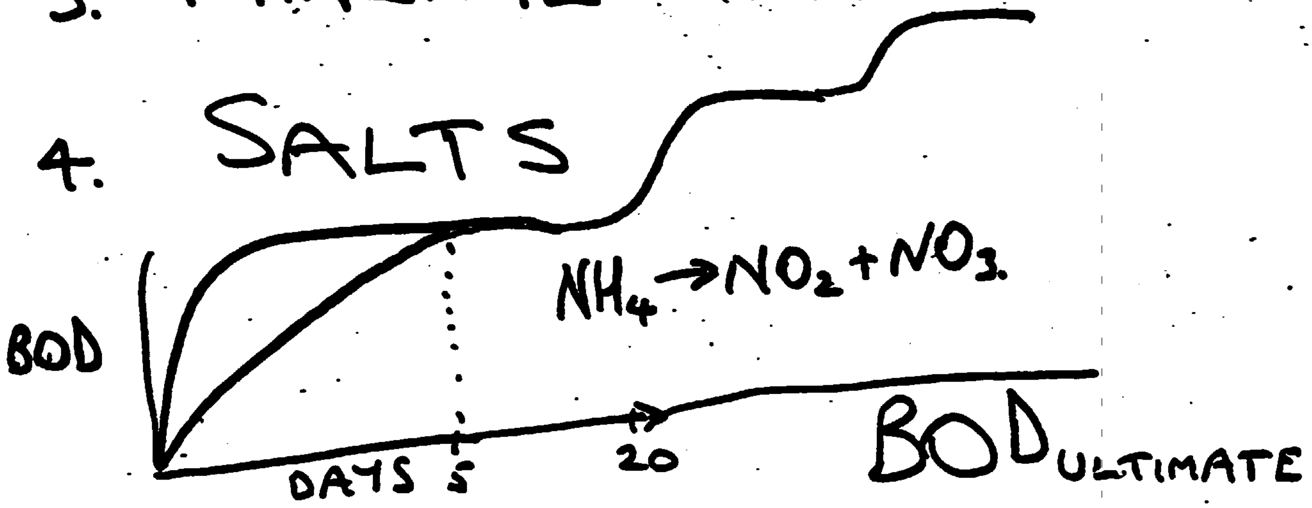
BUT DISPOSAL IN RIVER OR SOIL IS MAINLY A PROBLEM OF ASH

1. INORGANICS

2. ASH

3. MINERAL MATTER

4. SALTS



1. ORGANICS

2. BOD_5 = BIOLOGICAL OXYGEN DEMAND

3. COD = Chemical Oxygen DEMAND

4. TOC = Total Organic Carbon
not CO_3, CO_4

5. P.V = Permanganate Value.
3min and 4hr
$KMnO_4$

VALUE OF DUNDER

10 MILLION LITES $C_2H_5OH_5$ PER YEAR

Davy

		$
N	Aqua NH_3	80,000
P	Superphosphate	14,000
K	Potassium Chloride	400,000
Ca	Lime	24,000
Mg	Magnesium Sulphate	500,000
		$1,018,000

	COD
STILLAGE	50,000 mg/l
MOLASSES	600,000 mg/l

Davy

IRRIGATION

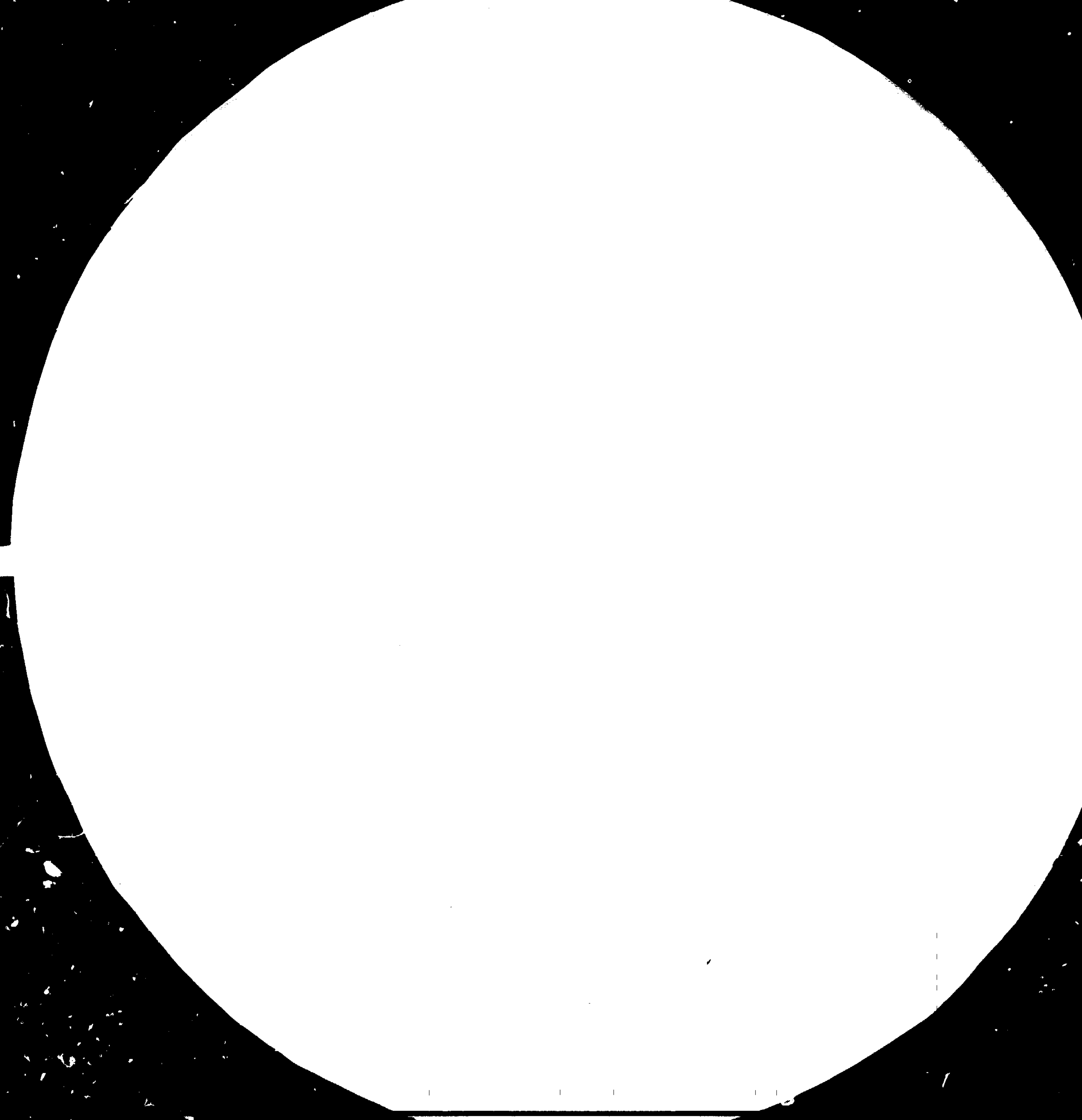
REF.	APPLICATION m^3/ha	COUNTRY	
ALMEIDA	650-1000	BRAZIL	PROBLEMS
ROSS	93 /DAY		OK
DUBEY	1280 /YR	UK	OK
GUIMARAES	382-419	BRAZIL	OK
COOPER	185	W. INDIES	OK
BEISKE	6.4-12.9	AUSTRALIA	OK
MONTEIRO	650-1000	BRAZIL	PROBLEMS
GLORIA	35-50	BRAZIL	OK
USHER	400	AUSTRALIA	OK

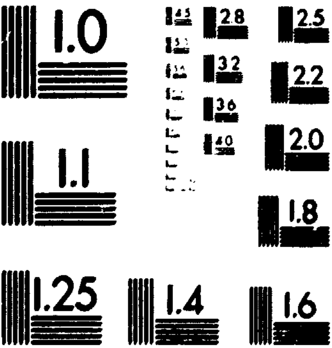
At 70 TC/ha

328 TC/hr = 46 T C_2H_5OH/day = 552 T STILLAGE/day

So, 70 TC = 4.9 T STILLAGE = 4.9 m^3 STILLAGE

MUST IRRIGATE 4.9 m^3/ha/yr TO RETURN ALL DUNDER TO ALL CANE IT CAME FROM.





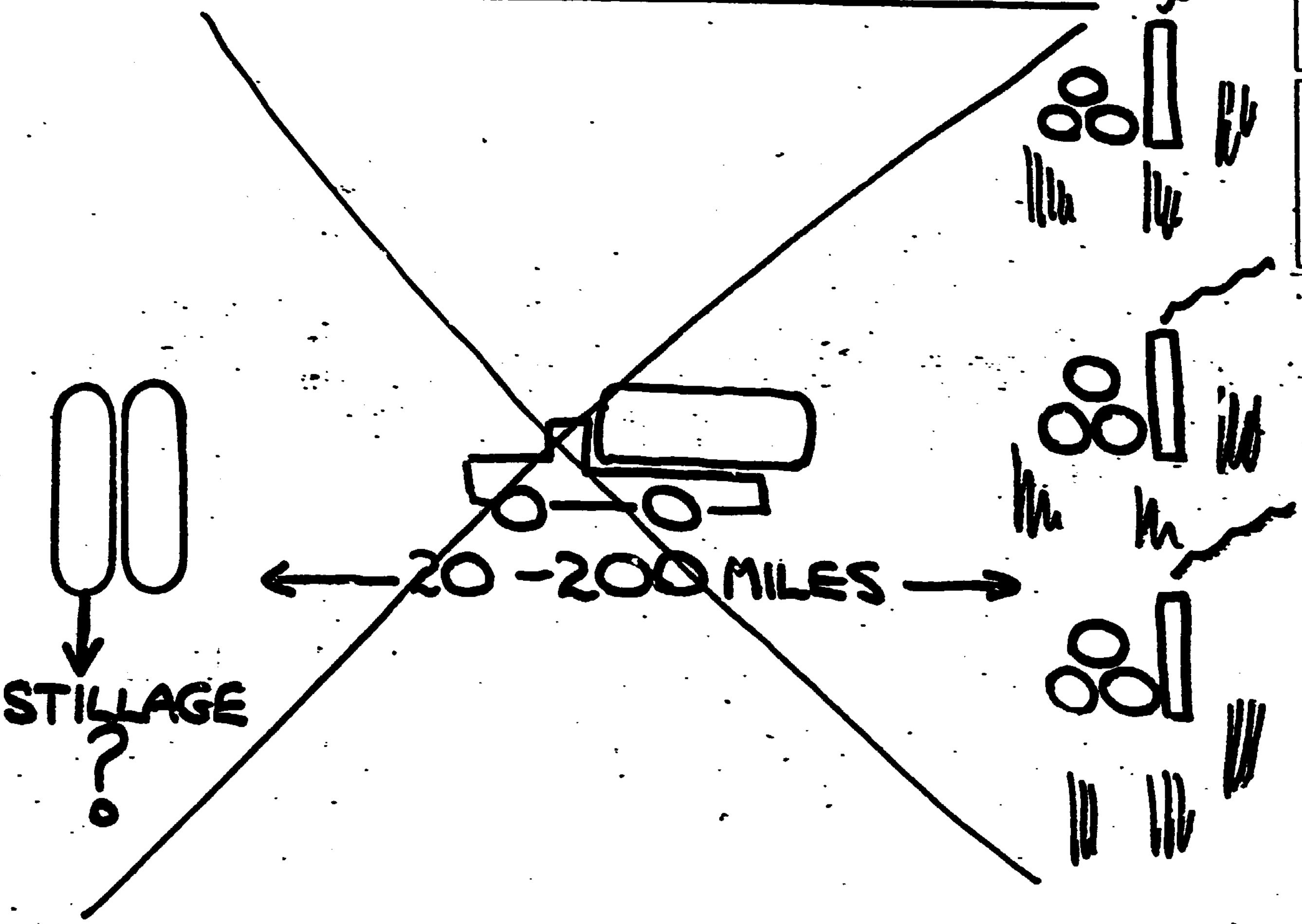
MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS

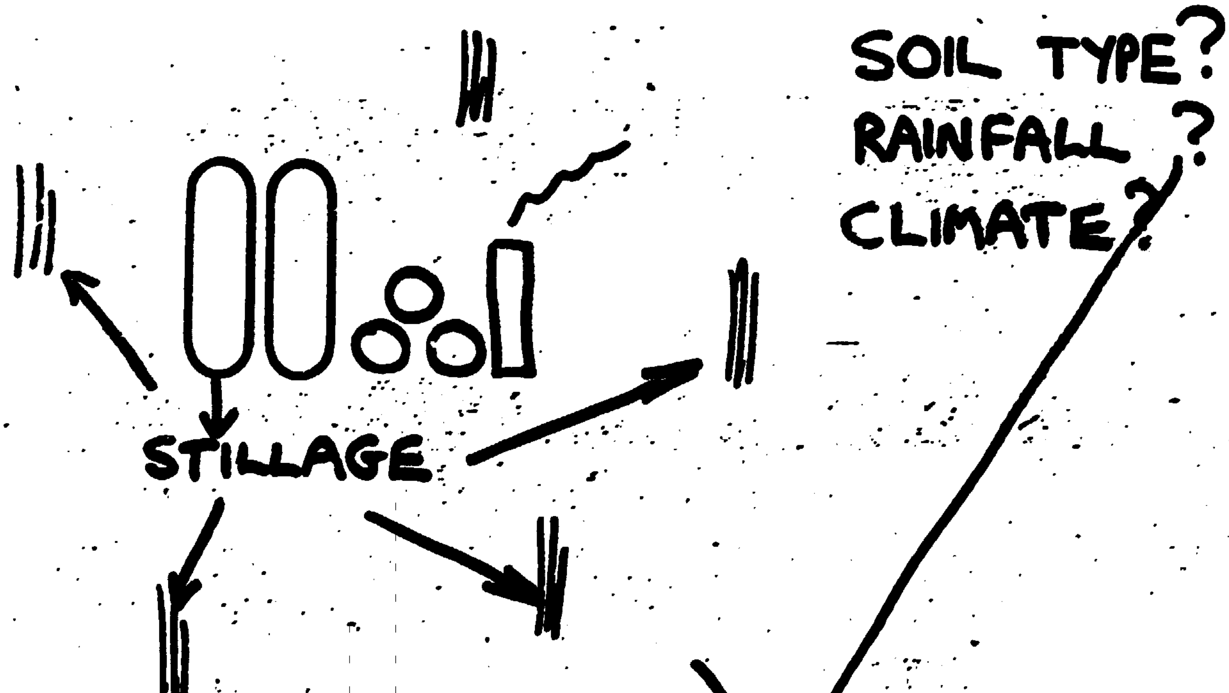
STANDARD REFERENCE MATERIAL 1010a

(ANSI and ISO TEST CHART No. 2)

CENTRAL DISTILLERY

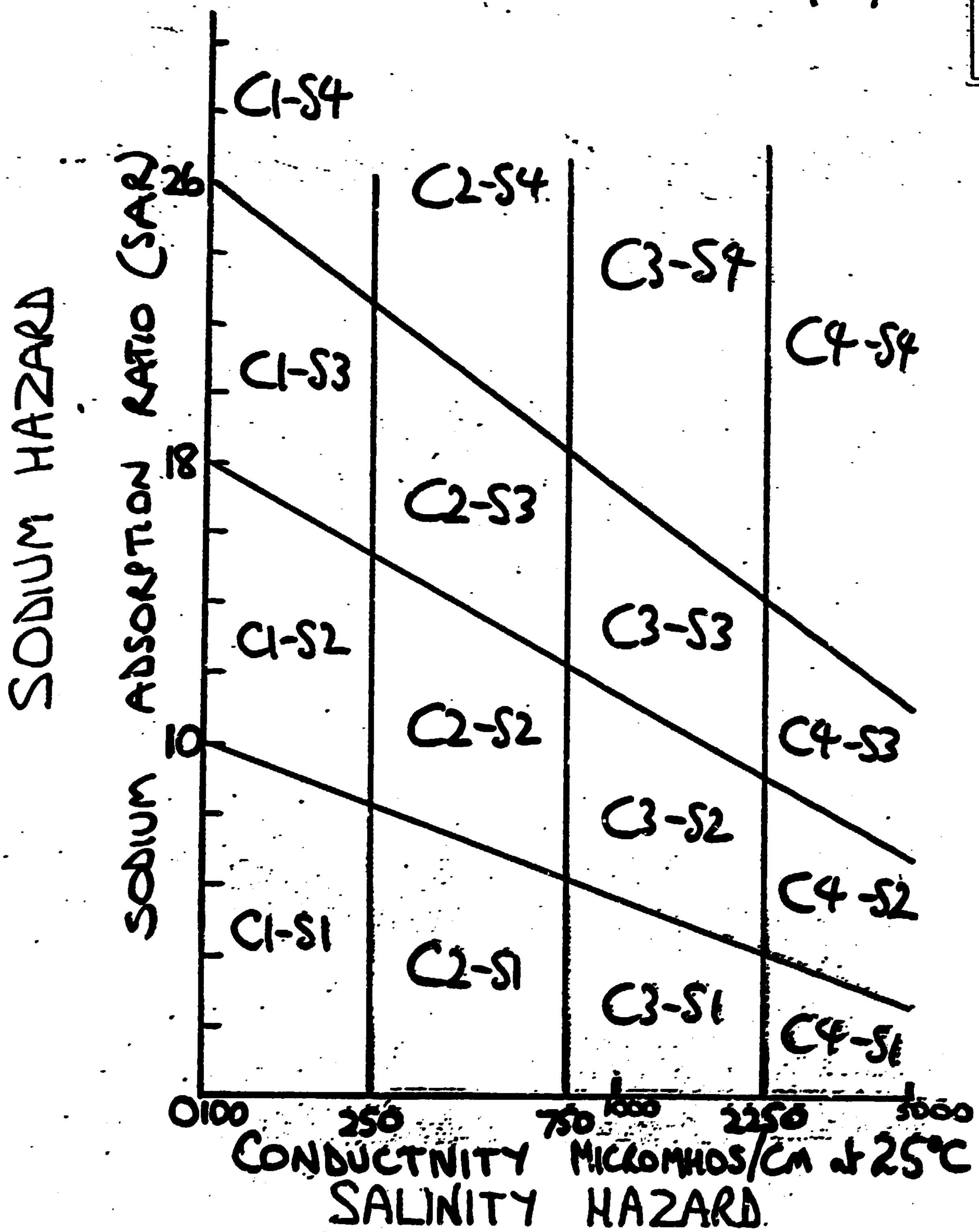


ANNEXED DISTILLERY



SAR is $Na^+/\sqrt{(Ca^{++} + Mg^{++})/2}$

millequivs/litre



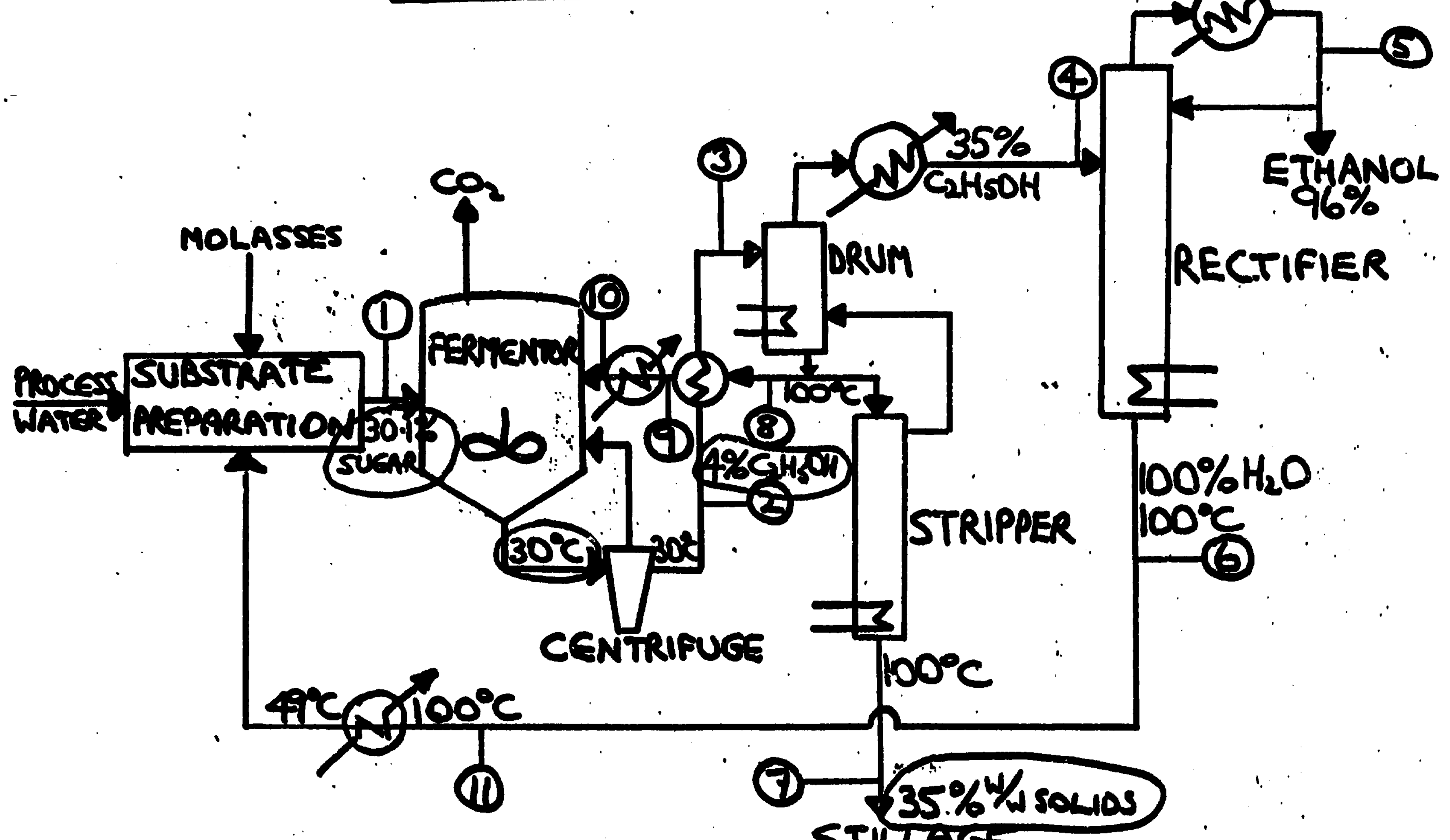
CLASSIFICATION OF IRRIGATION WATER

Davy

BIOSTIL - FOR CANE MOLASSES STILLAG

1. ELIMINATION OF EFFLUENT IS CLAIMED.
BUT NO ASH REMOVAL AND ONLY 10% BOD_5 LESS
THE STILLAGE VOLUME IS REDUCED TO 3-5 LITRES/LITRE ETHANOL
2. LESS HEAT REQUIRED BY BIOSTIL IS CLAIMED.
I CALCULATE 4.8% LESS HEAT IF 60% SOLIDS IS REQUIRED
AND MORE HEAT IF STILLAGE CONCENTRATION
NOT NECESSARY. ← LIKE IN CHINA
3. IF 9% v/v C_2H_5OH PRODUCED CONVENTIONALLY
(RATHER THAN 7%) THEN CONVENTIONAL IS
19% LOWER HEAT THAN BIOSTIL FOR CANE MOLASS
4. THEY CLAIM LOWER EQUIPMENT COST FOR BIOSTIL
HOWEVER CONVENTIONAL IS NON PRESSURE VESSEL MILD STEEL
WITH NO STIRRER AND NO METERING PUMPS
BIOSTIL IS STAINLESS STEEL PRESSURE VESSEL, STEAM
STERILISABLE, STIRRED, METERING PUMPS
5. THEY ADMIT BIOSTIL NEEDS 25% LARGE CENTRIFUGE
BUT A CONVENTIONAL FERMENTATION SYSTEM NEEDS
NO CENTRIFUGE. PEOPLE CLAIM C_2H_5OH LOSS OCCURS
DURING CENTRIFUGING.
6. I HAVE USED 35% w/w DS FOR STILLAGE IN MY
CALCULATIONS. IN CORRESPONDENCE THEY CLAIM
BIOSTIL WILL ONLY GIVE 30% w/w DS WITH THIS MOLASSES.
7. WITH OSMOTOLERANT YEAST CONVENTIONAL
BATCH FERMENTATION COULD REACH HIGHER THAN
12.5% w/w DS. A USEFUL RESEACH PROJECT FOR CHINA.
8. CONVENTIONAL FACTORY GIVES 9-12 LITRES STILLAGE/LITRE ETHANOL
DEPENDING ON STILLAGE RECYCLE.

BIOSTIL PROCESS



Davy

METHODS OF DISPOSAL IN SUGAR MILL

1. SPRAY ON BAGASSE GOING TO BOILER (OR COAL)
2. SPRAY INTO SUGAR MILL BOILER
3. SPRAY INTO CHIMNEY
   a) Before dry collectors
   b) After collectors + scrubber
4. MIX WITH FILTER CAKE (FEED TO FISH PONDS)
5. IRRIGATE ON CANE FIELDS.

MILLAQUIN FACTORY 7900 TCD.

	BOD (TPD)	ASH (TPD)
SUGAR FACTORY	14.5	9.56*
DISTILLERY	18.9	12.1*

* FILTER CAKE 37.9 TPD ; BAGASSE 57.7 TPD

* 70-80% SOLUBLE.

Davy

FILTER CAKE:- A GOOD SOIL ADDITIVE?

	CAKE	STILLAGE
H_2O %	74	87.5
ASH %	8.6	3.2
N %	0.48	0.3-0.75
P %	0.31	0.02
K %	0.02	0.85*
POL %	4	
BOD_5 mg/l	40,000	50,000
TONNES/DAY	440	380

*CHINA CANE SOILS ARE DEFICIENT IN POTASH.

John WARNER, 1981 Tour of GUANDONG with MIN. of LIGHT INDUSTRY

FILTER CAKE + STILLAGE

Davy

FILTER CAKE: MOISTURE % 74
POL % 1.59
JUICE PURITY 85
JUICE POL % 2.15

SJM GIVES 90.5%
FUGAL TO 40% H_2O = 4.8 TPD EXTRA SUGAR
(0.5% OF FACTORY PRODUCTION)

ADD STILLAGE AT 10%. CAN USE 66% OF STILLAGE

ADD STILLAGE AT (13.3%) CAN USE ALL STILLAGE

	FILTER CAKE	FILTER CAKE + STILLAGE
N	0.5%	0.5%
P	0.3%	0.2%
K	0.02%	0.49%

SLOPPING BACK MAY REACH THIS

Davy

BIOLOGICAL TREATMENT

DO WHAT NAT[URE] DOES, BUT MORE INTENSIVELY.

1. ANAEROBIC DIGESTION
   - THERMOPHILIC 55°C
   - MESOPHILIC 35°C

TALK OF SPECIALS.

2. ANAEROBIC FILTERS

3. LAGOONS

4. ACTIVATED SLUDGE

5. TRICKLING FILTERS.

AEROBIC 0·3-0·6 Kgs SLUDGE/Kg COD REMOVED

ANAEROBIC 0·1-0·15 kgs SLUDGE/Kg COD REMOVED.

WHAT TO DO WITH SLUDGE?

IF PUT ON LAND THEN WHY USE PROCESS

AS INORGANICS ARE IRRIGATION PROBLEM AND ASH UNCHANGED

Davy

DIGESTION - ENERGY FACTS.

FUEL	CALORIFIC VALUE		
	BTU's/lb	kJ/kg	kJ/m^3
1. DIGESTOR GAS (50% CH_4)	12,000	27,975	20,000
2. CH_4	24,000	55,850	39,890
3. ETHANOL	11,600	27,000	
4. COAL (BITUMINOUS)	12,300	29,000	
5. FUEL OIL	18,300	42,600	

DIGESTION - GAS YIELD

STARCH → 830 litres/kg of 50% CH_4

PROTEIN → 830 litres/kg of 70% CH_4

CARBON (IN ORGANIC MATERIAL) → 1970 litres/kg of 50% CH_4

SLUDGE YIELD 0·1-0·2 kg/kg BOD_5 REMOVED

Davy

DIGESTION – ENERGY FACTS

DIGESTOR GAS @ 50% CH_4 = 20,000 kJ/m^3

At 26.7°C, to evaporate 1 kg H_2O

$$= (100-26.7)4.18 + 2233 = 2540 \text{ kJ/m}^3$$

1 m^3 BIOGAS evaporates $\frac{20000}{2540}$ = 7.87 kg H_2O

Engine efficiency = 20%

1 m^3 BIOGAS = 20,000 × 0.2 = 4,000 kJ

OR = 1.13 kWh

OR 0.2 kW ENGINE FOR 5.5 hrs.

DIGESTORS

1. TRADITIONAL

Tanks, lagoons: 30 DAYS Residence Time
5,000 – 10,000 mg/l BOD_5

2. MODERN

2.1. FILTER SYSTEMS

2.2 FLUIDISED BED SYSTEMS

2.3. SLUDGE BLANKET

2.4. TOWER

2.5. CHINESE TWO STAGE SYSTEM.

1. $C_6H_{12}O_6 \rightarrow CH_3COOH$

2. $CH_3COOH \xrightarrow[\text{pH}>6.5]{\text{OBLIGATE ANAEROBES}} CH_4 + CO_2$.

UASB - DIGESTION

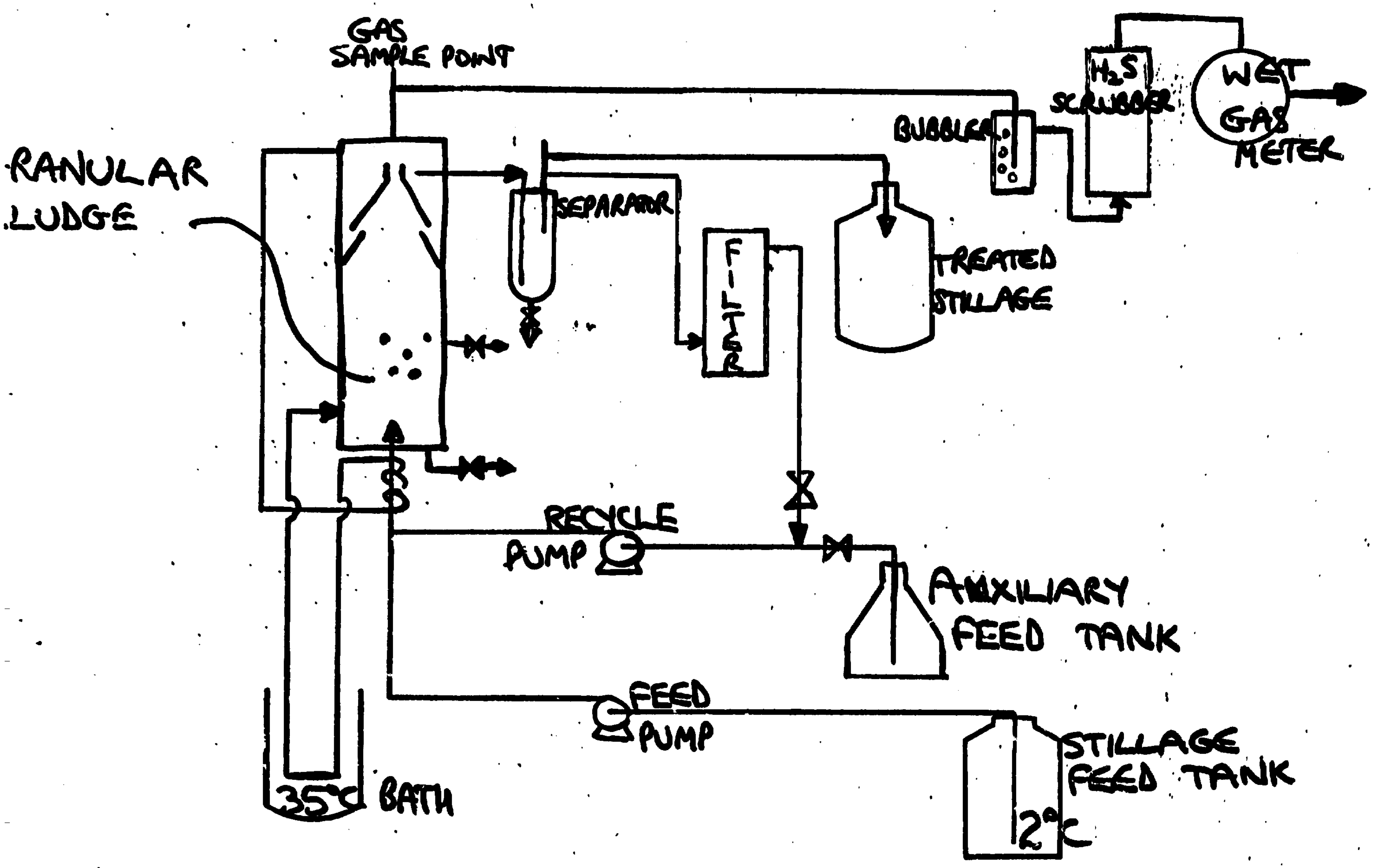
Davy

UPFLOW ANAEROBIC SLUDGE BLANKET

LETTINGA, HOLLAND

FEED COD	60,000 mg/l
LOADING	12 kg COD/$m^3 d^{-1}$
REDUCTION	90-95% (300-600 mg/l)
METHANE	0·35 m^3 CH_4/kg COD (3 m^3 CH_4/$m^3 d^{-1}$)
HYDRAULIC LOADING	4 m^3/$m^3 d^{-1}$
COD:N:P	100:2:0·3

UASB - DIGESTER



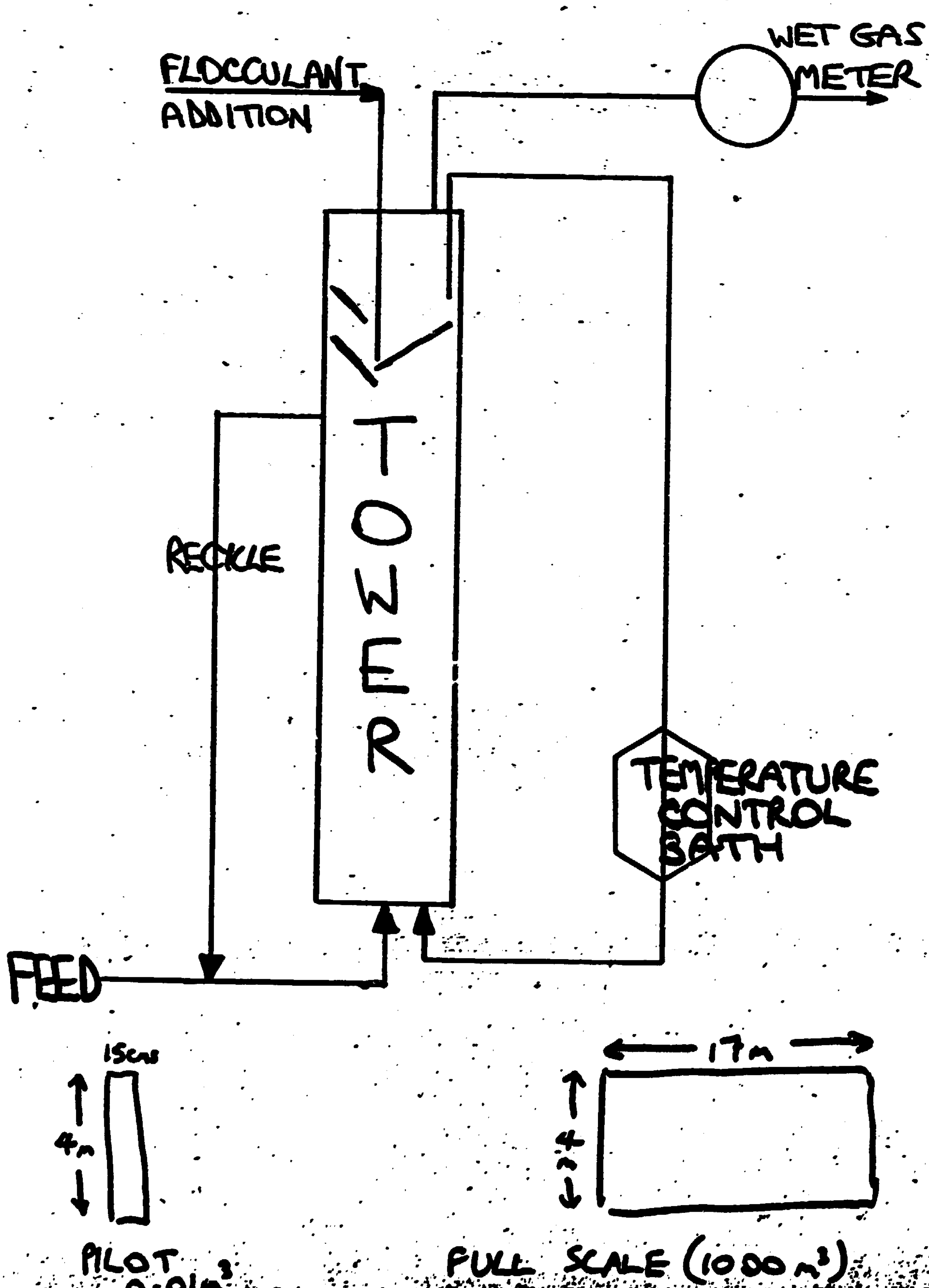
UASB DIGESTION

1. STANDER G.J (1967) PROC. OF 22nd Indust Waste Conf., p.892-907
2. HALBERT E.J. (1980) PROC. OF 16th Conf. Inst of Brew (Australia) p 219
3. RIBIERO C.C. (1981) Proc. Biochem. 16 (3) 8-13
4. RIERA F.S. (1982) Biotechnol. Lett. 4 (2) 127-132
5. BRAUN R. (1982) Proc. Biochem. 17 (4) 25-27
6. LETTINGA G (1983) Wat. Sci. Tech. 15, 177-195
7. LETTINGA G. (1980) Biotechnol. Bioeng. 22 (4) 699-734

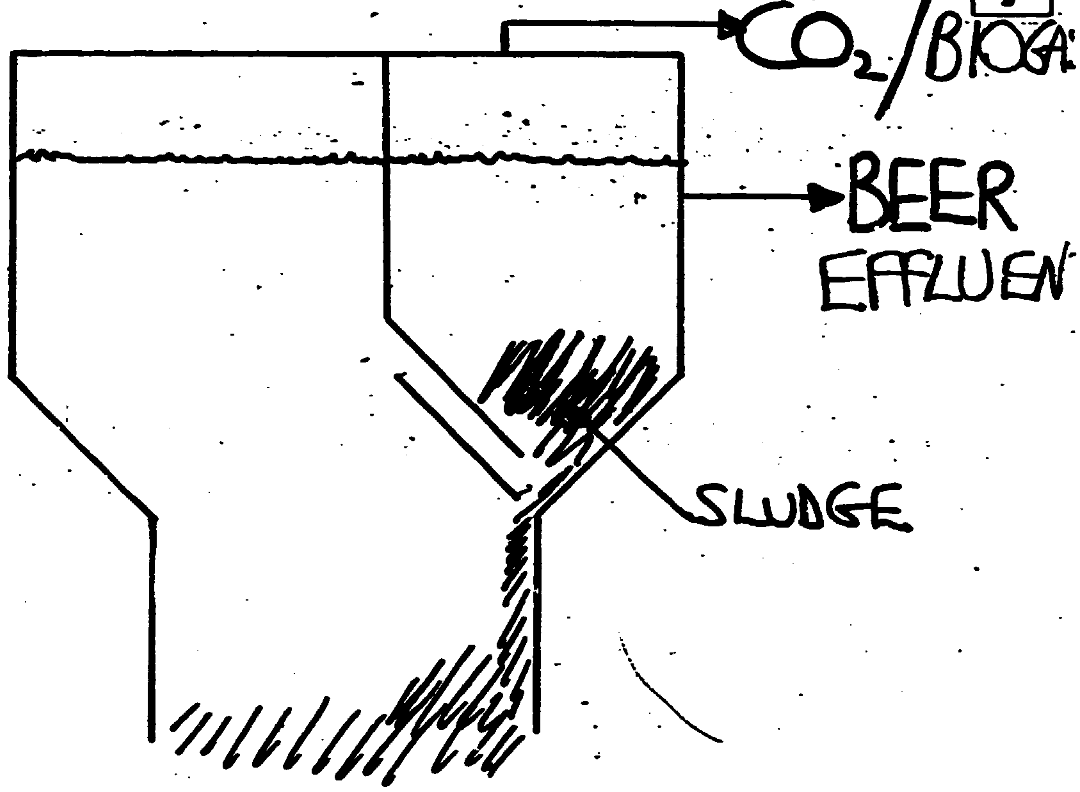
Davy

32.

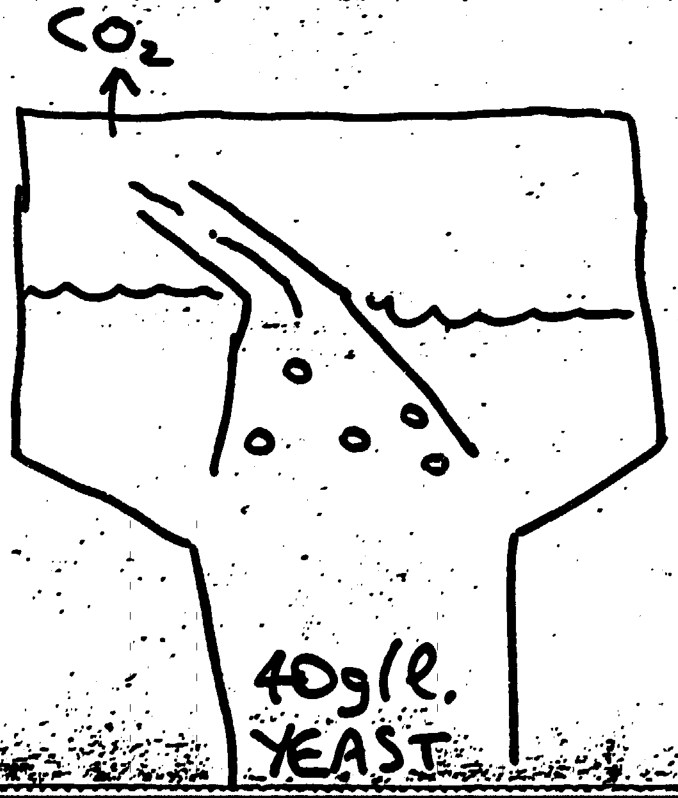
TOWER DIGESTER - UFFD
UpFlow Flocculated Digestor



TOWER (TOP DESIGN)



APV Co. - BEER MAKING



Davy

UFFD - DIGESTION.

FEED COD 5,000-10,000 mg/l

LOADING 25 kg COD/$m^3 d^{-1}$
(1-1.4 kg COD/kg VSS)

REDUCTION 95%

METHANE 0.32 m^3 CH_4/kg COD

HYDRAULIC LOADING 2.5-5 $m^3/m^3 d^{-1}$

SLUDGE PRODUCED 0.1-0.15 kg/kg COD
(7½% of STILLAGE AS 5% SLUDGE

FLOCCULENT 40-60 mg/l ZETAG 88N
ZETAG 76.

1500 mg/l S ~~440~~ mg/l SULPHIDE FeS ppt ∴ $FeCl_2$ add

NEVER CANE MOLASSES STILLAGE.

Davy

ANAEROBIC DIGESTION (THERMOPHILIC)

REF.	INITIAL BOD mg/l	LOADING kg BOD/m³/d	HOLDING TIME (DAYS)	% BOD REMOVAL
SEN				
BASU		4—1	7–25	84 -92
BASU		2-3.5	10	97 -88
BORUFF	17,000	2.8	6.0	72 VS
BORUFF	17,000	8.5	2.0	58 VS
BUSWELL	15,000	2.4		99
DAVIDSON	700	0.7	1.0	93
DAVIDSON	700			85
STANDER		8.8		
STANDER		11.7		
JACKSON			10	60
ONO		6.4		96
SONADA	6:1 dilution	4.3		70
SONADA	3:1 dilution	15.3		70

ANAEROBIC DIGESTION (MESOPHILIC)

Davy

REF.	INITIAL BOD mg/l	LOADING kg BOD/m³/d	HOLDING TIME (DAYS)	% BOD REMOVAL
BIAGGI				87
HAURY	10,000			80
MERKEL	7,000		3.7	
PETTET		8.8 VS	3.75	55 TOC
RADHAKRISHNAN		3	10	80
DE		1.9	5	89
CILLIE		3.2	6.9	97.3
GHOSE			12	70
SEN		3.77		91.6
HAITT	100,000 COD	5.95	16.7	71.9
TANAKA		13.4 VS		
VITKOVSKAYA	15,000	1.84		95
BURNETT				30–50
KEENAN	22,620	2.83	8	35
SHEA	55,000	0.09	221	80
ROTH	55,000	9.86	5.5	80
SANDERS	12,320	1.23	10	98.8
CHUANG	4,500		10	85

ESTIMATE OF EFFLUENT TREATMENT NEEDS.

BASED ON 58,000 LITRES PER DAY ETHANOL.*

	AREA (HA.)	POWER (KW)	SLUDGE* PRODUCED	% BOD REMOVED	EFFLUENT mg/l.
ACTIVATED SLUDGE					
5hrs–12hrs 1. HIGH RATE	2	400	250	70	60
1 DAY 2. CONVENTIONAL	4	1000	270	90	20
2-3 DAYS 3. EXTENDED	10	2000	170	95	15
AEROBIC LAGOON	80	2000	120	80	20
FACULTATIVE POND	500	0	50	70	?
ANAEROBIC LAGOON	800	0	50	80	?

* THIS SLUDGE IS TONNES PER DAY WET WHICH MUST BE SPREAD ON LAND.

* 60,000 mg/l BOD_5; 80,000 mg/l COD IE MILLAQUIN SIZE

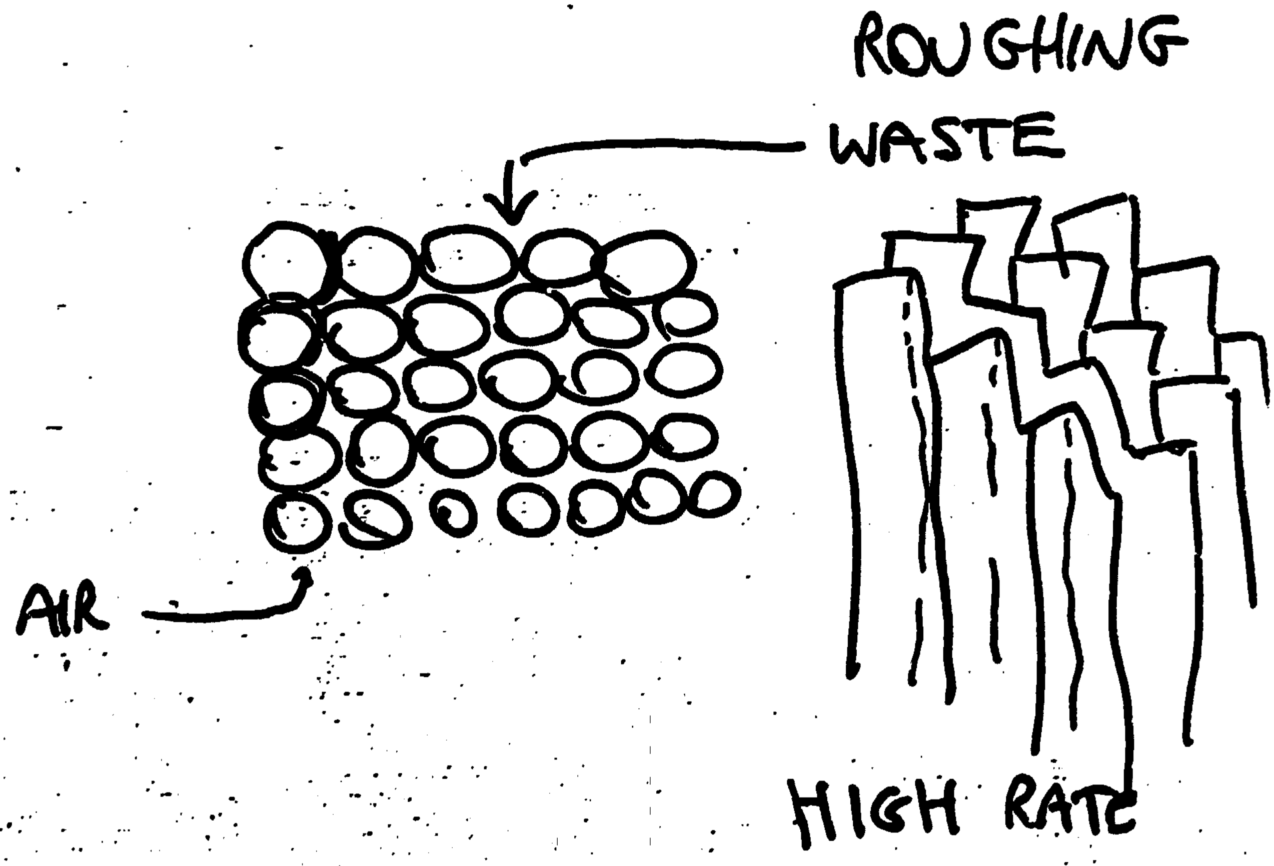
38

ACTIVATED SLUDGE

REF.	INITIAL BOD mg/l	LOADING kg BOD/m³/d	HOLDING TIME (DAYS)	% BOD REMOVAL
LONDONG	15400	0.97 – 6.21	18 – 51	82 – 65
	150			80
BURNETT	11,000	64 COD	4.5	33.3 COD
BIAGGI				28
BURKHEAD	266 – 564	0.29		91.5
ECKENFELDER		0.45		85 – 96
MATSUMOTO		0.15		85
WU	2350	2.45	24	93
	2350	6.75	8	96
		0.64	16	
BOLTON	3000	46		90

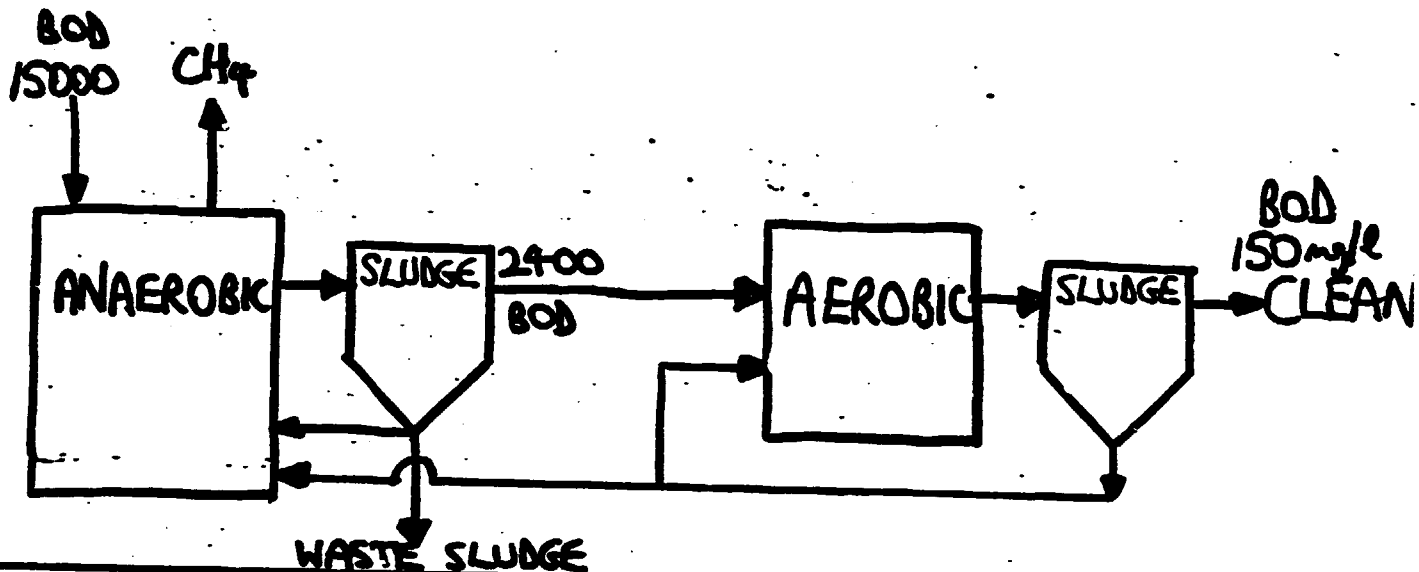
TRICKLING FILTER

REF.	INITIAL BOD mg/l	LOADING kgBOD/m³/d	RECYCLE RATIO	% BOD REMOVAL
ROBERTS		1.5-0.66	3-11	33-77
DAVIDSON		0.45	4	93
GURNHAM				
ECKENFELDER				50
CHIPPERFIELD	1000			98
CAMPBELL		0.87-3.15		
CALLELY		1.7	3	66
BASU		0.23 7		

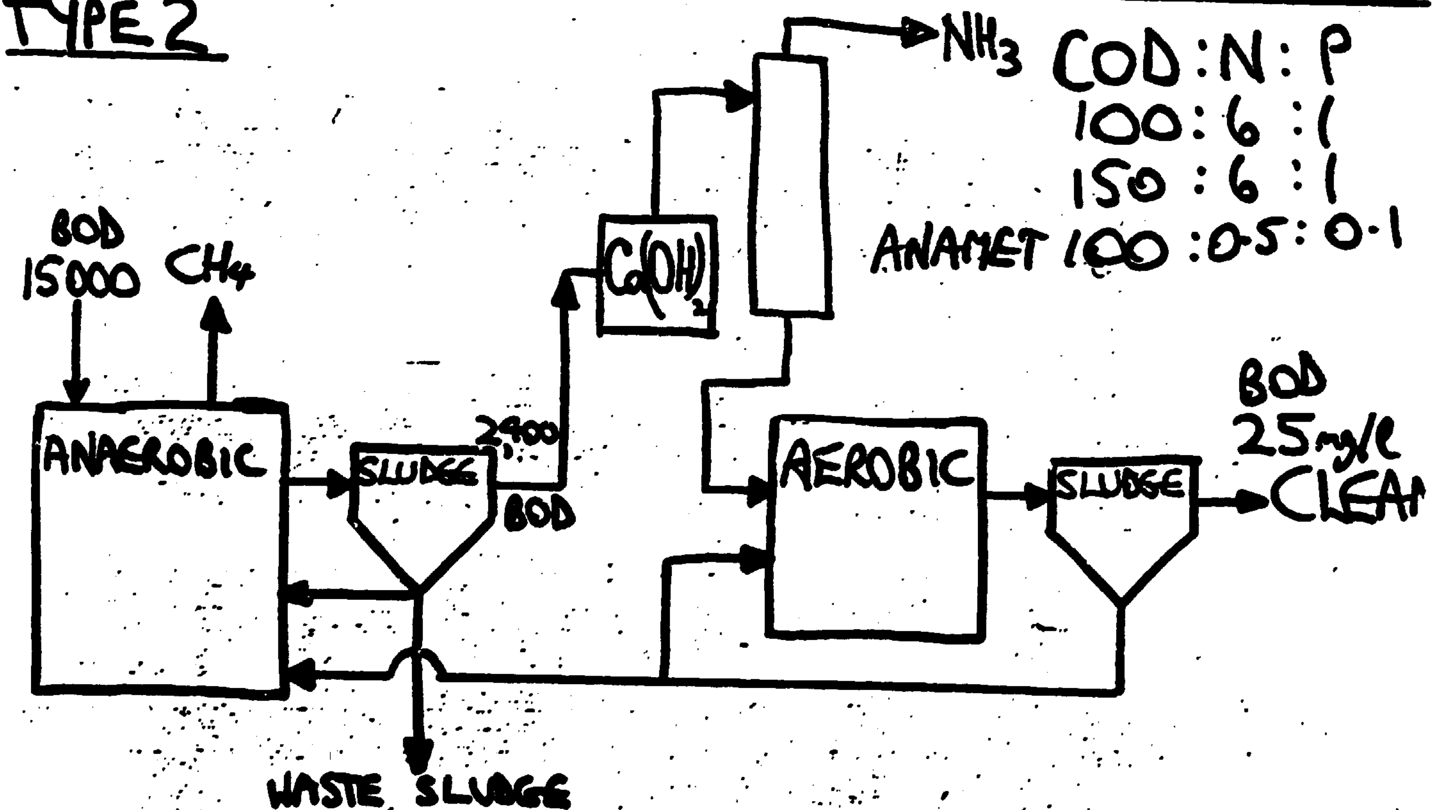


ANAMET PROCESS

TYPE 1



TYPE 2



Davy

INCINERATION DOES NOT DESTROY ALL THE COD.

STILLAGE AT 10 % w/w SOLIDS

CONCENTRATE AT 60 % w/w SOLIDS.

CONDENSATE FROM EVAPORATORS IS ALMOST THE SAME VOLUME AS ORIGINAL STILLAGE.

10 PARTS SOLID 90 WATER.

10 PARTS SOLID 6 WATER = 60% SOLID

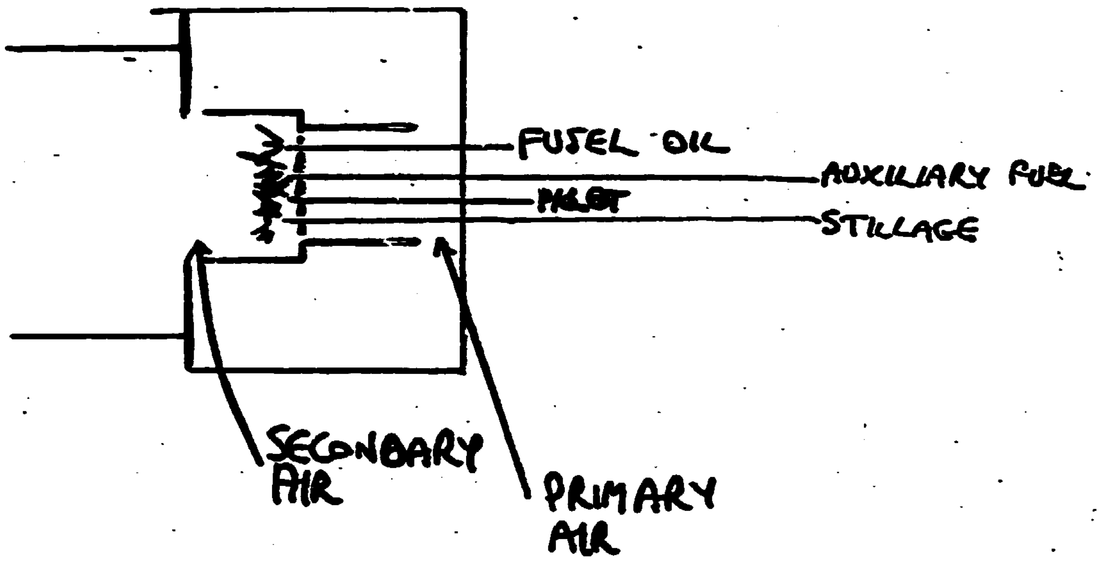
100 PARTS STILLAGE gives 84 CONDENSATE

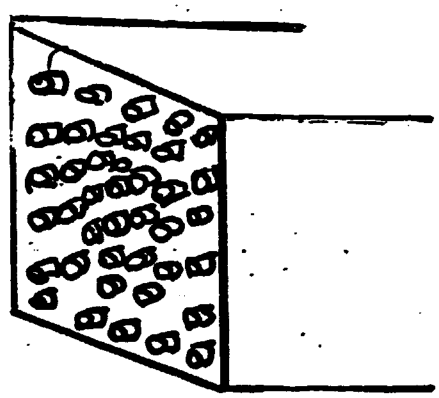
REDUCED THE VOLUME BY 16%.

CONDENSATE IS POLLUTING

pH = 3.3 COD = 3,500 mg/l

MULTINOZZLE BURNER





DIGESTION VS. INCINERATION.

FOR 180,000 LITRES PER DAY ETHANOL DISTILLERY.

Davy

INCINERATION:

STEAM

39tph steam raised – 18tph for evaporation of dunder = 504 TPD

EFFLUENT IS ASH AND WATER (CLEAN) !!!

AND $12-15 MILLION IN CAPITAL *

AND THERE ARE A NUMBER IN OPERATION

DIGESTION:

ASSUMING 80% EFFICIENCY GAS BOILER = 258 TPD

EFFLUENT IS 240-360 TPD WET SLUDGE AT 5% SOLIDS

AND. 900 M^3PD OF 10,000 mg/l COD LIQUID.

AND $12 MILLION IN CAPITAL.

AND DIGESTOR NEEDS POWER

AND THERE ARE NO FULL SCALE FACTORIES ON CANE MOLASSES STILLAGE

* THE FACTORY IN THAILAND COST $25 MILLION BUT IT WAS THE FIRST IN WORLD. A SECOND FACTORY WOULD ONLY BE $12-15 MILLION

44

BIOMASS FROM CANE MOLASSES STILLAGE

ORGANISM	REF.	BATCH TIME (hr)	YIELD kg/m^3	% ORGANIC REMOVED	
CANDIDA UTILIS	PAZ (1973)	9-12	18.75		
CANDIDA UTILIS	CHANG (73)	12	24		
YEASTS	IL'INA (69)		12-16		
FODDER YEAST	ISIK (77)		13.35		
CHLORELLA VULGARIS	OKUBA (67)	96		85	
TRICHOSPORA	IL'INA (69)		18-21		
FUNGI	ROLZ (75)		11-19	56	

① STERILIZE

② ADD $(NH_4)_2HPO_4$, CON_2H_4, $CaHPO_4$, $(NH_4)_2SO_4$, MOLASSES YEAST EXTRACT, ANTIFOAM, CHLOAMPHENICOL

③ 55-65 VOLUMES AIR PER VOLUME LIQUID PER HOUR.
IE. 400 VOLUMES AIR PER VOLUME STILLAGE

④ FERMENTATION AT 30-32°C, COOLING WATER UP TO 37°C IN TROPICS SO MAYBE NEED REFRINGERATION.

Davy

YEAST FROM STILLAGE

ACETIC ACID
GLYCEROL
FRUCTOSE
LACTIC ACID
SUCCINIC ACID
MALIC ACID

} USED

LEAVING

DIFFICULT TO REMOVE ORGANICS.

NO NITROGEN

NO PHOSPHATE

BIOMASS FROM STILLAGE

PROBLEMS.

1. ECONOMICS NOT FAVORABLE.
2. STILLAGE ONLY PROVIDES CARBON
   CELLS 46% PROTEIN I.E. 7.4% NITROGEN
   AND 50% CARBON
3. MUST ADD NITROGEN
   UREA (CON_2H_4), $(NH_4)_2SO_4$, $(NH_4)_2HPO_4$
4. MUST ADD PHOSPHATE
   $(Na)_3PO_4$, $(NH_4)_2HPO_4$
5. FERMENTATION AT 30-32°C
   EXOTHERMIC SO MUST COOL 3870 CALS/gm YEAST GROWN
   COOLING WATER IN EUROPE LESS THAN 20°C
   COOLING WATER IN TROPICS OFTEN 37°C
   SO PERHAPS REFRIGERATION.
6. LARGE ELECTRICITY DEMAND
   GROWING BIOMASS VERY AEROBIC
   400 VOLUMES AIR PER VOLUME STILLAGE.

SEE PAGE 2.

BIOMASS FROM STILLAGE

Davy

MORE PROBLEMS

7. MUST STERILISE STILLAGE

MUST BE CERTAIN ONLY PURE STRAIN OF FUNGI, YEAST, ALGAE GROWS OTHERWISE PERHAPS TOXIC PROBLEMS.

8. WHAT TO DO WITH WASTE?

a) STILL $\frac{1}{2}$ ORIGINAL ORGANIC STRENGTH SAY 30,000 – 40,000 mg/l BOD_5.

b) PROBABLY HIGHER SALTS THAN BEFORE

c) EASIEST ORGANICS NOW REMOVED

d) INCINERATION GIVES ONLY HALF HEAT I.E. NOW NOT SELF SUFFICIENT

e) DIGESTION MUCH HARDER, LESS THAN $\frac{1}{2}$ CH_4

9. CENTRIFUGED BIOMASS NOT CLEAN

AS CANE MOLASSES STILLAGE IS DARK BROWN AND FULL OF ASH, YEAST WILL HAVE STRONG TASTE AND COLOUR.

Davy

CANE MOLASSES DISTILLERY

TOTAL DISTILLERY (OPERATIONAL)	100
COST OF EQUIPMENT* (AT SITE)	29
FERMENTATION EQUIPMENT (AT SITE)	7

ALL TANKS, VESSELS, DISTILLATION COLUMNS, PUMPS, HEAT EXCHANGERS, VALVES, COMPRESSOR, BOILER, TURBINE. ERECTED.

NOT INCLUDING BUILDING, PIPING, INSTRUMENTS, ELECTRICAL

Davy

COST BREAKDOWN OF ETHANOL

	%
CAPITAL COST	28
RUNNING COST*	72

*INCLUDES LABOUR 6%, CHEMICALS 2%,
MAINTENANCE 7%, MOLASSES 51%*

* Molasses @ $72/tonne and 250 litres/tonne

VALUE IN IMPROVING FERMENTION

A 25% SAVING IN
FERMENTATION EQUIPMENT COST

=

A 1.5% SAVING IN FACTORY

=

0.4% SAVING IN C_2H_5OH COST.

YET PEOPLE SAY THEY
CAN REDUCE C_2H_5OH COST
BY 25-50%, BY CHANGING
FERMENTATION

Davy

VALUE IN IMPROVING FERMENTATIO[N]

A 0.8% EXTRA YIELD

OF C_2H_5OH FROM MOLASSES

ALSO GIVES

A 0.4% SAVING IN C_2H_5OH COST.

I.E. 252 litres/tonne MOLASSES

NOT

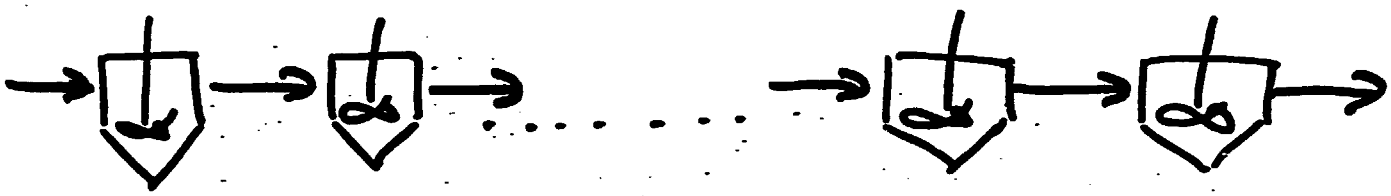
250 litres/tonne MOLASSES.

IMMOBILISED ENZYMES FOR C_2H_5OH.

12 DIFFERENT ENZYMES CONVERT

GLUCOSE $\xrightarrow{\text{12 ENZYMES}}$ ETHANOL

$C_6H_{12}O_6$ $\qquad$ C_2H_5OH



← 12 TANKS OR COLUMNS →

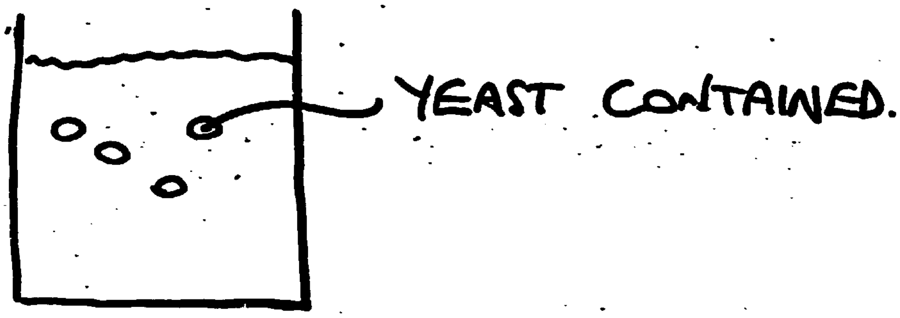
CHEAP PRODUCT.

NOT SENSIBLE.

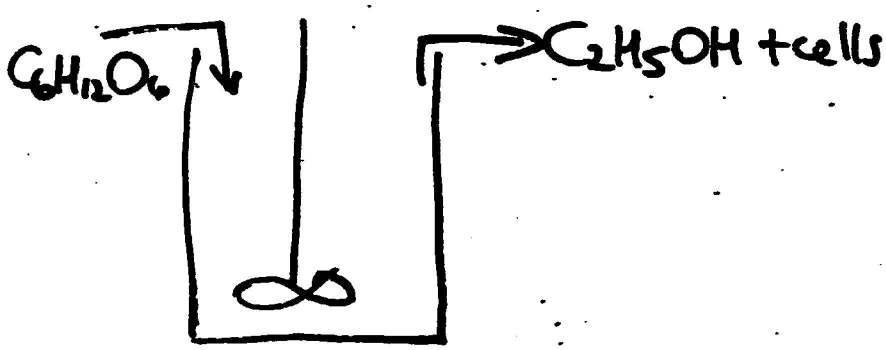
IMMOBILISED ENZYMES NO USE FOR C_2H_5OH FROM $C_6H_{12}O_6$.

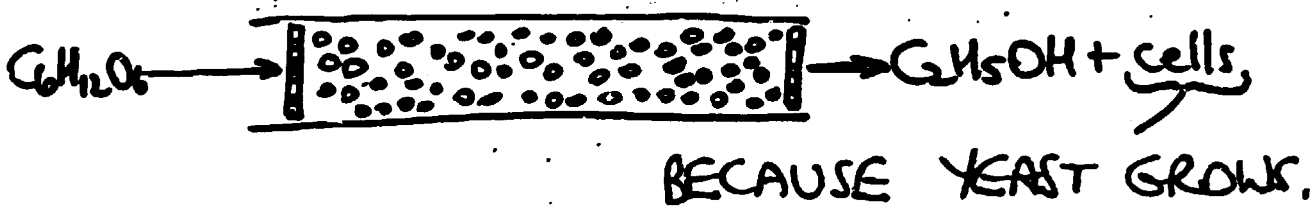
IMMOBILISED CELLS.

BATCH.



CONTINUOUS.





IMMOBILISATION METHODS.

ADSORPTION

- CELL
  - CELL WALL
  - CHARGE
  - AGE
- SURFACE
  - pH
  - SURFACE CHARGE
  - SURFACE AREA

ENTRAPMENT

- AGAR
- ALGINATE
- CARRAGEENAN
- CELLOPHANE
- ACRYLAMIDE

COUPLING

- ISOCYANATE
- GLUTARALDEHYDE
- METAL HYDROXIDE
- AMINO SILAN

Davy

IMMOBILISED ENZYMES + CELLS.

1. Extracellular enzymes stable

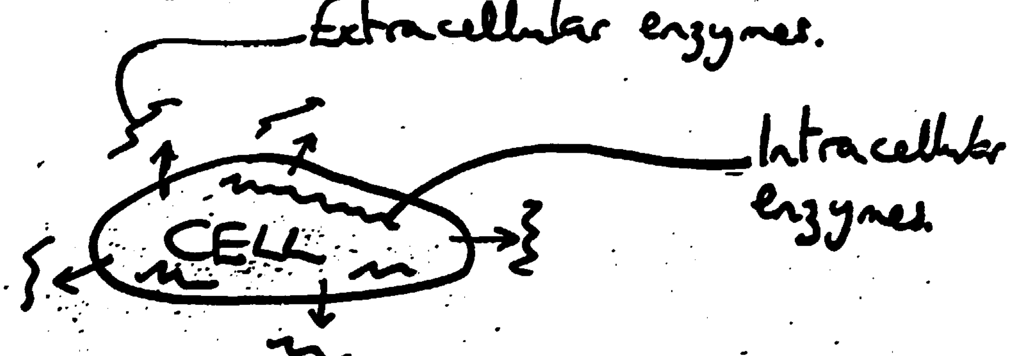
2. Intracellular enzymes unstable.

IMMOBILISATION

a) Stabilised intracellular enzymes.

b) Confines them in reactor.

c) Enzymes usually soluble and are lost with product unless held by immobilisation



e.g. $C_{12}H_{22}OH \xrightarrow[+H_2O.]{ENZYME} C_6H_{12}O_6 + C_6H_{12}O_6$
FRUCTOSE GLUCOSE.

e.g. $C_6H_{12}O_6 \xrightarrow[ISOMERASE]{ENZYME} C_6H_{12}O_6$
GLUCOSE FRUCTOSE

ENTRAPMENT

(1) 1 ml yeast culture + 50 mls of 4.5% CARRAGEENAN GEL soln @ 37°C
MIX.

(2) Add drop by drop to 2% KCl-soln @ 20°C
MAKE 4 mm diameter drops.

(3) Stir gently for 2 hrs

① 5mls of 125g/l yeast added to 50mls of 2% Na alginate @ 37°C

② Extrude as drops into 0.05M $CaCl_2$ @ pH = 4.5 @ 4°C
(Syringe + 26 gauge needle gave 1.8mm beads
18 gauge needle gave 3mm beads.)

③ Stir slowly for 12 hrs @ 4°C

④ Activate by growing 40hrs @ 30°C in 10% glucose soln with added yeast extract and peptone

IMMOBILISED CELLS.

BATCH FERMENTATION NO
CELLS ALREADY CONTAINED IN FERMENTER.

CONTINUOUS FEMENTATION PERHAPS

BUT

WHAT ARE ADVANTAGES.

1. PLUG FLOW - BETTER YIELD

2. SMALL FERMENTER. - CHEAPER

3. NO NEED TO SEPARATE CELLS.

BUT.

1. MOLASSES DIRTY, CLOG REACTOR (GUMS etc)
   BATCH FLEXIBILITY LOST

2. VERY COMPLICATED TUBULAR REACTOR - EXPENSIVE

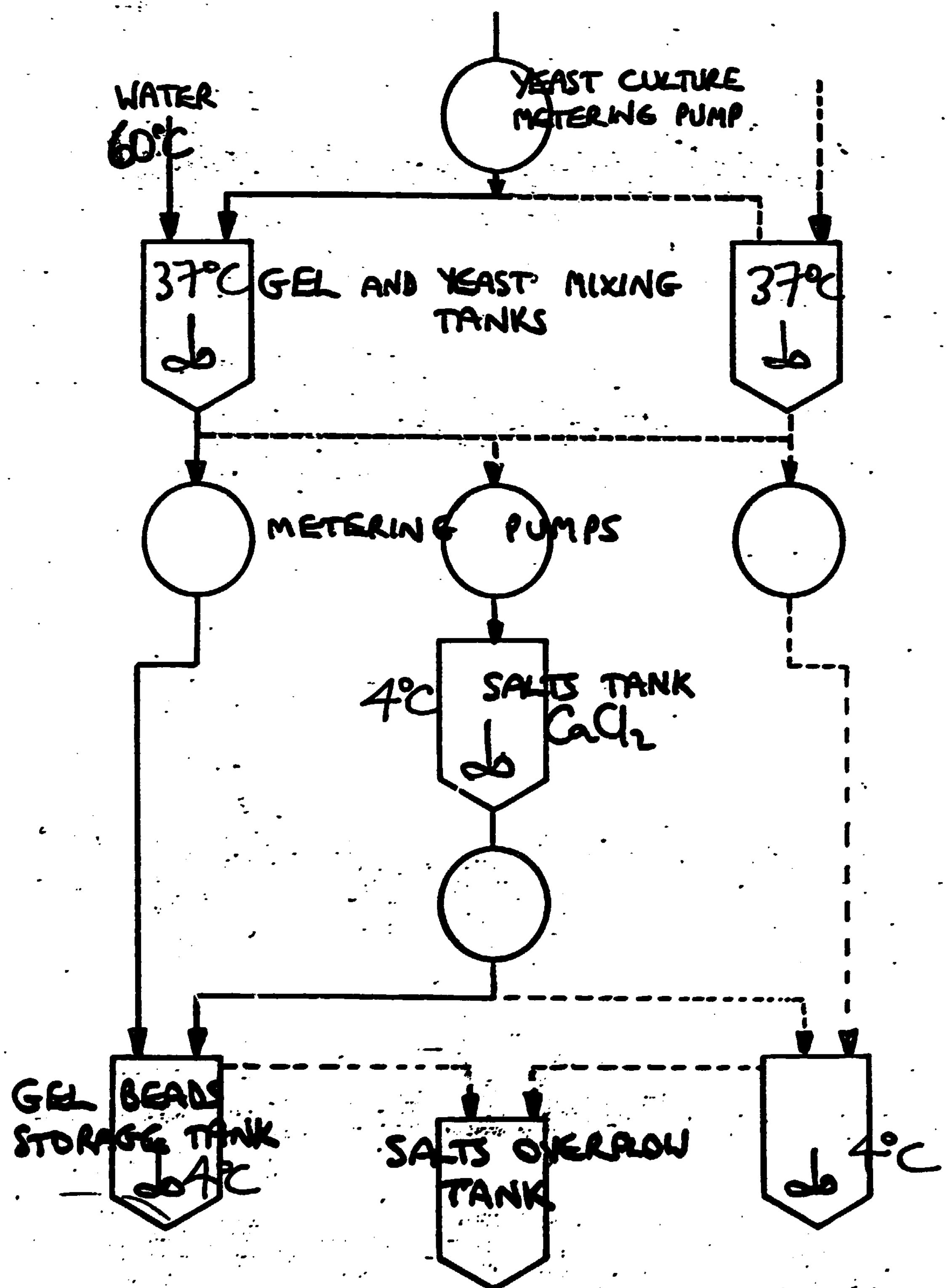
3. C_2H_5OH PRODUCTION CELL GROWTH LINKED

$$Y_{x/s} = 0.05 = 5\%.$$

SO STILL NEED TO SEPARATE CELLS

Davy

IMMOBILISED CELLS – COST.



IMMOBILISED CELLS COST

1. GEL BEADS WITH YEAST IN THEM
   - WOULD DRY OUT IF NOT KEPT IN WATER
   - HAVE NO GROWTH MEDIUM IN THEM
   - MUST BE STORED STERILE.

SO MUST BE MADE AT DISTILLERY.

FOR 10×10^6 LITRE PER YEAR DISTILLERY

CAPITAL COST	$ 450,000*
RUNNING COST/YEAR	55,000

* TOTAL FULLY ERECTED BATCH FERMENTATION SYSTEM ONLY = $1·8 MILLION

IMMOBILISE CELLS.

ADVANTAGES.

1. INCREASE REACTION RATE AS MORE CELLS
2. HIGHER SPECIFIC PRODUCT YIELD
3. OPERATE CONTINUOUSLY AT HIGH DILUTION WITH NO WASHOUT
4. ELIMINATES COSTLY FERMENTER DESIGN
5. EASIER CONTROL OF FERMENTION
6. ~~SUBSTRATE~~ INHIBITION EFFECT REDUCED
7. ETHANOL INHIBITION EFFECT REDUCED
8.
9.

DISADVANTAGES.

1. COST OF MANUFACTURE NOT COVERED BY LOW PRODUCT COST
2. NO INDUSTRIALISED SYSTEMS ARE IN OPERATION
3. GROWTH OF CELLS BLOCKS VOID VOLUME
4. GUMS + COLLOIDS BLOCK VOID VOLUME
5. ADDITIONAL BARRIER TO DIFFUSION
6. DIFFICULT TO REMOVE WASTE GAS I.E. CO_2.
7. $Y_{P/S}$ HIGH, $Y_{X/S}$ LOW BUT % CONVERSION LOW –COST.
8. REACTOR MUST BE STERILISABLE.

Davy

WHY DO RESEARCH?

1. TO IMPROVE PRODUCTIVITY

It is sound ECONOMICALLY to get more yield at greater internal cost if it does not affect trade balance.

2. TO REDUCE COSTS.

The cost of Research must be recovered by the cost reductions it suggests.

3. TO EDUCATE RESEACHERS.

Unfortunately this is often the first thought in researchers heads.

4. TO REPEAT another COUNTRIES WORK.

This often happens.

NEVER BE AFRAID TO REPEAT OTHERS WORK BUT **ALWAYS** QUOTE THE ORIGINAL

APPENDIX 4

Itinerary for Dr.R.B. Brook's visit
(11-02 Post)
1984

		A.M.	P.M.
Oct.	15th Mon.	- Arrive in Guangzhou	
	16th Tues.	- Session	Session
	17th Wedn.	- Session	Session
	18th Thurs.	- Session	Session
	19th Fri.	- Discussion	Discussion
	20th Sat.	- Discussion	Discussion
	21st Sun.	- Free	Free
	22nd Mon.	- Visit Shunde Mill	
	23rd Tues.	- Visit Sugarcane Industry Research Institute.	
	24th Wedn.	- Discussion and Consultation.	
	25th Thurs.	- Discussion and Consultation.	
	26th Fri.	- Discussion and Consultation.	Free
	27th Sat.	- Back to Australia.	

APPENDIX 5

ITINERARY FOR DR. R. B. BROOKS'S VISIT

(11-02 Post)
1984

Oct.	15th Mon.	- Arrive in Guangzhou	
		8-12 A.M.	2-5 P.M.
	16th Tues.	- Session	Session
	17th Wedn.	- Session	Session
	18th Thurs.	- Session	Session
	19th Fri.	- Discussion	Discussion
	20th Sat.	- Discussion	Discussion
	21st Sun.	- Free	Free
	22nd Mon.	- Visit Shunde Sugar Mill and Distillery - Consultation.	
	23rd Tues.	- Visit Sugarcane Industry Research Institute.	
		8-12 A.M.	1-5 P.M.
	24th Wedn.	- Discussion and Consultation.	
	25th Thurs.	- Discussion and Consultation.	
	26th Fri.	- Discussion and Consultation.	
	27th Sat.	- Visit Guangzhou Sugar Mill - Consultation.	
	28th Sun.	- Free	
	29th Mon.	- Visit Shitou Sugar Mill and Distillery - Consultation	
		8-12 A.M.	1-5 P.M.
	30th Tues.	- Discussion and Consultation	
	31st. Wedn.	- Discussion and Consultation	
Nov.	1st Thurs.	- Discussion and Consultation	
	2nd Fri.	- Discussion and Consultation	
	3rd Sat.	- Free	
	4th Sun.	- Back to Australia.	

APPENDIX 6 OBSERVATIONS

SUGAR INDUSTRY OF CHINA

GENERAL

Using the definition of acceptance by most countries, China does not produce any refined sugar from cane or raw cane sugar, rather it is white sugar. As in most developing countries a non centrifugal brown sugar is also produced.

Most of the equipment is relatively old, or old style, with the largest factories those that had milling trains imported in the 1950's and 1960's. Since that time, Australia has produced a much more efficient 5 roll mill which together with feed chutes has vastly improved performance over a 3 roll mill.

Although no factories were running during the visit, the installed equipment would tend to suggest that cane preparation could be improved.

It is clear from many discussions with Institute and factory staff that there is a positive move to try and develop a cane payment system based on quality rather than weight. Lectures were given on cane payment systems based on quality which may be the subject of a separate report. The major advantage of a system of cane payment based on quality is that it gives the farmer and the factory real incentive to improve their performance and get paid for it.

China has one advantage over many of its developing country near neighbours, farmers are assigned to a particular factory and cane transport is handled either by the factory or by a transport company which handles all the cane for a factory. This gives China the opportunity to schedule cane deliveries in a way that few countries can e.g. Australia. Cane can thus be delivered freshly cut.

There were discrepancies in the pol balances of the factories we were given some results for. This could be because of pol inflated by dextran in stale cane.

There is a real need for a better quality refined sugar for industrial users. This will enable China to produce goods for internal use and also for export which meet all the internationally accepted criteria. These goods would include fruit juice, soft drink, pharmaceutical use, canned fruits etc.

Fibre is not measured by analysis now in any of China's factories, it is calculated by weighing and analysing mixed juice and analysing bagasse, weighing imbibition water and assuming no loss of pol in the milling train. Although the bag method for fibre was time consuming, it is a backward step to abandon its use.

NCIRC

The National Cane Sugar Research Institute lies 40 minutes S.E. of the city of Guangzhou. It was founded in 1957 as a combination of the Industrial and Agricultural Institutes founded earlier. There are eight departments,

Industrial	1.	Analysis/Quality Control
	2.	Automation/Instrumentation
	3.	Pollution Control/Byproducts
	4.	Sugar Technology
Agricultural	5.	Cane Breeding
	6.	Agronomics
	7.	Plant Protection
General	8.	Information/Library
and three farms	1	Hainan Breeding Station (53 ha)
	2.	Jianjiang for new varieties on red soil
	3.	Guanzhou (80 ha)

There are 700 workers which includes 200 technologists and 100 administrative people. The top staff are very knowledgeable about sugar in other countries.

Davy Agro

Some of the major investigations made in recent years have been

- o Diffusers (first full scale factory in 1964)
- o Sulphitation tubular reactor (in 1964)
- o Shredder (in 1975)
- o In-line pH meter (1983)

Presently, they are researching:

- o a particle board from bagasse process (two factories in production).
- o Chinese rum (not a popular drink)
- o phosphatation/flotation for refined sugar
- o a turbidimeter
- o a white sugar reflectance meter
- o a five roll mill

These subjects are all reasonably well documented in the literature and so there should be little difficulty in transferring the information to Chinese context.

The Institute generates cash flow by making instruments in its Automation/Instrumentation department for the sugar industry. This, on the surface seems a good idea, in that it uses the facilities and technical resources to the full. However, the cash flow generated could be so useful in funding research at the Institute that it takes precedence over research and development. The in-line pH meters are guaranteed for life which seems like a good idea but of course the Institute does get funding and if an instrument became a loss making venture it would drain funds from the research budget.

It would seem that the first factory/major unit operation etc. is developed, designed, and commissioned by the NCIRC but future ones are then designed by the Guandong Design Institute. Both of these Institutes are National Institutes located near Guangzhou.

Davy Agro

DISTILLERIES

There is seldom any molasses clarification, pasteurisation or stillage recycle and the molasses is usually very fresh and often very warm. Molasses of this type is usually very "lively" and generates a great deal of foam during fermentation.

The standard batch fermentation is not universally used in China. Shitow distillery used a standard batch system, pitching a fresh yeast culture in each new fermentation, sterilising the dilution water (treated river water) with bleaching powder before using it to dilute molasses. They aim for 8% $^{v}/v$ ethanol in about 20 hrs fermentation. No bacteriacides are used during fermentation but antifoam is usually needed. They use a mixed yeast culture to give both fast fermentation and higher final ethanol concentration.

Many distilleries in China have converted to a continuous fermentation system using from 6-12 vessels in series. Usually, molasses is fed to the first two in the series and these are the only ones which need water cooling. Bacteriacides are added to control infection. (There are some remarks in the fermentation section of the main report which may be considered valid here).

There is a major worry in most distilleries that there is a large residual sugar content in stillage, causing the systems to lose yield. This resulted in many discussions and advice on how to confirm whether the substances being measured as residual reducing sugar were actually fermentable e.g. furfural will be detected by the reducing sugar method but is not fermentable. The HPLC will soon confirm whether the so called residual reducing sugar is fermentable.

Distillation systems are similar throughout China, similar to most overseas distilleries.

- o wash column (22 trays)
- o aldehyde column
- o rectification column (67 trays)

to make 95% industrial spirit from an 8% ethanol feed.

Davy Agro

It is interesting that even today, columns are made out of cast iron which would be too expensive for most countries in the world. In China, stainless steel is more expensive than cast iron for such equipment. Hot stillage is very corrosive and again, cast iron pipe is an ideal way to handle it.