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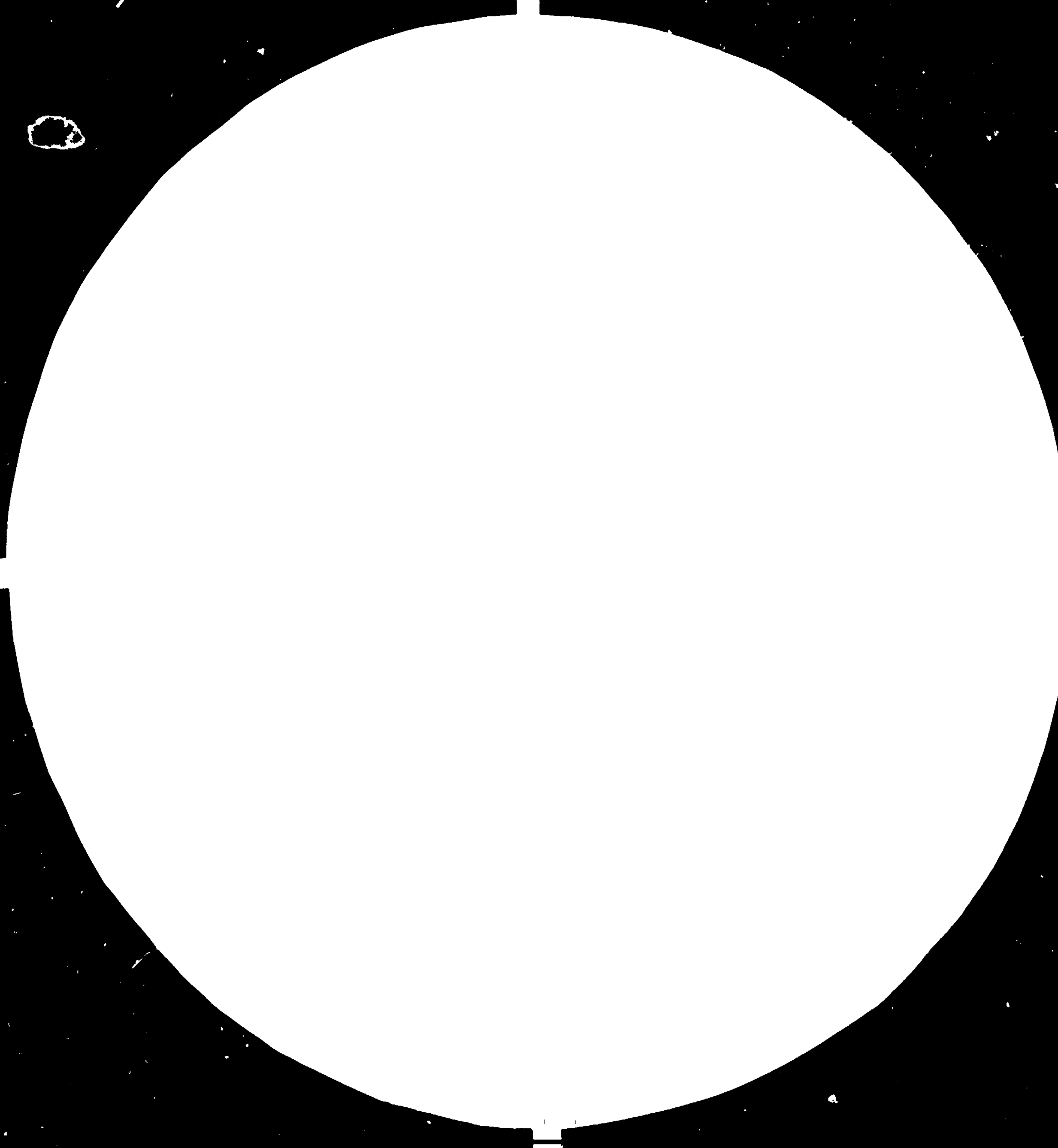

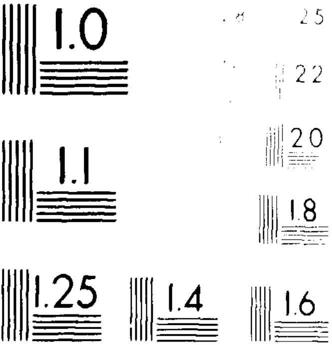
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CHEMICALS FROM ALCOHOL - Dr. V.R.S. Arni

STATEMENT OF THE PROBLEM

Sri Hiranyakeshi Sugar Cooperative (the 'Cooperative') is located in Sankeshwar in the Belgaum District of Karnataka (India). It is one of four sugar factories in the region and it is one of the most successful sugar enterprises in the Western Seaboard. The main products of the Cooperative are sugar (3500 tonnes a day cane crushing capacity) and industrial alcohol. The Cooperative produces around 8 million litres of alcohol per annum, all of which is presently marketted as denatured alcohol to a variety of industries. At the present time, the Cooperative has Governmental approval to convert 50% of its alcohol production into alcohol-based chemicals. Potentially, however, it may be able to utilise all of its alcohol for such conversion. The distillery is based on 75% captive and 25% purchased molasses.

The Cooperative desires to add value to the alcohol through its conversion to alcohol-based chemicals. The need is fairly acute as there is a surplus alcohol position in the country which has depressed prices.

The Cooperative is also faced with the problem of disposing alcohol distillery wastes. Presently, the distillery waste is subjected to anerobic fermentation in lagoons, with reduced-BOD sludge diluted with waste water and disposed off into a nearby small river. However, there is inadequate availability of water all round the year for dilution. In addition the flow of water in the river is deficient for several months in the year. The Pollution and Environment control bodies in the region are becoming increasingly strict on distillery waste disposals and hence waste disposal alternatives are of considerable importance to the Cooperative. It is to be noted that the distillery spent wash has a BOD of 35000 and a COD of 88,000 whereas disposable BOD & COD are 20-30.

REVIEW OF POSSIBLE ALTERNATIVES

Alcohol-based Chemicals

About twenty chemical products - of commercial tonnage - can be produced from alcohol. In one plant or other, all of these chemicals are being produced in India currently. The range comprises of high-value products such as polyethylene, synthetic rubber (SBR) and styrene, to intermediate-value products such as vinyl acetate and 2-ethyl hexanol and to low-value products such as acetic acid and its esters.

The following is a classification of such products:

I. High Value Products

polyvinyl chloride
polyethylene (low-density)
styrene + polystyrene
butadiene
styrene - butadiene rubber
ethylene oxide and ethylene glycol
ethylene vinyl acetate, EVA, which is not yet produced in India

II. Intermediate value products

vinyl acetate
monochloracetic acid
2-ethyl hexanol
pentaerythritol
butanol
glyoxal

III. Low-value products

acetone
acetic anhydride
acetic acid
ethyl acetate
butyl acetate
sorbic acid
pyridines and picolines

Except for category III products, almost all of the other products are also produced in India via petroleum hydrocarbons. Although cost efficiencies are different in the use of alcohol and petroleum hydrocarbons, the Government of India usually regulates installed capacity to meet growing levels of demand. Therefore, it is possible for chemicals based on differing feedstocks to co-exist and compete in the market place. The Government, at present, also has a liberal import policy and 'actual users' can directly import their requirements (if import tariffs allow for competition).

The types of alcohol-based products that an enterprise can consider making depend on the following:

(i) the 'economic size' of the plant intended to be used for the production of a candidate product

(ii) the quantity of alcohol available to the producer

(iii) the regional market (economic access) for the intended product

(iv) cost of inputs

Category I products

Economic-size units of Category I products would call for alcohol far in excess of the Cooperative's total production. For example, a 40,000 tonnes per annum low density polyethylene plant (minimum economic size in the Indian situation) would call for, at least, 82 million litres of alcohol per annum, 10 times the size of the Cooperative's distillery (8 million litres/annum).

Category II products

Category II products are viable in India, and perhaps for the Cooperative, if all of its alcohol can be diverted to production. Vinyl acetate and 2-ethyl hexanol are particularly attractive in the Indian scene, the former for latex paints and adhesives and the latter as PVC plasticiser base (for dioctyl phthallate DOP).

Investment levels would be large. VAM Organic, which now makes 5000 tonnes/year of vinyl acetate at Sahapur, UP was recently established at an investment cost of Rs.170 million. A 2-ethyl hexanol plant would probably involve an investment of Rs 90-100 million. In addition, with little experience in chemicals marketting (and technical service), the Cooperative would have to compete with three established plants:

(i) VAM Organic - 5000 tonnes/annum (expanding to 10,000 tonnes)

(ii) Polychem (at Poona) - 5000 tonnes per annum (being expanded)

(iii) Cellulose Products, Ankeleshwar - 2000 tonnes/annum

While vinyl acetate could be a forward-integrated project of the Cooperative, it would be ill advised to venture on the project at the present time.

In respect of 2-ethyl hexanol, there are, again, two established producers

Union Carbide at Bombay - 4000 tonnes/annum installed capacity

National Organic Chemicals at Bombay - 6000 tonnes/annum installed capacity.

In addition, Indo Nippon produces oxo-alcohols (10,000 tonnes/year) which compete with 2-ethyl hexanol.

The product, again, could be a forward integrated project of the Cooperative, but it would be a poor alternative since the Maharashtra Petrochemical complex will likely produce it.

Butanol, via acetaldehyde, could be yet another product that the Cooperative could produce. It is widely used as a solvent/thinner in the paints industry and as a base for butyl acetate, which, in turn, has uses in the paint/pharmaceutical (antibiotics) industries. Data on its demand/supply position will have to be generated and it could be part of a two-product plan of the Cooperative. Butanol is presently being made by several producers, among them being a Union Carbide India, Somaiya Organic, Kohlapur Sugars.

Category III Products

Category III products are viable, in the context of the 1980's in India, at the 10-20 tonnes per day level. As can be expected, there are several producers for each of the listed products.

Acetic Acid

It is the recommendation of the Consultant that the Cooperative consider acetic acid. With respect to the other products, the following remarks may be noted.

Acetone: There is only one Indian producer (a new one) who uses alcohol as a base. The main source of acetone in India is Herdillia Chemicals (Bombay) who produce it from naphtha-cracker-propylene. Hindustan Organic Chemicals, at Cochin, will be a new producer in 1985, based on refinery propylene. Acetone has a very wide mix of uses, with few concentrated demand sectors. Alcohol-based acetone production, worldwide, has been found to be uneconomic.

Acetic Anhydride (AA): AA is largely produced for captive use, as by Sirsilk (Hyderabad) for acetate rayon or as by Cellulose Products, for cellulose acetate. There are few possibilities of its marketting in the Indian context. There are 6 producers in India, all with captive production.

Ethyl acetate, butyl acetate, other esters

These products involve the interaction of various alcohols with acetic acid. They are largely utilised in the solvent, paint and pharmaceutical industries. It is Indian experience that while these products can be marketted at prices and margins higher than that obtainable with acetic acid alone, demand fluctuates greatly and the products go through wide price swings. In practically all such products, there is competition from non-acetate products.

Sorbic Acid, Pyridines and Picolines, Glyoxal

These are speciality, low-volume products. Their markets are growing in India but marketting calls for much effort. A chemicals firm, with a wide mix of products, would be attracted to them.

Some forecasts of demand for alcohol-chemicals have been made earlier and the data generated is reproduced here:

Unit: 000Tonnes

	1978	1983	1988
Acetone	17	34	56
2-ethyl alcohol	17	35	80
Ethylene glycol	17	70	135
Acetic acid(free sales)	24	30	48
Acetic anhydride free sales)	5	20	32
Vinyl acetate	12	30	40

(Source: Seminar on Perspective Plan for Petrochemicals, Indian Chemical Manufacturers Association, New Delhi, May 3, 1978)

ACETIC ACID

It is the recommendation of this Report that the Cooperative seriously consider the manufacture of acetic acid in the first stage, to be later forward integrated to Vinyl Acetate.

Acetic acid, like ethylene, is a volume commodity product with a wide spectrum of usage. A 500 tonnes/day acetic acid plant would not be uncommon in the USA, for example.

The present (1982) percentage distribution of acetic acid usage in India is as follows:

Vinyl acetate	20%
Acetic acid esters	30%
Drugs	18%
Textiles and anxillaries	14%
Dye intermediates and others	18%
	100%

(Source: Chemprofiles-Kharbanda).

The following are currently producing acetic acid in India:

		'000 Tonnes (1982)
1.	Andhra Pradesh Industrial Development Corpn. Hyderabad	1.7
2.	Andhra Sugar, Tanaku, AP	1.1
3.	Gujarat Distilleries Ankeleshwar, Gujarat	3.0
4.	Indian Organic, Khopoli	9.0
5.	Kohlapur Sugar, Kolapur	2.4
6.	Mysore Sugar, Mandya, Mysore	3.0
7.	Sirsilk Hyderabad	3.1
8.	Somaiya Organic Sakarwadi/Barabanki (UP)	6.0/7.6
9.	Union Carbide, Bombay	1.4
		38.3

In addition, several units have been licensed for producing the acid. Significant among them are:

Hindustan Organic Chemicals, Panvel	3.0
IDPL	5.0
Trichy Distillers	3.0
Southern Organic, Mysore	3.0
	14.0

These listings exclude the acetic acid produced for captive use, i.e. by Cellulose Products Union Carbide, Godavari Sugar, etc.

No reliable forecast for acetic acid demand is available and the range quoted in literature (at various times) varies from 40.000 - 80,000 tonnes by 1988 (excluding captive production). Only a market survey for the Western Region will indicate real scope for the Cooperative.

Technology

Acetic acid is made by the air oxidation of acetaldehyde using manganese acetate catalyst. The reaction takes place at 60°C at atmospheric pressure. The product is purified by distillation.

Acetaldehyde, in turn, is made by one of two routes: - (1) Oxidation of alcohol and (b) dehydrogenation of alcohol. Dehydrogenation - by the catalytic dehydrogenation route - is preferred when downstream chemicals may also be produced. The reaction is in the vapour phase with chrome-copper type of catalysts in fixed bed reactors operating at 260°C-330°C and 3-8 psig. Processes are usually continuous. Catalyst is regenerated outside the reaction system.

The technology for both the processes, is available in India, and can also be purchased from abroad (including Brazil)

Investment and Production Costing

In the estimates presented here it is assumed that 8 million litres of alcohol will be converted to acetaldhyde and acetic acid per year. The data provided in Tables I to VI will enable calculations to be revised for a smaller plant. The assumed capacity is 20 tonnes/day acetic acid which is an economic sized plant.

The fixed investment is estimated at Rs.22.2 million for the alcohol-to-aldehyde plant and Rs.24.7 million for the aldehyde-to-acetic acid plant. These investments are based on a proposed new 3000 tonnes/day acetic acid plant planned (for 1983) by Southern Organic Chemicals Ltd in Mysore at Rs.27.8 million. This data is consistant with other estimates available to the Consultant.Site costs are assumed to be zero.

The cost of production data is based on detailed estimates made available to UNIDO for Brazilian plants (UNIDO ID/WG.293/4 28th March 1979) and there is little reason to doubt the suitability of the data. Cost data for utilities, alcohol, labour, and supervision are those supplied by the Cooperative. Working capital standards are those adopted for chemical plants in Bombay and may be applicable to the Cooperative.

The cost of production of acetic acid (naked) is estimated at Rs. 4209.4 per tonne, or Rs. 4.2.kg approximately. The current selling price of the acid in the Bombay area is between Rs. 7.2 to 7.5 per kg.

Total Fixed Investment is estimated at Rs. 46.9 million and working capital at Rs 9.9 million, giving rise to a total employed capital of Rs 56.8 million for a plant rated to produce 7200 tonnes of acetic acid anually. Return on investment (before taxes) is approximately 38% (on total employed capital) if product acetic acid is marketted at Rs 7.2 per kg. It is possible, however, that the fixed investment is on the high side. The price of alcohol to the chemicals unit is taken at Rs 1740 per tonne as given by the Cooperative .

TABLE I

Estimate of Cost of Production of Acetaldehyde

Annual Capacity = 5600 tonnes (Te) per annum acetaldehyde

	Unit	Unit Cost Rs	Unit Consumption	Cost/Te product
Utilities				
Cooling Water	M^3	1.00	140	140.00
Process Water	M^3	10.00	0.60	6.00
Steam	Te	58	6.00	348.00
Electricity	Kwh	0.30	70.00	21.00
Fuel oil	M^3	2800	0.08	224.00
				739.00
Catalyst and Chemicals				
Cat and Chem	Rs		80	80.00
Raw materials				
Alcohol	Te	1740	1.14	1983.6

Depreciation

Investment = Rs.22.2 million
Depreciation/yr Rs.2.22 million

	Unit	Unit Cost Rs	Unit Consumption	Cost/Te product
Depreciation	Rs		396.43	396.4

Labour & Supervision

Operators	No.	Rs.35/day	4 per shift 3½ shifts

= Rs.490/day

Supervision = 5 times labour cost
= Rs.2450/day

Continuation of TABLE I

Labour & Supervision per Te aldehyde	$= \frac{2940}{15.34 \text{ Te aldehyde/day}}$	191.6
Maintenance	3% of investment $\frac{\text{Rs.}0.03 \times 22.2 \times 106}{5600}$	118.9
	Cost of production excl. interest on working capital.	3509.5

TABLE II

Working Capital - Acetaldehyde Plant

Inventories

Alcohol for 15 days
(@ 60% of selling price)

$$1983.6 \times 0.60 \times \frac{5600}{24} = \text{Rs.}278000$$

Chemicals and catalysts
(1 month)

$$80 \times 5600 \times \frac{1}{12} = \text{Rs. } 37000$$

Utilities

15 days

$$739 \times \frac{5600}{24} \qquad \text{Rs.}172000$$

Labour & Supervision

45 days

$$191.6 \times \frac{5600}{12} \times 1.5 \qquad \text{Rs.}134000$$

Finished Products Storage

30 days at production cost — Rs.1638000

$$\frac{5600}{12} \times 3509.5$$

Accounts Receivable

30 days at production cost

$$\frac{5600}{12} \times 3509.5 \qquad \text{Rs. }1638000$$

Total Working Capital — Rs.3897000

Interest rate - 15%

Interest cost per Te product

$$\frac{3897000 \times 0.15}{5600}$$

= Rs. 104.4

TABLE III

Summary of Costs - Acetaldehyde

	Cost/Tonne aldehyde Rs.
Utilities	739.00
Catalysts and chemicals	80.00
Raw materials	1983.60
Depreciation (10%)	396.40
Labour and Supervision	191.60
Maintenance	118.90
Interest on Working Capital	104.40
Total Cost of Production	3613.90

Estimate Cost of Production of Acetic Acid from Acetaldehyde

Utilities Annual capacity = 7200 tonnes/year

	Unit	Unit Cost Rs.	Unit Consumption	Cost per Te Product, Rs.
Cooling water	M^3	1.00	280.00	280.00
Process water	M^3	10.00	8.00	80.00
Steam	Te	58.00	3.60	208.80
Electricity	Kwh	0.30	293.00	87.90
Inst. Air	NM^3	0.01	2.50	0.03
				656.73
Catalyst				
Mn Acetate	Kg	60.00	0.2	12.00
Raw materials				
Aldehyde	Te	3613.90	0.78	2818.80

Depreciation

Investment = Rs.24.7 million

Depreciation (10%) = Rs.2.47 million

Depreciation Rs. 343.05 343.05

Labour and Supervision

Operators No. Rs.35/day 4/shift 3½ shifts

Rs.490/day

Supervision = 5 times labour cost = Rs.2450

Labour and Supervision per tonne acid

$$= \frac{2940}{19.72 \text{ tonnes acid/day}}$$ 149.04

Maintenance

3% of investment =

$$\frac{Rs.0.03 \times 24.7 \times 10^6}{7200}$$ 102.91

4082.53

TABLE V

Working Capital - Acetic Acid Plant

	Rs
Inventories	
Aldehyde for 15 days (at cost of production) $3613.90 \times \frac{7200}{24} \times 0.78$	845700
Chemicals and catalysts (2 months) $12 \times \frac{7200}{6}$	14,400
Utilities	
15 days $656.73 \times \frac{7200}{24}$	197,000
Labour and Supervision	
45 days $149.04 \times \frac{7200}{12} \times 1.5$	134,000
Finished Products Storage	
30 days at Production cost $\underline{7200} \times 4082.53$	2,450,000
Accounts Receivable	
30 days at product cost $\frac{7200}{12} \times 4082.53$	2,450,000
Total Working Capital	6,091,100

Interest rate 15%

Interest cost per Te acid $\frac{6,091,100 \times 0.15}{7200}$ = 126.90

TABLE VI

Summary of Costs - Acetic Acid from Aldehyde

	Cost/Tonne Acetic Acid, Rs.
Utilities	656.73
Catalyst and Chemicals	12.00
Raw Materials	2818.80
Depreciation	343.05
Labour and Supervision	149.04
Maintenance	102.91
Interest on Working Capital	126.90
	4209.43

RECOMMENDATIONS

It is recommended that the Cooperative first establish an acetic acid production line for a capacity rating of 3600 tonnes per year with infrastructure built-in for doubling of capacity and for the subsequent feeding in of acetaldehyde to a vinyl acetate plant (using the technology of Bofors, Sweden, who have already licensed their technology to VAM Organic). It is to be noted that the raw material for vinyl acetate is acetaldehyde and that a byproduct of the process is acetic acid. In a third phase the vinyl acetate plant can be expanded to produce polyvinyl acetate, polyvinyl alcohol and speciality laquers.

Prior to establishing the acetic acid plant it will be necessary for the Cooperative to appoint a consulting firm for carrying out a market survey for acetic acid in the Western region, taking into consideration existing manufacturers who produce acetic acid for sale (and not for captive use). Industrial Development Services, M-1 'Kanchenjunga' Barakhamba Road, New Delhi or Kirloskar Consultants, Poona may be appropriate consultants for this purpose. It is recommended that the survey establish a firm end-use pattern for acetic acid and provide details as to how it is moved in the region. The scope for contracted sales of the acid to firms such as Polychem should also be an objective of the survey.

For establishing firm investment data, recommendations of technology to be used for acetic acid, technology suppliers, detailed operating cost information, etc it is suggested that the Cooperative approach firms such as Dalal Consultants, Bombay, or Chemical and Metallurgical Consultants, New Delhi.

It is to be noted that despite the large number of acetic acid producers (now 14, including those who produce the acid for internal use) capacity utilisation by the industry in 1982 was 80% and acid price in the stable Rs 7.00 to Rs 7.50 region, although higher prices have prevailed in the past. Indeed, capacity utilisation in the 1976-82 period has stayed at 70%+ in practically of the years (see Economic Times Jan 11, 1984). This is because of the 'commodity' nature of acetic acid. Derivatives of acetic acid, however, have not enjoyed this type of stability. Furthermore, intensive marketting effort would not be necessary for the disposal of the acid as purchasers usually split their requirements among several suppliers.

The Cooperative may also wish to examine the market for butanol as an alternate product or as part of a two-product strategy. The raw material for butanol is acetaldehyde but the conversion of the aldehyde to the alcohol involves several steps and raises investment levels. Technology for butanol production, like that of acetic acid, will be available within India (but probably not from existing manufacturers).

SPENT-WASH DISPOSAL

The Cooperative discharges about 900,000 litres of distillery spent wash daily. This spent wash, like that of distilleries in general, has a large amount of organic matter. In technical terms the BOD of the wash is in excess of 35000 and the COD is in excess of 65000. Normal pollution abatement standards would require that if they are to be disposed off by river-water dilution the discharge should have a BOD of less than 20, and a COD of the same order.

Since the flow of water in the small river near the Cooperative is not heavy, and indeed is very lean in the months preceding the monsoon, the Cooperative discharges the spent-wash to a series of shallow lagoons, allowing for inefficient anerobic degradation.

No data is available of the quality of the wash after the degradation process. The wash is sometimes disposed off into the surrounding fields, sometimes into the river and some of the lagoon material is collected by farmers for feeding biogas generators.

However, the disposal of the wash is an urgent problem for the Cooperative and they are interested in investigating well-practiced and successful technologies.

There are no simple solutions to this problem and expert technical advise will become necessary to solve it. The general approaches to abatement are provided here and recommendations are made for further effort.

The classical way of handling the problem is through the activated sludge process, with variations of air or oxygen as the oxidising agent, the processes being aerobic. However, this Consultant is not aware of any system that can handle the levels of BOD met with in spentwash disposal. Typically, the spent wash would first be handled in a trickling filter and the reduced BOD outflow then handled with the activated sludge process. Other 'front-end' BOD-lowering processes may also be employed.

The second major way of handling heavy duty organic wastes would be through the anerobic processes using digesters. The waste would first have to be 'concentrated' by evaporation (natural or induced) before it enters the digesters. The process permits utilisation of its two 'byproducts' - methane gas (which can be used as a low calorie fuel since some carbon dioxide is present) and digester exudate which is rich in nitrogen and can be used as a fertiliser.

The third type of alternative is evaporation to dryness which is energy-expensive, or partial evaporation to serve as a furnace co-fuel.

Recently, however, processes have been developed for the use of immobilised enzymes but the Consultant is unaware of the success of such systems at the commercial level. Other modern variations involve thin film upward flow digesters under anerobic conditions, etc.

In order to develop a positive lead, the Consultant has agreed to help the Cooperative to locate European and American sources of technology and then put the technology owners in contact with the Cooperative. At the time of writing this Report this effort is underway. It is the Consultants opinion that technology presently available in India will not be successful and this is to an extent proved by the experience of several Indian sugar plants who experimented with minor variations of sewage-water-treatment technologies.

It has already been recommended to the Cooperative that as a short-term measure they experiment with the aerobic trickle filter. One of the surprising findings of a visit to the lagoons is that there is no fly nuisance which often prevents the use of such (otherwise well-practiced) processes.