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ENVIRONMENTAL ASPECTS OF INDUSTRIAL DEVELOPMENT IN DEVELOPING COUNTRIES

Case studies of the chemical industry in India

Prepared under the joint UNIDO/UNEP Environmental Programme

id.75-3814

CONTENTS

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Corrigendum

<u>Contents</u>

Before BOMBAY *insert* DELHI AND

<u>Page 4, paragraph 1, line 4</u>

For 160 g *read* about 200 g

<u>Page 5, paragraph 1</u>

Delete paragraph

<u>Page 6, line 4</u>

For remain at the desired standard *read* not be impaired

<u>Page 6, line 15</u>

For semi-colon *substitute* period

Delete except when the industry chooses as its location one of the 227 backward areas; then the Government will give a subsidy.

<u>Page 8, paragraph 4</u>

Delete paragraph

<u>Page 8, paragraph 5</u>

For "New Delhi" *read* "Delhi"

<u>Page 9, title</u>

Before BOMBAY *insert* DELHI AND

<u>Page 10, line 3</u>

For settable *read* settleable

id.75-7000

Page 12, paragraph 3

The first sentence should read Modipon Limited is one of the 24 industries of the privately owned Modi Enterprises Group of which 21 are located at Modinagar ...

Page 18, paragraph 3

For fluosilic read fluorosilicic

Page 31, line 1

For catalyst read contact

Page 34, line 14

For N_2 read N

Page 34, paragraph 5

For Babbock read Babcock

Page 36, table 4, under title

Add (Tons per day)

Page 39, line 6

Delete the cleaning of the vinyl chloride reactor section is discussed under "discharges"

Page 41, paragraph 5

For losses in fishery were considered to be lower read the potential loss to the fishery industry was considered to be less than the cost of the proposed sewer system

Page 41, paragraph 6

For in six months there are 20 power failures read in one six-month period there were 20 power failures

Page 44, paragraph 4

For oxides read oxidises

Page 46, line 7

For hydrosulphite read hydrosulphate

Page 50, line 5 of the table

For developed read dissolved

Page 55, paragraph 4

For ... soda ash for magnesium salt and calcium read precipitation of magnesium and calcium salts by addition of soda ash

INTRODUCTION

Following the United Nations Conference on the Human Environment, held at Stockholm in 1972, the United Nations established the United Nations Environmental Programme (UNEP). The United Nations Industrial Development Organization (UNIDO) and UNEP are now collaborating on a programme concerned with the effects of industry on the environment in developing countries.

This report is one of a series of case studies being carried out under this programme. Others in the series deal with the chemical industry in Turkey, the textile industry in Thailand, the cement industry in Iran and an integrated iron and steel mill in Brazil.

This report is based on the findings of a team of three experts that visited 14 chemical plants in India in June 1974. A factory at Bombay could not be visited because of the heavy monsoon rainfall. One factory near Calcutta also had to be dropped from the programme.

After visiting the factories, the team spent several days in New Delhi discussing the results of its mission with the Secretary General of the Ministry of Science and Technology, the Director General of the Council of Scientific and Industrial Research, the Director General of the Public Health Service, the Director of the Ministry of Industrial Development, and the Secretary of the Academy of Environmental Science.

An official of the Ministry of Science and Technology accompanied the team during the visits to factories at New Delhi, Nagpur and Bombay. An official of the Ministry of Industrial Development accompanied the team during the visits to plants at New Delhi and Calcutta.

I. BACKGROUND

India, with a population of about 580 million, representing one sixth of the world's total, is the second most populous and the seventh largest country in the world, with an area of 3.3 million km^2. The population growth during the period 1961-1971 was 2.2 per cent per year. At the present rate, the population is expected to double in about 31 years. In absolute numbers, the increase is about 12 million a year. This over-population causes many problems, and large groups of the people live below the minimum standard of consumption.

During the period of the Fourth Five-Year Plan (1968-1973), the average annual rate of economic growth was 5 per cent, as against a target of 5.6 per cent. During this period, 17.4 per cent of total public and private investment went to the agricultural sector and 21.4 per cent to the industry and minerals sector. Still, the Indian economy remains predominantly agricultural, with about half of the country's national income deriving from agricultural and allied activities that absorb nearly three fourths of its work force.

In 1972/73, the net national product was Rs 385,730 million, with a per capita net national product of Rs 681.5. The agricultural sector contributed 41.4 per cent to this net national product, whereas the manufacturing, construction and electricity, gas and water supply sectors together contributed 23.8 per cent.

During the period 1968-1973, the over-all growth of the industry and mineral sectors was below the target of the Fourth Five-Year Plan of 8-10 per cent. In 1969/70, the industrial production growth rate declined from 6.8 to 3.7 per cent in 1970/71, increased to 4.5 per cent in the period 1971/72 and was roughly 3 per cent for the period 1972/73. Factors that have contributed to an unsatisfactory growth rate were operational problems caused by lack of maintenance or design deficiencies, widespread shortage of power and the shortage of steel and non-ferrous metals.

The chemical industry

The chemical industry is closely linked with most of the other segments of the large and medium-scale industries in the broad industrial spectrum of the country. Of the major industries of India, the chemical industry ranks fourth (after the iron and steel, engineering and textile industries).

During the 1960s, the chemical industry recorded the highest growth rates. Investment rose from a total of Rs 3,040 million in 1961 to Rs 22,000 million in 1970. The fastest growing sectors today are petrochemicals, plastics, synthetic fibres, pharmaceuticals and fertilizers. The substantial expansion of the fertilizer, chemical and petroleum industries during the Fifth Five-Year Plan period (1974-1979) underlines the importance of rapidly developing the capabilities for the manufacture of chemical plant equipment and machinery. A total capacity of 45,000 tons 1/ per annum for such heavy equipment is expected to be achieved by 1979.

The growth planned for the chemical products in the first two years of the Fifth Five-Year Plan period is listed below.

	1974	1975
Caustic soda (thousand tons)	450	785
Soda ash (thousand tons)	500	880
Sulphuric acid (thousand tons)	1,400	3,200
Methanol (thousand tons)	25	60
Synthetic detergents (thousand tons)	8.5	300
Nylon filament and staple fibre (thousand tons)	16.2	19
Nylon tire cord and other industrial gear (thousand tons)	2.4	9
Drugs and pharmaceuticals (Rs million)	3,000	5,000
Industrial gas-oxygen (million cubic metres)	62	110

1/ Reference to tons throughout this study is to metric tons.

Fertilizers

Indian fertilizer projects include those introducing newer technologies for fertilizer application, those making effective use of indigenous raw materials and those concerned with high-pressure gasification of coal to produce methane rich gas for fertilizer production. Five new public-sector fertilizer projects will be implemented, three of which will be located inland and two on the coast. During the first years of the Fifth Five-Year Plan period a capacity of 4.1 million tons of nitrogen and 1.2 million tons P_2O_5 is planned.

The general productive efficiency of the operating units in India has been consistently below the accepted norms. For example, in 1970/71, the capacity utilization was only 63 per cent for the nitrogen fertilizers and about 54 per cent for the phosphates. This underutilization of installed capacity has been due to power shortage and thus unstable power supply, inadequate supply and poor quality of raw materials, design and technical limitations and problems in labour and maintenance.

Pesticides

Even though fertilizers and pesticides are complementary inputs in India, the use of pesticides per unit of area has not kept pace with the increased use of fertilisers. The average per hectare consumption of pesticides in India is only 160 g as against 1,000-10,000 g in the developed countries. For the Fifth Five-Year Plan period the following production is expected:

	Thousand tons	
	1974	1979
Pesticides (basic chemicals)	30	70
BHC	18	25
DDT (mainly used for eradication of malaria)	3.8	8

The Pesticides Association of India has estimated that without any further import substitution, and at the current level of technological expertise in this field, the value of imports would amount to Rs 690 million.

Besides the pollution caused by the production of pesticides, the main source of environmental pollution by pesticides is the transfer through the soil to other land areas and water courses. The solution to the problems of environmental pollution and the disturbance of the natural balance lies in gradually replacing production of the persistent types of pesticides with safer products, which are biodegradable and which leave no residual toxicity.

Legislation to ensure the proper use of pesticides already exists under various provisions of the Insecticides Act of 1971, but the machinery for enforcing it needs to be considerably tightened.

Measures concerned with pollution

Research

Monitoring of pollutants has begun in a very small way in India. For example, the zonal laboratory of the National Environmental Engineering Research Institute (NEERI) at Nagpur regularly monitors air pollution levels in the industrial areas of Bombay. This institute was commissioned by the Calcutta Metropolitan Development Authority to make a survey of the extent of air pollution in the Calcutta area. The aim of the survey, which is now being carried out, is to identify major emission points and to recommend steps to be taken for the control of air pollution. Monitoring stations have already been established for collection of air samples. The total project will cost Rs 440,000.

NEERI was also commissioned by the same Authority to make a study of water pollution. The aim of this study was to assess the quality of water in the Hooghly estuary within the

Calcutta Metropolitan District through a base-line survey; to locate the major sources of pollution from domestic, commercial and industrial sources; and to recommend steps for control of pollution so that the quality of the river water would remain at the desired standard. The total project will cost Rs 275,000.

Industrial licensing

Up to now, the older industries have not been forced by law to install anti-pollution equipment. There is little incentive to act, since the payback period either is too long or does not exist. However, new industries are being forced by the Government to install anti-pollution equipment. In October 1972, the Government introduced a regulation stipulating that a licence will be issued only when steps to control air, water and soil pollution by the industry to be established are satisfactory. However, the Government gives no credits either to old or to new industries for installing special pollution-abatement facilities except when the industry chooses as its location one of 227 backward areas; then the Government will give a subsidy.

Industrial estates

Several industrial estates, in which a variety of industries, mostly small industries, are clustered, have been established throughout India. By 1972, over 10,000 Indian industries producing goods worth Rs 1,970 million per year and providing employment for over 100,000 workers had been set up on these estates.

As of 1974, the Indian Government had developed 567 estates. Until now the best results have not been obtained owing to inadequate planning. The ideal industrial estate would use the waste products of one factory as raw material for another. The different residual pollutants would be treated by a centralized effluent treatment system. The two key environmental steps in planning an industrial estate are:

(a) Planning a combination of industries to maximize waste reutilization;

(b) Properly designing treatment facilities for the mix of effluents from the industries of the complex.

Legislation

The Indian Parliament passed a law on water pollution in 1974. As "water" is a subject reserved to the States, this federal law is not automatically valid in the States. The States can either accept the federal law, make their own laws or do nothing. The federal law is automatically valid only in some federal districts such as Delhi City and Goa. Most of the "Delhi" industries, however, are not situated in the federal district and thus the law does not apply to them.

The law envisages the setting up of central and state boards of water pollution to execute the following functions:

(a) To advise the Federal Government and the state governments on any matter concerning the prevention and control of pollution;

(b) To provide technical assistance and guidance to the state boards;

(c) To carry out and sponsor research relating to problems of water pollution;

(d) To plan and organize the training of persons engaged in or to be engaged in programmes for the prevention, control or abatement of water pollution;

(e) To collect, compile and publish technical and statistical data relating to water pollution and measures devised for its effective prevention and control;

(f) To lay down and modify, in consultation with the state governments concerned, the standards for a stream or well with regard to the quality of water, flow characteristics of the stream or well and the nature of use of the water;

(g) To organize through mass media a comprehensive programme regarding the prevention and control of water pollution;

(h) To plan and cause to be executed a nation-wide programme for the prevention, control or abatement of water pollution.

Up to now, the federal act has been accepted only by the State of Gujarat, and thus its validity is limited. It is hoped that the remaining States will follow the example of Gujrat, since environmental problems do not stop at state borders.

The law includes regulations for licensing new industries. Strict measures can, therefore, be applied to new enterprises, provided that the law is accepted by the state governments.

The State of Maharashtra passed the Maharashtra Prevention of Water Pollution Act, 1969, which regulates the situation in that State only. Since Bombay and Nagpur are in the State of Maharashtra, the Act is valid in these cities. This Act makes it possible to establish new industries in the State using technologies that cause little pollution.

In West Bengal (Calcutta) and in Uttar Pradesh (where part of the "New Delhi" industry is situated), no anti-pollution legislation exists at present. A bill on air pollution is now being discussed in the Federal Parliament. It is expected to be passed shortly.

The National Committee on Environmental Planning and Co-ordination and the National Committee on Science and Technology play an important role in pollution abatement. They are responsible for making recommendations on the institutional, legislative and technological changes needed to preserve the quality of the environment.

II. CASE STUDIES - BOMBAY AREA

Mohan Meakin Breweries Limited

Mohan Nagar, Ghaziabad, Uttar Pradesh

Founded in 1855 at New Delhi, Mohan Meakin Breweries, a privately owned Indian industry, operates several factories in different parts of India. The Ghaziabad factory produces beer and malt; alcoholic beverages (whisky, gin, rum); cereals (corn flakes, oatmeal); fruit juices and canned fruits; and glass bottles.

Personnel total 4,500, of which 75 are women. The minimum age is 18, the average being 30. Monthly salaries range from Rs 300-400 for unskilled workers to Rs 600-700 for skilled workers.

In 1961, the unit producing fruit juice moved from New Delhi to a new site at Ghaziabad. It was followed by a brewery in 1962, a distillery and cereal unit in 1964 and a glass factory in 1965. Brewery production is 150,000 hl/a. Malt is produced at a daily rate of 15 tons; a second unit (25 t/d) is under construction.

After preparing the wort, solids are separated by centrifuges and are sold as cattle feed; the liquid goes for fermentation. The yeast is separated, dried and sold for pharmaceutical purposes. Beer is stored for three weeks, then bottled and pasteurised. At present, all the beer is bottled, but plans exist to produce draft beer. Ten per cent of the bottles are returned. Washing water from bottle cleaning, mainly NaOH, is diluted and, if acid effluents are available, is partly neutralised.

One million litres of water is used for cleaning 100,000-150,000 litres of beer, which is diluted with cooling water to 1:5 to 1:10.

BOD value of brewery discharges is determined twice a year and amounts to 300-400 ppm. COD value has never been determined. The effluents contain 800 ppm of settable solids.

The layout of the brewery (built in 1965) is not very modern, but the brewery is well maintained and clean. The distillery consists of a fermentation house with several fermentation units; the carbon dioxide evolved is removed and evaluated. There are two stills producing 5,000 l/d (24 h) and 6,200 l/d of alcohol.

Discharges

Apparently there is no treatment of liquid effluent from the separate units. The team was told that discharges of the factory, mixed with sewage from the factory, are transported to the fields owned by the company partly through an underground sewer and partly through an open canal. On the way to the fields, part of the effluents is discharged into the Hindan River and into the Hindan Canal. It was stated that there were no complaints. The fields cover about 300 acres (120 ha). The main crop is wheat. The factory claimed that irrigation by waste water aided agricultural output (a very doubtful statement). The team was not able to visit the discharge outlet of the sewer, the settling device at the outlet or the fields, owing to the distance (3-4 km), and it was claimed that no direct route to the area existed.

In 1971, the company asked NEERI at Nagpur to make a study of discharge problems, as the members of the mission learned during their visit to Nagpur. NEERI proposed several treatment schemes varying in cost between Rs 620,000 and Rs 1,115,000 (June 1972). The proposed treatment schemes included the following:

Pretreatment of distillery waste either in (a) anaerobic lagoon or (b) digestor. Subsequent treatment of the effluent together with other waste in aerobic lagoons and oxidation ponds.

Expected discharge: BOD = 30-40 mg/l into public water
Investment: (a) Rs 762,000; exploitation costs, Rs 82,000/a
(b) Rs 1,062; exploitation costs, Rs 97,000/a

Treatment of distillery waste in anaerobic lagoons, effluent mixed with other wastes to oxidation ponds.

Discharge: BOD = 80 mg/l, to be used for irrigation
Investment: Rs 620,000; exploitation costs, Rs 25,000/a

Neither of these proposals was carried out because the costs were considered too high; when the team visited the factory, members were not able to discuss these proposals.

Apart from boiler house discharges and carbon dioxide produced from fermentation, no gaseous effluents have been reported. The stack gases of the boiler house are not measured. No bad health effects inside or outside the factory have been reported.

Labour

The plant employs 4,000 workers. Houses have been built in the neighbourhood for only some of them. The monthly wages paid vary from Rs 300 as a minimum wage to Rs 600 for more skilled labour. Unskilled workers do not receive training. On average, six accidents take place per year. Expressed in working hours, a loss of 10 per cent occurs owing to illness, which, expressed in costs, means Rs 50,000 per month.

Maintenance

The factory is not badly maintained. In the maintenance section 50 persons are employed.

Laboratory

The factory has a small laboratory with a labour force of 20 persons.

Recommendations

A treatment of liquid effluents as recommended by NEERI has to be seriously considered. At present, these wastes can neither be recycled nor processed into valuable products. The hazards to public health that now exist are not sufficient to justify the costs of setting up a treatment plant.

Modipon Limited Nylon Factory

Modinagar, Uttar Pradesh

Modipon Limited, which is part of the privately owned Modi Enterprises Group, comprises 24 industries, of which 21 are located at Modinagar, some 20 miles northwest of New Delhi. Textiles, edible fats, sugar, soap, steel, paints are among these industries. Personnel at the Modinagar factories total 22,000, most of whom live in factory-owned houses in the village. The mission members had the opportunity to visit this area.

The team visited only the nylon factory, which has a good layout and where only a very small volume of effluents is discharged. However, the other Modi factories have more polluting effluents, which can be observed in the central effluent canal, which discharges into the Hindan River.

The plant, which produces nylon-6 textile yarn, was built by Lurgi A.G. The capital costs were Rs 220 million. The plant came on stream in 1968. Production capacity is 3,800 t/a of nylon-6 from about 3,450 t of caprolactam as a raw material. The caprolactam is purchased from an Indian producer.

The plant itself is modern and very spacious. The spinning rooms are air-conditioned and can be entered only through sluice systems. The plant is kept very clean and well maintained, including the dyeing sections. No bad health effects have been reported.

At present, the production of nylon-6 is fixed at 2,000 t/a owing to production restrictions imposed by the Government. About 15 per cent of the nylon-6 produced is dyed in about 30 colours. The dyestuffs used are acid direct dyestuffs. The effluents from the dyeing department amount to 5,000 imp gal (23,000 l/d). From what the team could see, these effluents are not coloured. It was stated that BOD and COD were low. These data were determined only once on the request of the Government.

The boiler house produces 20,000 lb/h (9,000 kg/h) of steam of 150 lb/in^2; coal was used as fuel. No data were available on the SO_2 content and particulates.

A small production unit producing 200-250 t/a of a terylene type of polyester textile fibres has also been installed. The possibility of producing tire cords in the future is under consideration.

Wastes

About 10 per cent of nylon production is waste, which is reprocessed into caprolactam and recycled; thus pollution is minimized. This recovery system was added about a year ago. Waste terylene amounts to about 15 per cent. Although the technology to reprocess and recycle these wastes is known, they are nevertheless not recycled; the small amounts available do not make it economically worth while. Terylene wastes are sold.

Labour

In the nylon plant there are 660 workers with a supporting staff of 360 persons. The laboratory has a staff of 50. Low-rent housing is provided for some of the staff; electricity is free. The minimum wage is Rs 350 per month. Out of this wage, the worker has to pay 1 per cent for insurance, whereas the company contributes 5 per cent.

Modi factories devote a great deal of attention to the training of their personnel, both at high and low levels. The staff at a higher level is sent abroad for training.

Conclusions

The Modipon nylon factory can be considered a minimum-polluting industry. No recommendations as to adding or changing the equipment to diminish pollution are required. However, from what can be observed, the Modi complex at Modinagar as a whole discharges liquid wastes, and a thorough investigation of these discharges is suggested.

Modi Industries Group presents a good example of the beneficial impact of industrialization. Within four decades Modi developed a small village in a poor rural area into a prosperous little town, with a health centre and facilities for cultural activities.

DCM Chemical Works Limited

Najafgarh, Uttar Pradesh

DCM is made up of a large group of industries - textiles, sugar, food products, distilleries among others - located in all parts of India. These industries together employ 40,000 workers.

The factory at Najafgarh consists of a chlor-alkali electrolysis plant, a bleaching powder plant, sulphuric acid and hydrochloric acid units, a single superphosphate plant with facilities for granular superphosphates and NPK fertilizers and a fat-hardening plant. This factory employs 1,080 labourers, 280 supervisors and technical assistants and 200 administrative workers.

The New Delhi Chamber of Commerce requested DCM Chemical Works to investigate pollution by industry in the northern states. In February 1974 the company sent out a questionnaire to about 200 industries; to date only 30 answers have been received. A final report is to be submitted to the Government.

The team visited DCM's electrolysis plant, sulphuric acid units and fertilizer plant.

Chlorine and caustic soda plant

The chlor-alkali plant was designed in 1948 by West Vaco Co., United States of America. It uses diaphragm cells instead of mercury cells to avoid the pollution that is often associated with the use of mercury cells. The original cells were later modified and a better diaphragm construction, consisting of two layers of asbestos sheets, was introduced. The cell-house contains 1,710 cells. Voltage is 3.5-3.7V. Capacity is (t/d): caustic soda, 60; chlorine, 52-54; and hydrogen, 1.5.

Part of the hydrogen is used to produce hydrochloric acid (8,000 t/a of 30 per cent), the balance is used for fat hardening. Sodium hydroxide leaves the cell as a brine containing 8 per cent NaOH and 16 per cent NaCl. It is concentrated to 50 per cent of NaOH. The excess of sodium chloride crystallizes and is recycled. The caustic is sold as 50 per cent solution.

Chlorine is used for the production of 12,000-13,000 t/a of bleaching powder (active chlorine content 35 per cent), and 5,500 t/a of chlorine is sold to nearby Hindustan Insecticides. The balance is liquified and sold. Sniff gas from the liquefaction unit goes to the hydrochloride plant.

There are some losses, said to be small, in the production process, particularly in drying and cooling, which are emitted from a 30-m stack. The exact amount is not analysed frequently.

DCM standard emission is 77 ppm. As raw material, 34,000 t/a of sea salt and occasionally salt from an Indian lake is used. Impurities are calcium sulphate, magnesium sulphate and argillaceous matter. Sulphate is removed as calcium sulphate. No barium salts are used. Excess calcium and magnesium are precipitated, respectively, as calcium carbonate and magnesium hydroxide or oxide using soda ash and caustic soda. A Dorr clarifier (installed in 1957) and filters are used to produce a clear brine. Solids from the clarifier are sun-dried and disposed of in a landfill. The filters are cleaned once a day by backwashing. Washing water, containing about 2 grams of solids per litre, is disposed of in the main sewer.

Electricity consumption is 3,600 kWh/t of caustic soda.

A new diaphragm cell of DCM's own design is under development in a pilot plant. It is a modern type of cell with a diaphragm of asbestos fibres fitted between wire gauze. Experiments with it have been successful.

Since the factory began operations in 1949, no incidents of chlorine poisoning have occurred.

Chlorine cylinders are filled on scales. Neither an alarm system nor an automatic shut-off valve is used to prevent overfilling. Everything depends on the vigilance of the worker. About 5-10 per cent of the cylinders, taken at random, are controlled. In view of the danger of overfilling cylinders with liquid gas, the control is inadequate.

Hydrochloric acid plant

The reaction between hydrogen and chlorine takes place in a brick-lined mild steel vessel, the lining of which has to be renewed every two years. The gaseous discharges may contain a small excess of Cl_2 and some nonabsorbed HCl.

A reactor was destroyed some years ago by an explosion, and since then the acid-resisting, brick-lined reactor has been used. Production is 8,000 t/a of 31 per cent HCl.

Sulphuric acid production

There are two sulphuric acid units, one of which produces 120 t/d and the other 155 t/d. In both units sulphur is used as a raw material. The 120 t/d unit was built in 1958, the 155 t/d unit in 1967. The first unit was designed by a firm in the Federal Republic of Germany, but has been frequently altered. The second unit was built by DCM. Both are of the single-contact/single-absorption type. Investment costs of both plants were about Rs 8 million.

There are facilities for producing 20 per cent, 65 per cent and 98 per cent concentrations of H_2SO_4. Some of the sulphuric acid is sold to the neighbouring Hindustan Insecticides for the production of DDT. The used acid, which is regenerated at the Hindustan Insecticides plant, is sold back as dilute acid and used in the production of single superphosphate.

The two plants are run on three shifts of three men each. In both plants the sulphur conversion is 98 per cent and the absorption efficiency 99.95 per cent. SO_2 in gaseous discharges is 0.1-0.18 per cent by volume; stacks are 40 m and 34 m high. Steam production is 1.25 of 225 lb/in^2 (15 atm) steam per ton of acid produced.

Fertiliser factory

The fertiliser factory, built in 1957, produces mainly powdered single superphosphate. Investment costs were Rs 6 million. In 1970/71, a granulating plant was added at a cost of Rs 2 million.

The superphosphate factory comprises two 55 t/h Raymond-type mills made in India and one Bradley mill of 7 t/h capacity. As phosphate rock, Jordan rock (32-33 per cent P_2O_5) and Indian rock from Udaipur (36-37 per cent P_2O_5) are used in a 3:2 ratio. The Udaipur deposit is rather small and will be exhausted after 15 years.

The mills have closed circuits for pneumatic classification and for transportation. Excess air is bled through bag filters. Sulphuric acid attack is performed in two continuous Broadfield-dens each with a 200 t/d capacity. Storage space is available for 7-20 days maturing. The matured product contains 18-19 per cent of water soluble P_2O_5. Total P_2O_5 content is 21 per cent.

Gaseous effluents from the Broadfield-dens are washed with water, a 20 per cent solution of H_2SiF_6 resulting. No information about the fluorine content of the exit gases was available. The fluosilic acid is neutralized with a solution of lime and is discharged into the sewer. This discharge contains about 2-2.5 t/d of fluorine.

Material is transported by belts run at a low speed (100 ft/min or 0.5 m/sec), which results in very small loads of dust at discharge points. This gain is, however, nullified by the use of very primitive hand-operated sieves, which causes large clouds of dust.

The granulating plant was not operating when the team visited it. Only about 25-30 per cent of the superphosphate produced is granulated, and some 10 per cent of the superphosphate is used to produce mixed fertilizers. The plant contains a rotary drum granulator (length 40 ft, diameter 6 ft) and an oil-fired rotating drum type of drier (length 40 ft, diameter 6 ft). Drying air entry temperature varies between 300° and 500°C depending on the product. The exit air passes through a bag filter.

The dried product is cooled with a countercurrent air stream in a rotary drum (length 20 ft, diameter 6 ft), 11,000 m^3/h of air being used. The spent air passes through a bag filter. The cooled product is sieved; undersize and oversize particles are recycled. Production rate is 9-10 t/h.

A study was made to replace the bag filter, which frequently causes problems, with Venturi scrubbers and to use the resulting solutions as make-up water in the granulator. Plans exist to construct this installation soon.

Cost of production

Table 1 gives the breakdown of the production costs.

Table 1. Costs of production at DCM Chemical Works at Najafgarh (percentage)

Item	Chlorine and caustic soda	Sulphuric acid	Super-phosphate
Raw materials	50	65	40
Labour	4	2	2-3
Maintenance	10	10	10
Overheads, including training	6	2.5	5
Depreciation	10	10	10
Research	2	0.5	2
Marketing/administration	8	5	10

Labour

In the complex at New Delhi, DCM employs 1,080 workers, of whom 110 are employed in the chlor-alkali plant. DCM does not provide housing for its labour force. The minimum monthly wage is Rs 350-Rs 1,000 for skilled workers. Only the more highly skilled workers are trained.

Concerning safety inside the factory, only two to three accidents take place a year. Concerning the health situation in the factory, of the total working hours, 10 per cent is lost owing to illness plus leave, which amounts to 3-4 per cent of total labour costs.

Discharges

Ground-level concentrations (glc) were measured inside and outside the factory in October 1972, wind velocity, 6-8 km/h; direction, west to east.

The results of the measurements were:

Chlorine glc	0.1 ppm in the factory
Hydrochloric acid glc	0.5 ppm in the factory
SO_2	0.32 ppm in the factory
	0.28 ppm at 500 m to the east
	0.25 ppm at 1 km to the east

It is planned to install a continuous monitoring system.

Liquid discharges are mainly cooling water, floor cleaning water as well as effluents from the fertilizer factory containing fluorine compounds. All liquid wastes are discharged into the main sewers.

Management stated that no damage had been caused to the surrounding areas and no complaints had been received. No bad health effects within the factory had been reported.

Conclusions and recommendations

DCM management and engineers are well aware of pollution problems, and efforts are being made to abate them. However, the factory left a rather untidy impression. The sulphuric acid factory had faulty insulation. In the chlorine cell house, cell repairs were carried out and used material as well as spare parts were scattered everywhere.

Much of the apparatus is badly in need of paint. Attention should be paid to maintaining clean working conditions, since spent and lost material can cause pollution. Processing of fluorine effluents into valuable materials ($AlCl_3$) should be considered.

Hindustan Insecticides Limited

New Delhi

Hindustan Insecticides Limited is a public-sector enterprise. After a visit to the factory, the team met with the management and workers' representatives, several of whom expressed the fear that expensive measures taken to abate pollution might adversely affect employment. Unemployment had always been a great worry in the area even before it became industrialized. The workers' representatives were, however, unaware of the possible long-term health hazards of pollutants and did not share the Government's concern over these hazards.

Hindustan Insecticides produces chloral and chlorobenzene, from which products DDT is made, with oleum used as a reactant.

Chloral is made from ethyl alcohol and chlorine. Chlorobenzene is made from benzene and chlorine. Chlorine and oleum are bought from the nearby DCM Chemicals. Spent oleum is regenerated as sulphuric acid, which is sold to DCM for use in fertilizer production. Alcohol and benzene are purchased on the Indian market.

DDT production

Production of DDT began in 1954. The 600 t/a installation was a gift from the United Nations Children's Fund (UNICEF) as part of a malaria-eradication programme. In 1958, plant capacity was enlarged to 1,400 t/a.

Hindustan Insecticides set up a second DDT plant at Alwaye, Kerala. This plant produces 1,400 t/a. In 1964/65, the output of the New Delhi plant was doubled to 2,800 t/a, and the Alwaye plant added a 3,000 t/a benzene hexachloride plant to its DDT facilities. The present investment of the company is Rs 33,600 million, which will be increased by Rs 97,900 million.

In the New Delhi factory, apart from DDT products, some by-products are manufactured, such as medical-grade chloral hydrate; hydrated calcium silicate, which is used as an anti-caking agent in DDT formulations; and ethyl chloride (anaesthetic grade).

Chlorobenzene is made in a continuous process in three units with capacities of 2, 2 and 4 t/d. As a by-product, hydrochloric acid 30 per cent technical grade is produced and then sold. In the reaction house, concentration of benzene is 1.2 ppm. Rectification of the crude chlorinated benzene is carried out in an open-air unit. As a by-product, 24 tons of a mixture of ortho- and paradichlorobenzene is obtained yearly.

Chloral is produced by chlorination of ethyl alcohol in glass-lined equipment. By-product HCl is absorbed in water and sold as 30 per cent technical grade. The chloral alcoholate thus obtained is distilled with oleum to obtain pure chloral. Production is 4 t/d. Spent oleum is recovered as sulphuric acid and is sold to DCM. The alcohol is lost. The quantity of alcohol removed may be about 1.2 t/d.

DDT condensation from chloral and chlorobenzene is carried out with oleum 20 per cent in a batch process. Mild steel equipment is used. A batch contains 1,140 litres of oleum 20 per cent, 2,000 litres of chlorobenzene and 580 litres of chloral. DDT yield is 1,740 kg. The spent oleum is recovered as sulphuric acid of about 75 per cent and is sold to the neighbouring DCM for use in fertilizer production.

DDT is produced as a melt, which is washed with hot water. The pure melt is solidified after a steam distillation in which excess chlorobenzene is recovered for reuse. These operations produce 80,000 gal/d of acidic water that contains traces of DDT and chlorobenzene. This effluent has a pH of less than 1.0 and DDT content of 10-40 mg/l (see table 2). A filter system consisting of a fibreglass filter and an active carbon filter is used to remove the DDT. This system was recommended by NEERI.

Table 2. Summary of the results of treatment of composite effluent

	Raw waste	After chemical treatment	After chemical and biological treatment
pH	Less than 1.0	8.0–8.5	7.5–8.0
Acidity as $CaCO_3$ mg/l	6,750–12,000	nil	nil
DDT mg/l	10–40	Traces to 7.5	Traces
BOD (5 d, 20°C) mg/l	130–280	120–245	30–50

In a DDT formulation plant a 50 per cent wettable powder is made. China clay and surface-active agents are milled and mixed with the DDT. Three successive mills are used, the final one being an impingement-type air mill. Cyclone separation and a bag filter prevent dust losses.

The material balance for the production of 1 ton of technical DDT is (t): alcohol, 0.32; benzene, 0.84; chlorine, 0.77; and oleum, 1.32.

Labour force

There are 217 workers and a supervising staff of 21 in the factory. The minimum wage paid is Rs 302 a month. Out of this wage, 10 per cent is paid for housing compensation. All the workers receive uniforms and shoes from the factory.

On an average, the Hindustan Insecticide factories spend nearly Rs 500 per employee per year on staff welfare. The company arranges for periodic medical check-ups of employees. The investment for the first-aid medical centre was Rs 1.1 million. The company has set up recreation centres and co-operative stores.

The company spends Rs 20,232 yearly on staff training. Of the possible man-hours, loss due to illness and absence is 9 per cent.

Maintenance

If the lifetime of the factory complex at New Delhi is taken into account, maintenance can be considered good. Rs 38,000 is spent yearly on maintenance and new construction, and 191 persons work in this section.

Laboratories

There is a separate laboratory, with a total investment of Rs 7.2 million and a staff of 19. A great deal of attention is paid to research. The Hindustan Insecticides factories have contributed substantially to research projects at the National Chemical Laboratory at Poona and at the Regional Research Laboratory at Hyderabad.

Costs of production

Table 3 gives the costs of producing technical DDT and formulated DDT.

Table 3. Costs of production at Hindustan Insecticides (percentage)

Item	Production plant	Formulation plant
Raw materials	50	21
Imported DDT		44
Power	4	3
Steam	3	3
Salaries and allowances	20	14
Maintenance and repair	12	14
Depreciation	7	3
Factory overheads	2	2

Pollution control

A study was made recently of requirements for effluent treatment. The installation of a neutralization tank where limestone ($CaCO_3$) is used as a neutralizing agent and a clarifier to settle the gypsum has been recommended. The gypsum is to be disposed of by landfilling after it has been dried on an open-air drying bed. It was stated that the gypsum absorbed and enclosed the DDT particles during precipitation. A further biological treatment should reduce DDT content and BOD to low levels as shown in table 2.

The chemical treatment plant, which will cost Rs 920,000, is under construction. No decision has yet been made regarding the implementation of the biological treatment system, but there is a good chance of its realization.

It is not quite clear why the effective fibreglass/active carbon filter should be abandoned and replaced by coprecipitation and absorption in the precipitated gypsum. It is generally known that gypsum has no outstanding absorption qualities, and coprecipitation may be a hazardous operation.

As to gaseous discharges, mainly containing HCl, Cl_2 and types of vapours of organic compounds (alcohol, anthrylchloride, chloral etc.) a rather primitive washing tower system exists. This system contains two units of two rectangular towers made out of acid-resistant natural sandstone. The effluents from the towers pass a neutralising tank using lime and a settling tank before being discharged into the sewer. The investment cost of this treatment unit was approximately Rs 150,000.

Conclusions

Hindustan Insecticides is a relatively small factory, partly equipped with old production units. It is well managed and its products are good. Management is aware of the dangers of pollution. New equipment for pollution abatement, designed after a careful study had been carried out, is under construction. Spent sulphuric acid is recycled after appropriate treatment.

Ascu-Hickson Limited

Nagpur

Ascu-Hickson Limited, a privately owned company that produces wood preservatives, began its activities in India in 1904. The present units, however, are only about 25 years old. The factory comprises a mixing unit, where copper sulphate, sodium bichromate, arsenic trioxide and arsenic pentoxide are blended. The mixture, dissolved in water, is used for the impregnation of wood in a large cylindrical vessel. Such a treatment unit is included in the factory. An installation for sawing wood to prepare it for treatment is on the premises.

Attempts are being made to produce arsenic pentoxide from arsenic trioxide by oxidation with nitric acid 25 per cent in a batch process. Fumes from this process contain NO_2 and NO, which are absorbed in water and in a second absorber containing dilute caustic. The water solution is recycled. The exit stack of this unit showed no coloured discharges; no analyses of the stack gases have been made. The small production unit for this process is called a pilot plant.

There have been difficulties with this process in that up until now a crystalline reaction product has not been obtained. Only a hard, solid mass containing mother liquor in its pores has been obtained, which is used in the solutions for wood preserving in the plant itself. In formulations to be sold, this hard mass with entrained mother liquor cannot be used, and imported arsenic pentoxide is used instead.

Production

Total production is 550-600 t/a, of which about 50 tons are exported. The balance is used in about 200 wood-preservation plants in India. About 60 tons of arsenic pentoxide are used yearly, of which about 40 are imported. As mentioned before, this production is not entirely satisfactory, and attempts to produce a crystalline free-flowing product are being continued.

Most of the raw materials used in blending the final product can be used directly. Copper sulphate ($CuSO_4 \cdot 5H_2O$) has to be ground. A hammer mill fitted with a bag filter is used for this purpose. Some dust was evolved. The operator was protected only by a cloth covering his nose and mouth.

The blending equipment consists of rotating drums. The formulation contains one part of arsenic pentoxide, three parts of hydrated copper sulphate and four parts of sodium dichromate. The product is filled in small drums, and no precautions against dust are taken.

Maintenance is poor. The plant is not kept tidy, and a great deal of material spills on the floor. Apparently the floor is cleaned infrequently (once a month). The team found that in the room where arsenic trioxide is oxidized, relatively large amounts of this poison had been spilt on equipment and the floor. All the floor cleanings are flushed into a small, open sewer, which was said to be connected to the public sewer system.

The wood-treatment section, which has been in operation for three quarters of a year, comprises a horizontal pressure vessel about 20 m long. Impregnation is done with a 4-6 per cent solution of the preservative. The solution penetrates the wood through hydraulic pressure, and the time it takes depends on the type of wood and its use. After impregnation, the resulting liquid is pumped back and used for the next batches. Spilt liquid is dropped on the soil. Normally 0.25 lb/ft^3 of wood is used, but in special cases 1.25 lb/ft^3 has to be used, for example, for wood to be used in cooling towers.

Of production, 25 per cent is for cooling towers, 50 per cent for poles (electricity, telephones etc.) and 25 per cent for use in building houses and fences.

A wood-sawing unit has recently been built containing the usual types of saws. Safety and protection equipment has not been installed. A ventilation system with cyclones to remove sawdust is shortly to be installed, and the sawdust is to be used as fuel. The wood-drying unit is also recent. The wood is dried in cells using steam and hot air.

Economic data

Total investment costs are Rs 750,000, of which 60 per cent is for raw material and 2-3 per cent for maintenance. The factory employs 30 labourers. One person works in the laboratory and there is a works manager and a general manager.

Discharges

Yearly losses in production are said to be 5 per cent, worth Rs 50,000, which means that about 30 tons of a highly poisonous product escape to the environment (into the sewer and the soil). This factory is very untidy. Floors and machinery are covered with too many materials, and more than should be permitted in view of the highly poisonous nature of the raw materials and products.

The workers are not sufficiently protected against the poisons and wood saws. The physician, who besides running a general practice in the city also takes care of the factory employees, reported that five of the workers were allergic to arsenic compounds and that they were suffering from dermatitis. Two or three of the workers were suffering from chronic ulcers. In the team's opinion, a physician specialized in industrial health may find more signs of poisoning from Cu, Cr and As.

Recommendations

A thorough study of the factory as a whole, with special attention given to safety and pollution, should be made. New floors should be made seamless, and adequate washing facilities should be provided. Floor washings should be collected and correctly treated to remove copper, chromium and arsenic. Treatment processes should be under strict control, and effluents into the open sewers should not contain more than 3 ppm Cu, 2 ppm Cr and 1 ppm As (preferably less). Spillings into the soil should be completely prevented.

Equipment should be such that dust cannot be emitted (hammer mill, mixers etc.). The wood saws should be fitted with proper safety devices. Sawdust should be removed by a ventilation system.

To produce arsenic pentoxide, a highly poisonous product, the services of a consulting engineer are required. The facilities of such a small enterprise are not sufficiently large to carry out these investigations.

Management feels some uneasiness about what would happen with the preserved wood if, after many years of service, it should require replacement and have to be destroyed. The best solution would probably be incineration, but then the ashes would contain all the poisonous preservatives. This is a real problem, especially as the preserved wood is sold for use throughout a large geographical area. The use of organic preservatives such as pentachlorophenol could avoid the above-mentioned problems, since incineration does not produce poisonous ashes.

Fertilizer Corporation of India

Trombay, Bombay

The Fertiliser Corporation of India (FCI), which is state-owned, has many factories all over India. The Trombay factory, which is situated about 25 km from the centre of Bombay, came on stream in 1965, when a 350 t/d ammonia plant, built by Chemico, a company in the United States of America, started production. It was soon followed by a urea plant (300 t/d), a complex fertilizer plant (700 t/d), a sulphuric acid plant (200 t/d) and a nitric acid plant (320 t/d as 100 per cent). Annual output is (t): N, 81,000; P_2O_5, 36,000; K_2O, 30,000.

Plans for a phosphoric acid plant are being made, and reconstruction of the sulphuric acid plant originally built by Chemico is underway. Modern, low-pollution technology is being used.

Sulphuric acid plant

Sulphur is used as raw material. Design emissions are: SO_2, 0.2 vol per cent, and acid mist (H_2SO_4), 0.03-0.06 vol per cent, or 1,070-2,100 mg/m^3. Under normal conditions at full capacity, SO_2 is 0.13-0.14 per cent and acid mist 800-860 mg/m^3. Stack height is 17 m; total emissions are 2,700 kg/d of SO_2 and 700 kg/d of acid mist.

During the team's visit, the economizer used to recover waste heat broke down. To keep the plant on stream, the gas stream was being cooled by air quenching. As a result, the absorption tower was overloaded and huge clouds of acid mists were emitted. The emission was said to be about twice the normal amount, but no measurements were taken. The team doubted the validity of this statement. Shutting down the plant was apparently out of the question, as orders had to be met for other production schemes. The situation was expected to continue for several weeks, polluting the environment heavily.

The sulphuric acid plant is to be enlarged so that its capacity will be 300 t/d. A turbulence filter is to be added where acid mist is precipitated by impingement on glass balls and where the mist is collected as sulphuric acid. Pressure drop is to be about 250 mg/m^3. Moreover, the sulphuric acid plant itself is going to be rebuilt using the Bayer process of double catalyst/double absorption. Discharges should be 250 ppm SO_2, or 1,000 kg SO_2/d plus 40 kg/d of acid mist. Sulphuric acid yields are high, and the subsequent higher acid production will pay off extra costs in two to three years.

Phosphoric acid plant

A phosphoric acid plant designed by Nissan, Japan, using the hemihydrate/dihydrate principle, is now under construction, and capacity is anticipated to be 100 P_2O_5 t/d. Phosphoric acid having a concentration of 28-30 per cent P_2O_5 is produced. This product is subsequently concentrated to 50 per cent P_2O_5. Fluorine is emitted during the reaction between phosphate rock and sulphuric acid and while the acid is being concentrated. Fluorine compounds are washed with water, and a 25 per cent solution of H_2SiF_6 is recovered. This solution can be used for the production of aluminium fluoride or other fluoride products. Such production is under consideration, which the team strongly encouraged, especially since it can be economically self-supporting. Gaseous effluents are about 100,000 Nm^3/hour. The total fluorine emission should be 9 kg/d (4-4.5 ppm); stack height is 36 m. Ground level concentration (glc) is expected to be 0.07-0.1 ppm. Solid waste is gypsum. The Nissan process gives rise to waste gypsum of high purity. Both F and P_2O_5 content are low, and the product can be used without further treatment for the production of construction materials/gypsum panels and blocks for building inner walls. Eventually the waste gypsum could be used for the simultaneous production of sulphuric acid and cement, but this process is only economically feasible under certain conditions.

Ammonia plant

The ammonia plant, which was built by Chemico, produces 350 t/d using reciprocal compressors. It is a naphtha partial oxidation plant using 760 kg of naphtha per ton of ammonia. Carbon dioxide of the naphtha processing is used in the urea plant. As a by-product of the partial oxidation, 6-7 tons of carbon black are produced daily. No particles of soot are emitted. Wash water contains carbon black, and treatment with kerosene produces a carbon black suspension from which kerosene is distilled and recycled. Apparently there are no hydrocarbon emissions.

Nitric acid plants

Two nitric acid plants each produce 60 per cent acid at a rate of 160 t/d of HNO_3 (as 100 per cent). The plants are identical and are of the high-pressure oxidation and absorption type. They were designed by Chemico in 1965.

Emission control

Gaseous discharges of NO_x are reheated to 485°C, mixed with tail gas of the ammonia plant (co-purification unit) and combusted using a catalyst. Tail gas contains 40 per cent CO, 6 per cent H_2 and 6 per cent CH_4; oxidation products are CO_2 and N_2. Discharge gases are 34,000 m^3/h from each unit; concentration is below 0.05 per cent NO (by volume); the discharge is not coloured. Stack height is 25 m. A NEERI report (1971/72) stated that the denitrification unit did not work properly, but from what the team could see, no coloured fumes were emitted from the stack. The unit apparently now works well.

NPK production unit

The treatment of phosphate rock with nitric acid is the basis of the NPK production unit. Several types of rock phosphate are used as raw materials. Apart from the local Udaipur rock (36 per cent P_2O_5), which is available only in a limited quantity, Morocco, Jordan, Florida and Naura phosphates are used. Nitric acid and some sulphuric acid are used as well as ammonium phosphate. Ammonia is used to neutralize the acid solution after digestion of the rock. Potassium is added as potassium chloride.

Seventeen U-shaped reactors are placed in series. Nitric acid, sulphuric acid, phosphate rock, ammonia, ammonium-phosphate and potassium salts are added in an appropriate sequence into the row of reactors. The resulting slurry is heated, dried and granulated in a spherodizer. This is a rotating drum of large diameter into which a return stream of undersize and (broken) oversize of granules is recycled. A sieving system, a cooler and a powdering drum complete the installation. Excess ammonia is scrubbed with acid and recycled to the reactors. No ammonia losses are recorded.

Discharges

Fumes from the nitric acid treatment contain fluorine compounds, nitrogen oxides and SO_2. These exit gases are washed in a scrubber system containing three scrubbers in series.

FCI calculates that 15-20 kg/d of F are discharged into the atmosphere. The liquid discharges of the scrubbers are discharged into the sewage system and ultimately end up in the sea. The liquid effluents are not treated.

Gaseous discharges from the spherodizer contain dust, F and SO_2 (the latter from fuel oil combustion to 10 t/a). A cyclone system separates part of the dust; further "dedusting" by a bag filter is not appropriate owing to the hygroscopic nature of the products that contain up to 50 per cent of ammonium nitrate. The exhaust contains 0.6 t/d of SO_2. The content of mixed oxides of nitrogen is 0.95 mg/l.

NEERI investigated some of the gaseous discharges of FCI in 1971/72. According to the report, the NPK plant emits a gaseous discharge of 30.4 kg/d of F. The F content of the gases is

1.2 mg/l before and 0.2 mg/l after the scrubbers. Consequently, the discharge of F into the wash water amounts to 177 kg/d. These effluents are discharged into the sewer system, which discharges into the Thana Creek.

Also reported is a total emission from FCI of:

	Tons per day
SO_2	3.6
Acid mist	1.1
NO_x	0.5
Dust	0.1

The main products of the NPK plant are 15:15:15, 20:20:10, 18:18:9. (These numbers are percentages of the nutrients nitrogen, phosphorus, and potassium respectively and calculated on the bases of percentages by weight of N_2, P_2O_5 and K_2O.) At present, production is 200,000 t/a of NPK, and an expansion of capacity to 300,000 t/a is being planned.

The plant, especially the part where the phosphate rock is digested, looks rather untidy, with much dust everywhere and spilt hygroscopic material. This material may be the cause of the excessive corrosion.

Boiler house

There are three Babbock boilers and one Thompson. Total fuel consumption is 60 t/d containing 3 per cent S. Emission of SO_2 is, therefore, 3.6 t/d. Also emitted is 0.5 t/d NO_x.

Labour

The minimum wage is Rs 193.50 per month, made up as follows:

Basic wage	70
Living allowance	116
City compensation allowance	7.50
	193.50

The company also pays Rs 150.60 a month in fringe benefits:

Pension contribution	14.88
Annual leave	59.90
Gratuity	2.90
Uniform	9.92
Medical and health services	24.10
Canteen subsidy	4.00
Leave travel concession	2.00
Recreation activities	0.40
Family pension	23.30
Incentive scheme production bonus	9.20
	150.60

Medical aid is available to employees at the company's hospital. The total expenditure on medical facilities in 1974 was Rs 1.30 million. A "fair price shop" and a consumer's co-operative have been opened. A sport club with swimming pool facilities has been organized. Cultural and social activities are encouraged.

Special attention is paid to the training of personnel at all levels. A special training institute has been created to give, for example, development courses for all categories of employees. This training department offers training facilities not only to the other units of the corporation, but also to educational institutions and other chemical factories. The total expenditure on training in 1974 was Rs 1.80 million.

Workshop

In the central workshop, employing 133 workers, a great deal of construction work is done. One of the reasons for having a workshop is that delivery from the construction firms is very irregular, with long delays caused mainly by the scarcity of raw materials. Most of the plants have additional small workshops.

Laboratories

The company has laboratories for production control but none for pollution control. The total investment in the laboratories is Rs 600,000, total wages, Rs 400 million.

The annual consumption (tons) of fuels and raw materials is: refinery gas, 25,000; fuel oil, 30,000; petroleum naphtha, 120,000. The factory consumes 4-6 million gal/d of water.

Summary and recommendations

The previously mentioned NEERI report gives a summary of gaseous discharges in 1971/72, as shown in table 4.

Table 4. Gaseous discharges at FCI plants at Trombay in 1971/72

Discharge	SO_2	Dust	NO_x	NH_3	Acid mist	Fluorides as F
Sulphuric acid	2.64	-	-	-	0.75	-
Nitric acid	-	-	4.12	-	-	-
Ammonia	3.26	-	-	-	-	-
NPK	0.6	?	?	-	-	-
Methanol	0.95	-	-	-	-	-
Urea	-	4.8	-	3.94	-	-
Boiler house	3.56	0.1	0.5	-	-	-

The FCI plants at Trombay, with the exception of the NPK plant, are well maintained. The management is aware of pollution, and new extensions are under way where technologies may be able to guarantee low discharge levels. Denitrification equipment on the nitric acid units is proof of management's concern.

It is recommended that the reprocessing of fluorine from the discharges be carefully considered, since it appears to be economically feasible.

No bad effects on health have been reported, even though some of the units are not well maintained. Some kind of bad effects could be expected.

On the other side of the hill near the plants and the residential area, a nuclear power station is in operation. The nearness of this power plant to a chemical complex may cause complications from interaction of discharges. This possibility should be investigated.

National Organic Chemical Industries Limited

Thana Belapur, near Bombay

About one third of the shares in the National Organic Chemical Industries (NOCIL) is held by the Government, one third by the Shell Company and the remainder by private Indian citizens. Shell provided NOCIL with know-how on the processes, on anti-pollution measures and on management procedures.

The factory produces ethylene, ethylene glycol and chlorinated products, of which vinyl chloride and polyvinyl chloride (PVC) are the most important. It uses naphtha, delivered from a Burmah Shell refinery at Trombay, 32 km away, as a raw material. It also produces organic solvents (acetone, isopropyl alcohol and others), alcohols, benzene and butadiene. The factory also has an air-liquefaction unit producing oxygen.

The factory came on stream in 1968. It is situated in the Thana Creek industrial area north-east of Bombay. Total capital costs were Rs 550 million. Since 1971, the company has made a profit, and for the last two years the profits have been reinvested.

About 5,000 Indian industries use NOCIL products as raw materials or intermediates.

Production

The initial step in production is to distil naphtha, of which 225,000 tons are used yearly. The naphtha contains about 10 per cent aromatics. Production is (t/a): ethylene, 60,000; propylene, 35,000; benzene, 14,000; butadiene, 7,200; and liquid fuel, 55,000. The plant also produces 6,500 t/a of oxygen.

The products that are imported most are vinyl chloride and PVC, since only 3,000 and 16,500 t/a are produced, respectively. Chlorine is purchased from Standard Chemicals Limited, which is located nearby.

The process used is chlorination of ethylene to ethylene dichloride. Through further treatment this compound is decomposed into vinyl chloride and hydrochloric acid. The Shell vinyl chloride process is used for this step. The hydrochloric acid is dissolved in water and returned to Standard Chemicals. No gaseous discharges containing HCl exist. Part of the vinyl chloride is sold as such; the greater part is processed into PVC and PVC compounds.

The vinyl chloride plant is an open-air plant, well laid out. Vinyl chloride levels were measured to be 50 ppm by volume. Management hopes to bring the level down shortly to that of no detectable traces.

The factory also produces solvents based on propylene. The main products are isopropyl alcohol (2,000 t/a) made by hydroxylation and acetone (7,000 t/a) made by oxidising propyl alcohol. Another important product is 2-ethylhexanol (10,000 t/a) made by a polymerisation reaction. Shell processes are used.

Storage

Propylene is stored under pressure in a Horton Sphere. Butadiene is stored in a cold tank at +10°C. Other volatile products are stored either in floating roof tanks or under nitrogen blankets. The storage processes are apparently efficient, since no hydrocarbons have ever been detected in the input air stream to the air-liquefaction plant.

Maintenance

The factory is very well maintained. The maintenance section employs 146 workers. The annual operating expenditure on maintenance is Rs 1,510,000. The cleaning of the vinyl chloride reactor section is discussed under "discharges".

Labour

The plant employs 748 persons, of which 302 work in the head office and in sales and distribution centres.

The minimum monthly wage is divided as follows:

	Rs
Basic wage	150
Cost of living allowance	241
Other allowances (rent, food, insurance, bonus etc.)	244

In 1973, approximately 4 per cent of possible man-hours was lost owing to illness and absence, which corresponds to a loss of Rs 50 million.

Management has devoted a great deal of attention to the training of workers. Before the plant started, management made great efforts to train workers in the various phases of operation, maintenance and administration of the plant to ensure a smooth start and efficient running. Many staff members were sent abroad to be trained in the various aspects of operations and to work in plants similar to the NOCIL plants. After returning from abroad, they in turn instructed other staff in the detailed aspects of operation and maintenance based on their newly acquired knowledge. Training consisted of instruction in theory and many hours of practical work in the plants under construction until all workers were fully acquainted with the many intricate details of the design and operation. As a result of this training, practically all workers are skilled.

After operation began, the training of employees continued, and a permanent training centre was established within the plant. NOCIL established a technical training centre outside the plant to train villagers. In 1973, the total training costs amounted to Rs 332,000.

A scheme for the economic and social development of three villages in the neighbourhood has been developed in association with Polyolefins Industries Limited and Standard Alkali.

Discharges

The plant discharges:

(a) Highly chlorinated products such as tetrachloroethylene and chlorinated polymers. These wastes, which are mainly liquid, are disposed of in a landfilling area, with government consent. The groundwater in this area is brackish and cannot be used for human consumption;

(b) Solid wastes from the solvents and alcohol plants, which are highly polymerised products from side reactions. These wastes are incinerated.

Three separate sewer systems exist:

(a). For rain water, which goes direct to the Thana Creek. Cooling water is also discharged through this sewer;

(b) For chemical discharges apart from those previously mentioned. Those that are acid are neutralised with limestone before being discharged;

(c) For discharges containing oil. These discharges pass a separation plant with plate interceptors and where part of the oil is separated. It is used as fuel.

The effluents from (b) and (c) pass through a pond and are then discharged into the Thana Creek, together with the effluent from (a).

In all, 250 m^3/h is discharged containing less than 1.5 mg/l of oily substance and less than 200 mg/l of suspended matter. BOD is less than 75 mg/l and COD less than 200-300 mg/l.

An emergency discharge for HCl effluent (in case the absorption unit fails) consists of a lime pit where the effluent is neutralized. This unit has hardly been used. A small lake with a rocky bottom serves as an emergency outlet. This lake cannot discharge into the sea. A pipeline is used to fill and empty the lake.

According to data obtained from the Ministry of Industrial Development, 6 million cubic metres of gaseous effluents containing CO_2, water vapour etc., are discharged daily. No noxious discharges have been reported.

NOCIL is a well-organized factory, and pollution control more than meets government requirements. However, the Thana Creek is highly polluted. The tide is not strong enough to cleanse the creek of the discharges of the many industries along its banks. The government considered building a sewer system to bring effluents from industries to a point near the open sea. However, since investment costs were high, the plan was never implemented. Losses in fishery were considered to be lower.

The many power cuts stop plant operations and thus increase costs. For example, in six months there are 20 power failures.

Health

The physician in charge of the medical department is the president of the Indian Society of Occupational Health. (He obtained his industrial health training at the London School of

Hygiene.) He is well aware of the possible effects on health of such an industrial complex. No health problems from working on the vinyl chloride and PVC production lines have been noticed. This may be because the cleaning of the reactors has been carried out by an outside contractor with a high turnover in personnel. These workers are not medically supervised by NOCIL.

There are several villages near NOCIL. NOCIL provides material and know-how to build sanitary outhouses and supply drinking water. In this way sanitation and health conditions are improved.

Laboratories

Investment in the laboratories as of December 1973 was Rs 381,500. The laboratory staff consists of 31 persons. The total operating expenditure in 1973 was Rs 856,000.

Herdillia Chemicals Limited

Thana-Belapur, near Bombay

Herdillia Chemicals is a private enterprise, a joint venture of British Petroleum Chemicals, formerly Distillers Chemicals, (United Kingdom), Hercules Incorporated (United States of America) and EID-Parry Limited (India). The 300-acre factory site is on the Thana Creek. Herdillia produces phenol, acetone, diacetone alcohol, phthalic anhydride. Raw materials used are benzene, propylene, o-xylene and alcohols.

The total costs of the enterprise were estimated at Rs 106 million in 1964. However, the final figure was Rs 140 million.

The investment in the various plants is as follows:

	Thousand rupees
Phenol plant	77,842
Diacetone alcohol plant	5,729
Phthalic anhydride plant	32,837
Dioctyl phthalate plant	10,772

Annual production is as follows: cumene, 14,500 litres which is further processed into phenol (10,000 litres), and acetone (6,000 litres); phthalic anhydride, 6,000 litres, part of which yields 3,000 litres of phthalic esters; diacetone alcohol, 2,000 litres.

Water consumption is 2,800 m^3/d. Production of steam of 30 atm is 25 t/d. Installed electric capacity is 4,000 kWA.

The company employs 300 workers.

Phenol unit

Benzene and propylene are purchased from the neighbouring company NOCIL. These two products are reacted to form cumene, $C_6H_5CH(CH_3)_2$ in a plant designed by Lumnus in 1967. Daily input is 49 tons of benzene and 28 tons of propylene; yield is 65 tons of cumene. All cumene produced is processed further to make phenol and acetone.

Discharges

The plant is built in the open air and the layout is modern.

There are few, if any, noxious gaseous effluents. According to data obtained from the Ministry of Industrial Development, 1.11 million m^3/d of gaseous effluents are emitted (as calculated), but no data about pollutants have been produced. There are phenol-containing liquid effluents totalling 180,000 imp gal/d = 550 m^3/d containing 200 lb = 90 kg of phenol. No acetone is contained in the discharges of the phenol plant.

All the wash and spent cooling waters are mixed in an open concrete basin and then pumped to a gravity oil-skimmer, where most of the oily substances are separated. The oily products are sold. Waste water then enters a basin (120 ft x 40 ft x 8 ft) having a holding time of 24 hours. Apparently nothing happens in this basin, since no aeration facilities are present. It is planned to add aeration equipment if the destruction of phenol wastes is required by the authorities. Whether the dimensions of the concrete basin are large enough for successful treatment should be thoroughly investigated.

From two holding tanks, which together have the same capacity as the basin, the wastes are pumped into the creek through a 5-km pipeline. Discharge is permitted only at high tide.

Discharge of phenol is 200 lb/d; discharges of 350 lb/d is permitted. Furthermore, the waste water contains sodium sulphate and small amounts of organic material. An investigation carried out by Distillers Chemicals gave the results listed in table 5. Manganese, a poisonous substance, is present as an inorganic pollutant.

Phthalic anhydride unit

The plant oxides o-xylene. The layout is such that naphthalene can be used as a raw material, but at present this product is not available to Herdillia. Input is 23 t/d of o-xylene; production is 18 t/d of phthalic anhydride, part of which is esterified to produce 18 t/d of dioctyl phthalate. By-products are maleic anhydride and non-identified organic wastes, which are either incinerated or sold.

Maintenance

A separate section for maintenance employs 111 workers. The total expenditure on maintenance is Rs 2,180,000.

Laboratories

Thirty-eight persons work in the laboratories. Investment in the laboratories amounts to Rs 771,000. The operating cost is Rs 603,000.

Table 5. Discharges of Herdillia Chemicals plants

(a) Discharges from phenol plant

Constituents	Pounds per hour	Pounds in 12 hours
Cumene	4.8	57.6
Cumene hydroperoxide	13.7	164.4
Phenol	21.5	258.0
Acetone	7.4	88.8
Mesityl oxide	Trace	
Sodium phenate	4.7	56.4
Sodium carbonate	12.8	153.6
Sodium sulphate	22.6	271.2
Sodium peroxide	8.8	105.6
Acidic material	31.6	397.2

(b) Discharges from other processes

Constituents	Pounds in 12 hours
Cumene	
Caustic soda	30
Sulphur	1.2
Phthalates	
Sulphuric acid	100
Benzene sulphonic acid	33
Soda ash	356
Caustic soda	105
Potassium permanganate	126
Sodium bisulphate	147
(plus traces of manganese compounds)	

Source: Distillers Chemicals (now British Petroleum Chemicals).

Indian Dyestuffs Industries Limited

Kalyan, Bombay

Indian Dyestuffs Industries Limited, a privately owned company, belongs to the Mafatlal Group but collaborates on technical matters with the Indian Montedison Group. Production started in 1956 in Kalyan, which is north of Bombay. Originally only a few vat dyes were produced, but now some 80 dyestuffs and several intermediates, such as aluminium chloride, anthraquinone, sodium hydrosulphite and sulphuric acid (including oleum) are produced.

Labour

The company employs 1,800 persons, of whom 700 work in production and finishing; 500 in maintenance and utilities; 250 in research and development; and 550 in administration, security etc. The average age is 38 years. Only six women are employed. Most of the personnel have been trained by the company. Annual expenditure for training, including classroom training, is Rs 50,000.

Production

Table 6 shows production in 1973/74 and annual capacity.

Table 6. Production in 1973/74 and annual capacity of Indian Dyestuff Industries

(Tons)

Product		Production in 1973/74	Annual capacity
Dyes		850	1,170
Vat	660		
Disperse	70		
Fibre reactive	120		
Aluminium chloride		9,000	10,000
Sodium hydrosulphate		3,000	3,000
Sulphuric acid and oleum		165,000	198,000

Production is carried out in batches, and most of the equipment is used for several products.

The team discussed and observed the production of aluminium chloride, sulphuric acid, anthraquinone and some of its derivatives and a vat dye of the indanthroene type (Navinon blue RSN), a disperse dye Navicet Brilliant Yellow 'G. At the end, the disposal of wastes was discussed.

Aluminium chloride

Aluminium chloride is produced by a continuous process carried out in brick-lined furnaces in which aluminium metal is melted by a gas fire. The furnace lining has a lifetime of about 15-18 months, after which is must be fitted with a new brick lining.

As soon as the metal is in a liquid form, chlorine gas is introduced and a vigorous reaction takes place, evolving enough heat to melt the continuously added aluminium. $AlCl_3$ sublimates and is condensed in a water-cooled condenser, where it solidifies in the form of a white crusty material. There is a slight excess of chlorine, which is absorbed in a sodium sulphate solution. Ten kg of this product are used in the production of one ton of $AlCl_3$. Apparently, chlorine absorption is complete, but some SO_2 may be evolved in the absorption reaction. Neither chlorine nor SO_2 is analysed in the discharge gas. The spent sodium sulphate solution goes to the sewer without any treatment or analysis.

The crusty material is ground and sieved and then stored in tightly closed metal containers, since $AlCl_3$ is very hygroscopic. However, the team found the mill and the sieves open to the air. Owing to the hygroscopicity of $AlCl_3$, the sieves are wet, dirty and corroded. Fumes of HCl (evolved in the reaction: $AlCl_3 + 3H_2O \rightarrow Al(OH)_3 + 3HCl$) filled the milling room. Since the $AlCl_3$ unit was well kept and clean, the team could not understand why the milling and sieving had not been done in closed and dry equipment.

Sulphuric acid

The plant produces H_2SO_4 of 20 per cent and 60 per cent strength. This is a 15 t/d plant designed by Chemiebau in 1960, based on sulphur. It is a single contact/single absorption type of plant. Although no data were available, it is likely that with a sulphur yield of 97 per cent, daily emission of SO_2 into the air may be 300 kg.

Anthraquinone and 2-amino anthraquinone

Anthraquinone is produced out of phthalic anhydride and benzene using aluminium chloride as a catalyst. The plant produces 2,400 t/a, part of which is sold.

The reaction yields as a waste aluminium salts that are removed with the waste water used in purifying the reaction product. Small amounts of unreacted phthalic anhydride and of anthraquinone will be present in the waste water, which is discharged without treatment or analysis.

A two-step batch reaction from anthraquinone is used in the production of 350 t/a of 2-amino anthraquinone. In the first step anthraquinone is treated with oleum to yield anthraquinone-sulphonic acid and its sodium salt. In this reaction, several spent products are formed, such as sodium sulphate, some sulphuric acid and organic materials from side reactions. All spent liquids are discharged without any treatment except some partial neutralisation.

In the second step, the silver salt is reacted with 25 per cent ammonia solution at 200°C and at 35 atm. At the end of the reaction the excess ammonia is discharged and absorbed in water. Some NH_3 may be lost, but no analyses are made. The reaction product is washed; the wash water contains sodium sulphate, some ammonium sulphate and organic materials. The wash water is discharged without treatment. The yield of pure 2-amino anthraquinone amounts to 350 t/a.

Vat dye (Navinon Blue RSN)

Navinon Blue RSN is made out of 2-amino anthraquinone by fusion with alkali and sodium chlorate at a high temperature using gas as a heating medium. There are many side reactions and consequently much waste material. The uncoloured reaction product is purified with sodium hydrosulphate and crystallized. Again, this procedure gives rise to much organic and inorganic waste. Finally, the purified reaction product is oxidized in acid solution with air. The final dyestuff is washed, dried and pulverized. In 1973/74, production was 168 tons. Wash waters contain acids, salts and organic materials.

Boiler house

The boiler house uses 29 tons of fuel oil (sulphur content of approximately 2.5-3 per cent) per day. This means an SO_2 discharge into the air of about 1.6 t/d.

Maintenance

Maintenance costs are 9 per cent of the turnover, which in 1973/74 was valued at Rs 165 million.

Laboratories

The investment cost of the laboratories was Rs 2,002,000. The operating costs of the laboratories, in which 250 persons work, are Rs 12,000, which includes research and development.

Discharges

Most of the batch equipment - several hundreds of vessels, filter presses, tanks etc. in all - have vents to the open air. There is no precise information as to gaseous discharges from these vessels. As for the continuous equipment, only the aluminium chloride unit has a washing device to prevent escape of excess chlorine. Gaseous discharges should be carefully studied and analysed.

All liquid discharges pass at a rate of 28,000 m^3 per 24 hours from the factory buildings through a sewer system to an open tank. According to company officials, the effluents do not contain great amounts of dyestuffs because these products are highly insoluble. However, very large quantities of highly coloured by-products from side reactions are present. Most of the discharges are acidic. In the open tank some neutralization takes place, but there is no systematic treatment. The BOD is said to be 80-120 mg/l and the COD is estimated at 150-200 mg/l. Analyses are made by a laboratory in Bombay about twice a month. The highly coloured effluents are discharged direct into the nearby river. No plans have been made to remove the coloured materials.

The Central Labour Institute in Bombay provided the following analysis:

pH	1.1-4.3	
Acidity	130-1,500	mg/l
BOD	85-300	mg/l
COD	150-955	mg/l
Total developed solids (TDS)	1,300-7,000	mg/l
Total suspended solids (TSS)	25-200	mg/l
Sulphates	25-200	mg/l
Chlorides	20-2,480	mg/l
Phenol	0.8-8	mg/l
Copper	0.5	mg/l
Dissolved oxygen	2-4	mg/l

The Government requested that an investigation be made on effluent treatment, specifically, neutralisation. Consultants are studying the problem. A neutralisation plant will cost approximately Rs 7 million. According to company officials, the water in the river has a neutral pH about 1 mile from the discharge point.

Discharges and health

All spent liquids are discharged into the sewer without treatment. Floor washings are added to these wash waters from processing. As a result of the poor production techniques in the batch process, all kinds of fluids are spilt, leaving the floors and equipment wet.

Workers are constantly in contact with the products, especially because the equipment (including filter presses) is loaded and unloaded by hand. The medical director reported that about 300-400 workers suffered from dermatitis (allergy), owing to exposure to chemicals, and about 150-200 from anaemia. He also mentioned that the rainy season brought a high number of infections of the intestinal tract and the winter season many cases of bronchitis and other infections of the respiratory tract. He requested information and assistance in treating allergies.

Recommendations

A thorough investigation of batch processes should be made, preferably with the assistance of a consulting firm, in order to modernise these processes. Ways of minimizing the liquid discharges should be studied.

III. CASE STUDIES - CALCUTTA AREA

East India Pharmaceutical Works Limited

Calcutta

The East India Pharmaceutical Works is a privately owned enterprise consisting of two factories situated within a few miles of each other. The first factory produces mainly finished pharmaceuticals and some vegetable extracts. The second factory, with which the team concerned itself, produces chemicals.

Both factories together employ about 2,000 workers. The chemical factory employs 150 persons working in two shifts.

Production

The important products are:

(a) Rhenia, a 2-phenyl quinoline 4-carboxylic acid, synthesized from indigo imported from Europe. About five tons per month are produced by a batch process in two steps. First, indigo is oxidised to isatin and the latter is reacted with acetophenone. Acidic effluents, highly loaded with organic materials from side reactions, are discharged into a pond;

(b) A sulpha drug made by acetylation of sulphamide. One ton per month is produced. Only a small amount of effluents is produced;

(c) Enteroquinol, which is a chloro-iodo-hydroxyquinoline. Production is about 100 t/a. It is synthesized in a five-step reaction scheme from phenol. All steps are batch processes. Reactions include chlorination, nitration with nitric acid, reduction with iron and hydrochloric acid, condensation with sulphuric acid and glycol and finally iodination. All steps produce large amounts of spent liquors containing acids, iron salts, organic materials from side reactions and wash waters.

Discharges

The nature of the discharges has never been investigated. All liquid effluents from the various processes are discharged into a pond near the factory, a few of them after partial neutralization with limestone. This pond is in the immediate neighbourhood of a residential area. It has no outlet, and the products penetrate into the soil; part of the water evaporates. The pond is very dirty and has a putrid smell.

The factory is untidy and effluents spilt all over the floors have not been wiped up. Since the factory employs many scientists familiar with the effects of pharmaceuticals, it is astonishing that environmental conditions are so bad.

In about two years the factory must leave its present site; a new factory is to be built at Durgapur, 150 km north of Calcutta.

Recommendations

A thorough survey of all chemical activities should be made, giving ample attention to discharge problems.

To improve the present factory, most of the equipment would have to be rebuilt. When the factory at Durgapur is constructed, modern technology should be used. Consultants should be engaged to make plans for a well-equipped modern factory that would have only minor pollution problems.

The Alkali and Chemical Corporation of India

Rishra

The Alkali and Chemical Corporation of India (ACCI) was formerly part of Imperial Chemical Industries (United Kingdom), and it still maintains close relations with ICI with respect to technical experience and know-how. ACCI has another factory at Hyderabad.

The factory at Rishra began operations, in 1940, with the production of chlorine and caustic soda. From 1949-1952, hydrochloric acid, benzene hexachloride and paints were added to the production programme. In 1959, polyethylene production started; and, in 1963, the factory began producing rubber chemicals using diaphragm cells of ICI design. Total investment costs were Rs 250 million. In 1972/73, turnover was Rs 310 million.

Of the many production units, the team discussed and visited the chlor-alkali plant, the benzene hexachloride (BHC) plant, the paint section and the polyethylene unit.

Chlorine and caustic soda

The production of chlorine and caustic soda uses diaphragm cells of ICI design. Production is 21 t/d of Cl_2, 47 t/d of caustic soda of 48 per cent and 6,700 m^3/d of hydrogen. Chlorine is used for BHC production (13 t/d) and for hydrochloric acid (16 t/d of Cl_2). The balance is liquified and sold. Caustic soda is sold as a 48 per cent liquid; only 5 per cent is used in the factory. Hydrogen is used for HCl production and for making nitrogen out of air by using the oxygen to burn the H_2. The remaining hydrogen is sold after drying and removal of oxygen traces.

The electrolysis plant works well, the only problem being the frequent power breakdowns. Even though there is a stand-by power unit, power failure causes many difficulties.

There is an emergency let-out for chlorine when cooling in the chlorine liquefaction is discontinued. The excess of chlorine is then absorbed in lime. As no cooling is available, mainly calcium chloride is formed. This solution is discharged through a canal to the Ganges.

The chlor-alkali plant is well kept. Hardly any chlorine odour can be detected in the cell house. In the evaporation of NaOH, there is no contamination apart from floor sweepings. The cell house contains 11 groups of 78 cells. Each group consumes 920 A. Average capacity is 2.9 MW. Rectifying equipment is based on silicon and germanium rectifiers. Each cell has an asbestos diaphragm of three layers of asbestos paper. Cells are made out of mild steel. Carbon rods are used as cathodes.

Hydrochloric acid

The production of hydrochloric acid gives no pollutants. Absorption removes potential gaseous effluents. The preparation of the brine includes precipitation of sulphate by barium chloride, soda ash for magnesium salt and calcium. Starch is added for flocculation. The total amount of barium chloride used is less than 1 t/a.

Sludges from purification are separated in a clarifier and finally discharged into the river. About 100 kg of dry product is discharged per week.

Benzene hexachloride

Benzene and chlorine are the raw materials used in benzene hexachloride production. Ultra violet rays are necessary to maintain the reaction, which is carried out in lead-lined reactors.

There is no danger of injury by ultra-violet rays, since the reactors are tightly closed.

When 8 per cent of the benzene has reacted, the liquid passes to a still, where the benzene is distilled off and is recycled to the reactor. At the bottom of the still, BHC is collected. It is then granulated in hot water, filtered and dried in a rotary drier using 140 m^3/min of air. The air passes through a large filter. The discharged air contains about 50 ppm of benzene. Stack height is only 20 ft above ground level.

The layout of this plant is good, with one exception: the product is conveyed from filter to drier manually and is usually spilt along the way. This causes corrosion, and workers' hands and skin come into contact with BHC. The transfer could easily be mechanised.

Paints

The paint factory is essentially a formulation plant where pigments (purchased from elsewhere) are blended, milled and packed. Some of the intermediates, such as alkyd resins, are made using batch processes. Alkyd resins are made out of phthalic anhydride and glycerol or pentaerythritol. These processes do not create pollution or by-products.

Total discharges of this plant amount to about 100 gal/week (450 l). These discharges are incinerated. The ashes are disposed of in a landfilling area.

Polyethylene

Polyethylene is produced at 1,500 atm and 250°C using a two-step piston-compressor system for compression. Organic peroxides are used as catalysts. The excess ethylene is recycled. Production is 13,500 t/a. By-products are butylene, propylene, ether etc., totalling about 1 per cent of the input. These by-products are used as fuel to heat reaction furnaces.

Boiler house

The boiler house contains six small, coal-fired boilers, (stack 35 m high) using 22,000 t/a of coal (25 per cent ashes, no sulphur content mentioned) and one oil-fired boiler (stack 12 m high) using 2,400 t/a of oil (3 per cent sulphur content).

The emissions of SO_2 and particulates have never been measured. Cinders of the coal fires are sold.

Labour

The plant employs 2,000 workers, of which 1,100 are in the production units, 350 in maintenance, 180 in the laboratory and about 100 in management. The average age is about 35. Minimum wages are Rs 318 per month, with an additional 20 per cent in extras. The average wage is Rs 700 + 20 per cent per month. Forty-five per cent of the employees live in a residential area owned by the company. The colony maintains several facilities for cultural activities (including drama, dances, theatre, sports and schools).

Health

The medical department of the factory has not observed harmful effects on health.

Sewer systems and discharges

Human sewage from the colony passes through septic tanks and a clarifier and is then discharged, together with the factory's effluents, into a canal that discharges into the Hooghly River (Ganges). Chlorine discharges via emergency lime pots amount to 6 t/month of Cl_2.

BHC losses are estimated to be 20-30 kg/d. Some BHC goes into the sewer. Some of it is separated in a catch basin and goes to a landfilling area. Waste waters from the BHC plant contain 0.007 per cent benzene in 10,000 gal/h (45 m^3). Polyethylene production gives some process water containing oily substances, which are separated before the water is discharged into the sewer.

In the BHC unit, 5-15 ppm of benzene in the air was measured. The chlorine in the cell house is not measured, but is said to be very low.

Conclusions

ACCI is a well-maintained plant. Management is aware of pollution problems. The only recommendation is that the conveyance system in the BHC plant be modernized. Mechanization can reduce spilling and untidiness.

Hindustan Lever Limited

Shamnagar, Calcutta

Two factories of Hindustan Lever are located in the Calcutta area, one producing soap and detergents and the other hardened fats. The team visited the latter factory. Serious labour troubles in the soap factory made a visit there inadvisable.

The rather old fat-hardening factory was taken over by Hindustan Lever in 1952. Hindustan Lever is owned partly by Unilever and partly by a private Indian enterprise. The equipment is modern and Unilever know-how is used. The general manager worked for many years with Unilever in Europe.

The factory consists of a hydrogen production unit based on the electrolysis of a dilute solution of caustic soda. Apart from hydrogen, oxygen is formed. The hydrogen is used for hardening several types of vegetable oils, such as linseed oil, groundnut oil, castor oil and rice bran oil. Hardened oils and by-products are used in the manufacture of soaps and edible fats, including margarine.

Total investment costs for the two factories have a net book value of Rs 265 million (December 1973). Separate data for the fat-hardening factory could not be obtained.

Hydrogen plant

The hydrogen plant comprises the following cells:

Quantity	Type	Cell capacity (m^3/h)
48	Knowles (old)	0.5
36	Vasant	1.0
2	Bamag (new)	7.0

The cells contain a sodium hydroxide solution that is continuously regenerated in the process itself. Decomposed water is supplied by a feed of demineralized water.

Total production is 74 m^3/h of hydrogen. Total power consumption is about 1,200 kW. Mercury arc rectifiers supply direct current. As a by-product, 37 m^3/h oxygen are produced. This by-product is sold to the neighbouring factory of India Oxygen.

Oil-hardening plant

Raw oil - castor oil, groundnut oil, linseed oil, rice bran oil and others - is neutralised with hot dilute caustic soda to remove fatty acids, which are subsequently neutralized by sulphuric acid and sold as stock for soap production. At this stage about 1 t/h of wastes containing sodium sulphate and oily material is discharged. The purified oil is bleached with bentonite, which is subsequently filtered. Spent bentonite is discharged. Bleached oil is hydrogenated using a mild catalyst and hydrogen in pressure vessels under moderate pressure. The catalyst is filtered and reused. Edible oils are hydrogenated up to 90 per cent saturation, industrial oils up to 100 per cent.

For edible oils, treatment after hydrogenation comprises a second bentonite bleaching step. Bentonite is filtered and the resulting oil is deodorized in vacuum. Finally, either edible fat called vanaspati (90 per cent) is obtained or the fat is emulsified (10 per cent) after the addition of vitamins, and margarine is formed.

Total annual production is 10,000 tons of industrial oils and 10,000 tons of edible oils.

Indian laws permit the use of margarine only in bakeries and biscuit factories. Household margarine may not be sold.

Boiler house

Seven t/h of low-pressure steam are produced. The coal-fired Babcock-Wilcox boilers require 1 t/h of powdered coal. Ash content is high (20 per cent), sulphur content, low. Stack height is 45 m. No analyses of stack gases (SO_2, particulates) are made. As a dust precipitator, only a mechanical separator is used. Ash from the boiler house is dumped in a landfilling area.

Labour

The labour force of 273 is broken down as follows:

Production	104
Maintenance and emergency	66
Administration	23
Laboratory	3
Stores, transport	44
Miscellaneous	33
	273

Discharges

Hindustan Lever is a well-managed and well-maintained factory. Discharges are estimated to be relatively low, and most are in liquid form. The discharges are:

(a) Solids. Spent bentonite is sold to small soap manufacturers, who boil the spent material with caustic soda and obtain a soap of rather poor quality and a high pH. High-quality soap cannot be produced in this way. Therefore the company sells spent bentonite to small manufacturers. Disposal of bentonite from these activities is beyond the control of the company;

(b) Spent catalyst. The activity of the catalyst finally diminishes and fresh catalyst has to be added. The spent material is sold. Its high nickel content makes it a valuable product;

(c) Liquid discharges. At each filtering stage wash waters are obtained. The same applies to vacuum deodorizing. A total of 350 t/h of water (including floor washing) is obtained. These effluents contain oily substances that are separated from the waste in a special unit. Oil is re-collected and used for technical purposes. The effluent, which contains about 17 ppm of fat and 0.25 ppm H_2SO_4, is discharged into the Hooghly River;

(d) Gaseous discharges. There are no discharges apart from some vented hydrogen.

Discharges into the Hooghly River do not do much harm as long as they are organic wastes, as in the case of Hindustan Lever. The river always contains large amounts of water, and tidal movements from the nearby sea also promote cleaning.

The BOD content of the river is rather low (3-4 mg/l), whereas the microbiological contamination is very high and represents the main pollution problem.

Durgapur Chemicals Limited

Durgapur

Durgapur Chemicals (DCL) is situated about 150 km north of Calcutta and is a government-owned factory. It was founded in the mid-1960s, though its units came into production in 1968 and later.

The Durgapur area was originally essentially woodland with some agriculture. Some 15 years ago the Government decided to develop the area industrially. It now contains two steel mills, a coke factory, a tar distillery, a fertilizer complex (phosphates, ammonia and urea) and a chemical complex. The general opinion is that the area is highly polluted. The team observed many gaseous discharges. No pollution control was provided for in the original plans.

Durgapur Chemicals comprises:

(a) An electrolysis plant producing chlorine and caustic soda. It was designed and constructed by Krebs (Paris) and came on stream in 1968;

(b) A phenol plant with chlorobenzene as an intermediate. It was designed and constructed by Krebs (1969);

(c) A plant producing phthalic anhydride from naphthalene. It was designed by St. Gobain and constructed by Krebs (1968);

(d) A pentachlorophenol plant, designed by Progil and constructed by Krebs (1969).

The team visited all four plants.

Operations have never been satisfactory. In 1973/74, production was 25 per cent of design capacity; hourly production rates never exceeded 50 per cent. In the first few years results were even worse. It was claimed that Krebs did a bad job; but this is difficult to understand, since Krebs is an experienced firm and generally has a good reputation.

Bad management certainly has been the reason for the poor results. About half a year before the team's visit, the manager and many engineers were dismissed and replaced by a new manager and a new staff. Some of the engineers at the time of the team's visit had started working only a week earlier. The equipment was in bad condition and only part of it was in working order. Maintenance had been neglected for long periods.

Total investment costs were Rs 110 million in 1968. Financial losses were reported to amount to Rs 30 million over 6-7 years. The losses include a depreciation of only 5 per cent of equipment costs, so the figure of Rs 30 million may be inaccurate. Since 1973/74, the depreciation rate has been 10 per cent.

This low depreciation policy may be criticized. Because of poor maintenance, equipment life has been shortened, which means a high depreciation rate.

Chlorine plant

The chlorine plant is of the mercury type and is designed for a production of (t/d): caustic soda, 30; chlorine, 27; and hydrogen, about 0.75.

Brine is made from sea salt. The input is 60 t/d. Brine preparation includes removal of sulphate by barium carbonate, of magnesium by caustic soda and of calcium by soda ash. Precipitates are removed by a leaf filter and go to a landfilling area.

None of the products from the plant is analysed with regard to contamination. Hydrogen is vented into the air; plans for compressing and bottling are vague.

Chlorine can be stored to a small extent, but no facilities to bottle it exist nor have plans to set them up been made. If such facilities existed, it would not be necessary to shut down chlorine production when difficulties in the phenol plant arise. As it is, neither of the two plants can function properly. It was recently decided to buy chlorine cylinders.

Mercury losses were reported to be over 10 tons in 6.5 years, which means a loss of 1 kg Hg per ton of caustic soda. The Krebs guarantee was 135 g Hg per ton of caustic soda. Modern plants now have a guarantee of 40 g per ton of product and lower. In fact, with added special equipment, very low discharges can be realised (2 g Hg per ton of caustic soda). It was stated that at least part of the losses was due to theft. A visit to the plant, however, showed large amounts of spilt mercury.

There are 18 cell blocks. Each cell is built in two stages, the lower one being the amalgam-decomposition cell. Flanges between several parts of the cell were in bad condition. Joints had faulty packings from which mercury escaped. The spilt mercury by each mercury pump indicated leakage. A plant in such a condition can easily have mercury losses of 1 kg/t of caustic. Nothing is known about the actual mercury losses in the caustic soda, or in the chlorine, hydrogen and brine bleed.

Phenol plant

The design capacity of the phenol plant is 20 t/d; however, the actual maximum output is 5 t/d. The plant comprises two reaction units. The first is a benzene chlorination unit yielding monochlorobenzene. Hydrochloric acid and o- and p-dichlorobenzene are obtained as by-products. In the second step the monochlorobenzene is decomposed by hot caustic soda (20 per cent), and sodium phenolate plus sodium chloride is formed. As a by-product, diphenyl oxide is formed, which perhaps could be sold.

The phenolate is decomposed by the hydrochloric acid of the chlorination step. A pure by-product sodium chloride can be obtained and recycled to the chlorine plant.

At present, the production of phenol out of benzene and propylene is favoured, since this is a cheaper way to produce phenol and acetone is produced as a valuable by-product. However, propylene was not available in Durgapur, and therefore the chlorobenzene process was chosen, a well-known and technologically satisfactory process that has been used for many years. Several modifications exist.

If this plant had been running properly, it could have showed a profit. It is not quite clear what kind of difficulties caused the very poor performance. It appeared to be due to mechanical failures and a lack of knowledge of technology on the part of the staff.

Pentachlorophenol plant

Pentachlorophenol (PCP) and sodium salt are produced in this plant. PCP is used as a wood preservative. The design capacity of the plant is 3 t/d as PCP (1,000 t/a). Actual production is 60 t/a.

Reaction is an excessive chlorination of phenol, yielding PCP and by-product hydrochloric acid. The PCP is solidified on a flaking machine. The flakes contain 80 per cent PCP, 18 per cent tetrachlorophenol and 2 per cent polymers.

The sodium salt is prepared by treating the crude PCP with hot 30 per cent caustic soda and cooling. PCP sodium crystallises and is filtered and dried. Spent liquor is discharged.

Phthalic acid plant

The design capacity of the phthalic acid plant is 10 t/d. Maximum production has been 250 t/month.

This plant used naphthalene as a raw material that is oxidised using vanadium oxide as a catalyst. The process is from St. Gobain. There are no technological difficulties; the supply of naphthalene is the bottleneck.

The plant produces 1-2 per cent of maleic acid and naphthoquinone. Marketing of these products is difficult. About 0.5 t/d of caustic soda is used for neutralising wastes.

Discharges

Effluents from the pentachlorophenol unit are collected in a pit and pumped to a tank where they are oxidised with $KMnO_4$ and air until the colour has disappeared. After neutralization they are discharged to the drain. Effluents from the pentachlorophenol-sodium-salt unit are treated in the same way after acidification with hydrochloric acid.

Liquid effluents of the phenol plant are treated in a similar way with potassium permanganate ($KMnO_4$) and are discharged after neutralization. In this way organic phenolic effluents are minimised, but manganese salts are discharged. All liquid effluents flow to the Tamla Nulla, which belongs to the Ganges estuary system. Apart from the permanganate treatment, no other treatment is planned or carried out.

Labour

The labour force of 796 is broken down as follows:

Production	400
Maintenance (mechanical)	149
Maintenance (electrical)	75
Maintenance (instruments)	25
Administration, finance	72
Laboratory	45
Civil engineering, public health	30

The average age of the workers is 30-35 years.

About 50 per cent of the personnel live in company housing. The Government is now drafting plans for housing and city development. The basic wage is Rs 270 per month; the average wage is Rs 500 per month.

Health

The medical officer of the enterprise described the various health problems. In general, during the rainy season gastrointestinal disorders are common, around January, infections of the respiratory tract, including influenza. Tuberculosis is increasing, especially because workers consult the physician too late. Liver diseases, leading to hepatitis, are common.

Preventive measures in the factory are lacking, which results in high exposure levels to different agents. Even in the residential area, a chronic chlorine poisoning has been observed. Help is needed in all forms, including pollution monitoring, education in industrial hygiene and implementation of pollution control measures in the factory.

The following occupational health hazards have been registered:

From exposure to chlorine:

- Chronic conjunctivitis
- Rhinitis - nose bleeds
- Laryngitis
- Chronic and acute bronchitis
- Bronchopneumonia
- Asthma
- Pulmonary oedema
- Chronic gastritis
- Chronic esophagodynia

From exposure to hydrochloric acid:

- Chronic bronchitis
- Rhinitis
- Chemical burning of the skin

From exposure to phenol:

Damage to kidney, liver, pancreas and spleen

Pulmonary oedema

By absorption through the skin:

Headache, dizziness, muscular weakness, dimness of vision, ringing in the ears, irregular breathing, weak pulse, dyspnoea

By the intestinal tract:

Nausea, severe abdominal pain, erosion of lips, mouth, throat, oesophagus and stomach perforation

Skin:

Burns, gangrene, contact dermatitis

Chronic poisoning:

Excessive salivation, diarrhoea, loss of appetite, headache, dizziness, mental disturbances

From exposure to phthalic compounds:

Allergy

Asthma

Emphysema

Irritation of eyes and upper respiratory tract

Pneumonia

Contact dermatitis

From exposure to pentachlorophenol:

Burns, contact dermatitis

Acute poisoning, weakness, convulsions

Collapse

Damage to liver and kidney

From exposure to benzene:

Leukemia

Damage to liver and kidney

From exposure to mercury:

Loss of teeth
Inflammation of the liver

Recommendations

Since these plants are in very bad shape, one or more experts with long experience in chlor-alkaline electrolysis and in the production of phenol should make a thorough study of the plants and bring practices up to accepted international standards. It would also be highly desirable to appoint an engineer with long experience in electrolysis to manage the plant.

If the plants are operating properly, the problems of pollution can be tackled. The mercury problem is primarily caused by bad maintenance and bad management in the electrolysis plant.

IV. CONCLUSIONS AND RECOMMENDATIONS

Conclusions

1. Overpopulation places a heavy burden on the environment. In comparison with this heavy burden, the possible negative environmental effects caused by polluting effluents from industry are hardly recognizable and are possibly underestimated.

2. Industrialization has in most cases brought a higher standard of living and improved sanitation in an area. These effects are highly appreciated by the residents.

3. As a result of overpopulation, hundreds of candidates are available for one free work place, and industry therefore absorbs the best elements of the population (the most healthy and the most active).

4. Discharges from industry are generally without value. Usually material that could be used in some way is either recycled or used elsewhere. However, in some cases bad maintenance, together with poor management, is responsible for economic losses. Training and education in maintenance is greatly needed if such economic losses are to be avoided.

5. In some factories the management has not been able to produce new ideas on advanced and modern technologies to broaden production programmes and at the same time to abate pollution. Management in most factories, however, is well aware of the problem.

6. In some factories the team observed high levels of pollution that could have been avoided through proper management and maintenance, such as:

   Mercury losses in the chlorine plant of Durgapur Chemicals
   Spillage of all kinds of chemicals in the plants of Indian Dyestuffs (in Kalyan, Bombay)
   Spillage of arsenic, chromium and copper compounds at Ascu-Hickson in Nagpur

Many factories are prepared to build the necessary equipment for effluent treatment (the space for, as well as some parts of, the future treatment plant are sometimes present). Industry's failure to act has often been due less to considerations of cost than to uncertainty about the ultimate emission standards.

Only a few factories were able to produce specific costs of pollution control.

Recommendations

In view of the importance of maintenance and the evidence that poor maintenance is the origin of spillage and of contamination of work places, the team supports the plan of the Ministry of Science and Technology to organize a seminar on maintenance. Special training programmes for foremen and managers are also recommended to eliminate losses in the production process and health hazards for workers in the factories.

The team observed that in well-managed factories emitting a minimum of pollution the technical managerial staff had been trained for two years or more in factories in developed countries. The team therefore recommends the establishment of a fellowship programme, to be administered by the Government, for training graduate personnel for at least two years in chemical factories in developed countries.

Physicians specialized in occupational and industrial health need to be trained. Such training courses might be established using the programme of the London School of Hygiene as a model. Fellowships to enable physicians to participate in such educational programmes in developed and developing countries should be encouraged.

In the training of workers, attention should be given to environmental problems.

Maps showing water pollution in all regions should be made.

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