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ESTABLISHMENT OF A HERBICIDE PLANT

DP/TUR/76/011

TURKEY

TERMINAL REPORT

Prepared for the Government of Turkey by the
United Nations Industrial Development Organization,
executing agency for the
United Nations Development Programme

United Nations Industrial Development Organization

id. 76-[illegible]

United Nations Development Programme

ESTABLISHMENT OF A HERBICIDE PLANT

DP/TUR/76/011

TURKEY

Project findings and recommendations

Prepared for the Government of Turkey by the
United Nations Industrial Development Organization,
executing agency for the United Nations Development Programme

Based on the work of J. Burton, consulting
chemical engineer

United Nations Industrial Development Organization
Vienna, 1976

Explanatory notes

A comma (,) is used to distinguish thousands and millions.

A full stop (.) is used to indicate decimals.

Use of a hyphen between dates (e.g., 1960-1965) indicates the full period involved, including the beginning and end years.

References to dollars ($) are to United States dollars, unless otherwise stated.

The following exchange rates are used in the conversion of country currencies to United States dollars:

Country	Currency	Exchange rate per US dollar in September 1976
Germany, Federal Republic of	Mark (DM)	2.52
Turkey	Lira (LT)	16.00

The following abbreviations are used in this report:

GL	Glass-lined
RL	Rubber-lined
TZDK	Turkiye Zirai Donatim Kurumu (General Directorate of Agricultural Supplies)

The following technical abbreviations are used in this report:

cfm	Cubic feet per minute
CMC	Carboxymethylcellulose
DCP	Dichlorophenol
Karbate	Type of impervious carbon
gpm	Gallons per minute
NaTCP	Sodium salt of trichlorophenol
psi	Pounds per square inch
psig	Pounds per square inch gauge
t/a	Metric tons per year
316 SS	Stainless steel, type 316

ABSTRACT

The project entitled "Establishment of a herbicide production plant" (DP/TUR/76/011) originated in a request made by the Government of Turkey in March 1976 and approved by the United Nations Development Programme (UNDP) in April 1976, with the United Nations Industrial Development Organization (UNIDO) designated as the executing agency, and the Ministry of Agriculture of Turkey as the government counterpart. The one-month mission began on 24 August 1976.

The duties of the expert were as follows:

(a) To review the technical feasibility of setting up a 2,4-D herbicide plant based on a study prepared by the Turkiye Zirai Donatim Kurumu (TZDK) (General Directorate of Agricultural Supplies);

(b) To complement, as required, the technical aspects of the above study, and to assist in finalizing the financial aspects of the project.

TZDK also requested the expert to provide process descriptions, equipment lists and estimated capital investment and manufacturing costs, and to evaluate the suitability of the proposed plant site.

The following conclusions of the report should be noted:

1. Based on 1976 and average 1975-1976 import prices, and assuming that the $3,000,000 needed for imported equipment and services to build the plant is obtained as an 8% long-term foreign loan, the estimated foreign exchange savings resulting from the replacement of imports by local production could vary from $1,200,000 to $5,800,000, depending on the level of plant operations as a percentage of total capacity.

2. Waste disposal and the selection of a suitable plant site are crucial, and should weigh heavily in any decisions regarding the purchase of plant technology.

3. Project plans should take into account the shortage of experienced chemical engineers in Turkey.

Its recommendations include, in particular, the following:

1. A study should be made of possible steps to integrate the proposed plant with another plant, so as to reduce both capital investment in general plant facilities and operating and overhead costs. The alternative of the installation of a smaller initial plant might also be considered.

2. A study should be made of the 2,4-D and 2,4,5-T market prices that can be expected in the next few years. These prices should then be used as a basis for an economic study of the proposed plant.

3. Consideration should be given to the use of equipment requiring less capital but more labour in the manufacturing process.

CONTENTS

Chapter		Page
	INTRODUCTION	7
I.	ANALYSIS OF THE TZDK REPORT	11
	A. General findings	11
	B. Market projections	13
II.	PLANT LOCATION	15
III.	RAW MATERIALS	17
IV.	WASTE DISPOSAL	19
	A. Waste water disposal in 2,4-D manufacture	19
	B. Waste disposal regulations	20
V.	ECONOMIC AND FINANCIAL QUESTIONS	22
	A. Capital investment	22
	B. Manufacturing costs	23
	C. Economic viability	30
	D. Foreign exchange	33
VI.	CONCLUSIONS AND RECOMMENDATIONS	34
	A. Conclusions	34
	B. Recommendations	35

Annexes

I.	PROCESS DESCRIPTIONS	37
	A. Basic processes	37
	B. Alternative processes	44
II.	PROCESS EQUIPMENT COST SUMMARY AND LISTS	47

Tables

1.	Estimated viability of proposed herbicide plant	8
2.	Calculation of production requirements	12
3.	Herbicide use during the 1969-1974 period	13
4.	Estimate of total plant cost by categories of expenditure	22

		Page
5.	Raw material costs for each stage of production...............	24
6.	Raw material costs for 2,4-D products.........................	25
7.	Raw material costs for 2,4,5-T products.......................	26
8.	Total manufacturing costs.....................................	27
9.	Distribution of processing costs..............................	28
10.	Manufacturing cost for each product..........................	29
11.	Estimated return on new plant................................	30
12.	1975 and 1976 import prices..................................	31
13.	Comparison of estimated manufacturing costs and 1975-1976 average import prices..................................	31
14.	Revised manufacturing and import cost estimates for 1979-1983.	32

Figures

I.	Material flow diagram..	10
II.	Dichlorophenol production process............................	39
III.	2,4,5-Trichlorophenol production process.....................	40
IV.	2,4-D acid production process................................	43
V.	Butyl 2,4-D and 2,4,5-T esters production process............	46
VI.	Isooctyl 2,4-D and 2,4,5-T esters production process..........	46

INTRODUCTION

Pesticide consumption in Turkey is growing rapidly, and its important role in the production of cereals, wheat in particular, makes it essential to ensure a continuous flow of adequate supplies. The cost of imported pesticides, which represent by far the major supply source, reached an estimated $40,000,000 in 1975. However, in 1974 and 1975 the use of herbicides had to be restricted because of supply shortages and substantial import price increases, especially those resulting from the world-wide shortage of the herbicides used in wheat-growing, 2,4-D (87%) and 2,4,5-T (13%).

In view of the major importance of pesticides in agricultural production, the Government of Turkey decided to promote the gradual establishment of pesticide production units to ensure the regular provision of needed supplies and to reduce expenditure for imported goods that drain the country's foreign exchange reserves. It therefore made a request in March 1976 for assistance from the United Nations Development Programme (UNDP) in carrying out a feasibility study of herbicide production in Turkey. The request was approved in April 1976, and led to the project entitled "Establishment of a herbicide production plant" (DP/TUR/76/011), for which the United Nations Industrial Development Organization (UNIDO) was designated as executing agency, and the Ministry of Agriculture of Turkey as the government counterpart. The budget for the one-month project, which began on 24 August 1976, called for a UNDP contribution of $10,000.

The duties of the expert were as follows:

(a) To review the technical feasibility of setting up a 2,4-D herbicide plant based on a study prepared by the Turkiye Zirai Donatim Kurumu (TZDK) (General Directorate of Agricultural Supplies);

(b) To complement the above study in technical terms as required;

(c) To co-operate with the project evaluation economic expert in finalizing the study and elaboration of the financial aspects.

TZDK also requested the expert to provide process descriptions, equipment lists and estimated capital investment and manufacturing costs, and to evaluate the suitability of the proposed plant site at Aliaga. It was agreed that the requested data would be provided only in the amount of detail needed for estimating work and giving the broad outlines of the plant and manufacturing methods. The know-how necessary for the actual process design plant would have to be acquired as part of the final design and engineering phase.

For the establishment of a plant in Turkey producing 4,350 t/a (metric tons per year) of 2,4-D and 650 t/a of 2,4,5-T herbicides, the expert estimated that the capital investment needed would amount to approximately LT 125,000,000, or $7,800,000 (using a conversion rate of LT 16 = $1), with an accuracy at the current stage of ± 20%. Of this amount, 62% would be spent in Turkish liras.

An important factor in the economic viability of the plant is the size of the market for the products during the first years of operation. According to the TZDK market forecast, the plant would need to operate during the first five years at an average of 40% of capacity in the 2,4-D section and 63% in the 2,4,5-T section, after allowing for that part of the market which may be supplied by a private plant to be established at Gelibolu. If the Gelibolu plant does not go into production, the complete TZDK plant could operate at an average of 63% capacity during the first five years.

Another important economic question is the forecast of the prices that would be paid for these products as an alternative to manufacturing them. Importation prices dropped sharply in 1976 from the 1975 level. The estimates of economic viability given in table 1 below are based on 1975-1976 average prices, with 1976 prices as alternates. The estimates have been calculated on the assumption that the $3,000,000 needed for imported equipment and services to build the plant is obtained as an 8% long-term foreign loan.

Table 1. Estimated viability of proposed herbicide plant

Herbicide output (percentage of plant capacity) 2,4-D	2,4,5-T	Reference years	Manufacturing costs[a] minus import costs (in LT and as a percentage of import costs)	Annual foreign exchange savings resulting from domestic production ($)
100	100	1975-1976	-8,600,000 (-4,5)	5,800,000
63	63	1975-1976	6,500,000 (+ 5)	3,500,000
40	63	1975-1976	12,000,000 (+14)	2,400,000
100	100	1976	42,000,000 (+30)	2,700,000
63	63	1976	38,000,000 (+43)	1,900,000
40	63	1976	32,000,000 (+49)	1,200,000

a/ An annual depreciation charge of LT 10,000,000 is included in the manufacturing costs.

The above examples are intended only to illustrate the general outlook for the projeot. Many items of capital investment and operating costs are only at the preliminary estimate stage.

The flow of materials between the main sections of the plant is shown in figure I. More process details are given in annex I.

The main process steps are:

1. Phenol and chlorine react to produce dichlorophenol, with hydrochloric acid as a by-product.
2. Dichlorophenol, monochloroacetic acid, 50% caustic soda and hydrochloric acid react to produce, 2,4-D acid.
3. A portion of the 2,4-D acid is sold, other portions are reacted with butyl alcohol to produce butyl 2,4-D ester and with isooctyl alcohol to produce isooctyl 2,4-D ester.
4. A reaction of 1,2,4,5-tetrachlorobenzene with solid caustic soda and methyl alcohol produces 2,4,5 trichlorophenol.
5. A reaction of 2,4,5-trichlorophenol with 50% caustic soda, monochloroacetic acid and hydrochloric acid produces 2,4,5-T acid.
6. A portion of the 2,4,5-T acid is reacted with butyl alcohol to produce butyl 2,4,5-T ester, and the other portion is reacted with isooctyl alcohol to produce isooctyl 2,4,5-T ester.

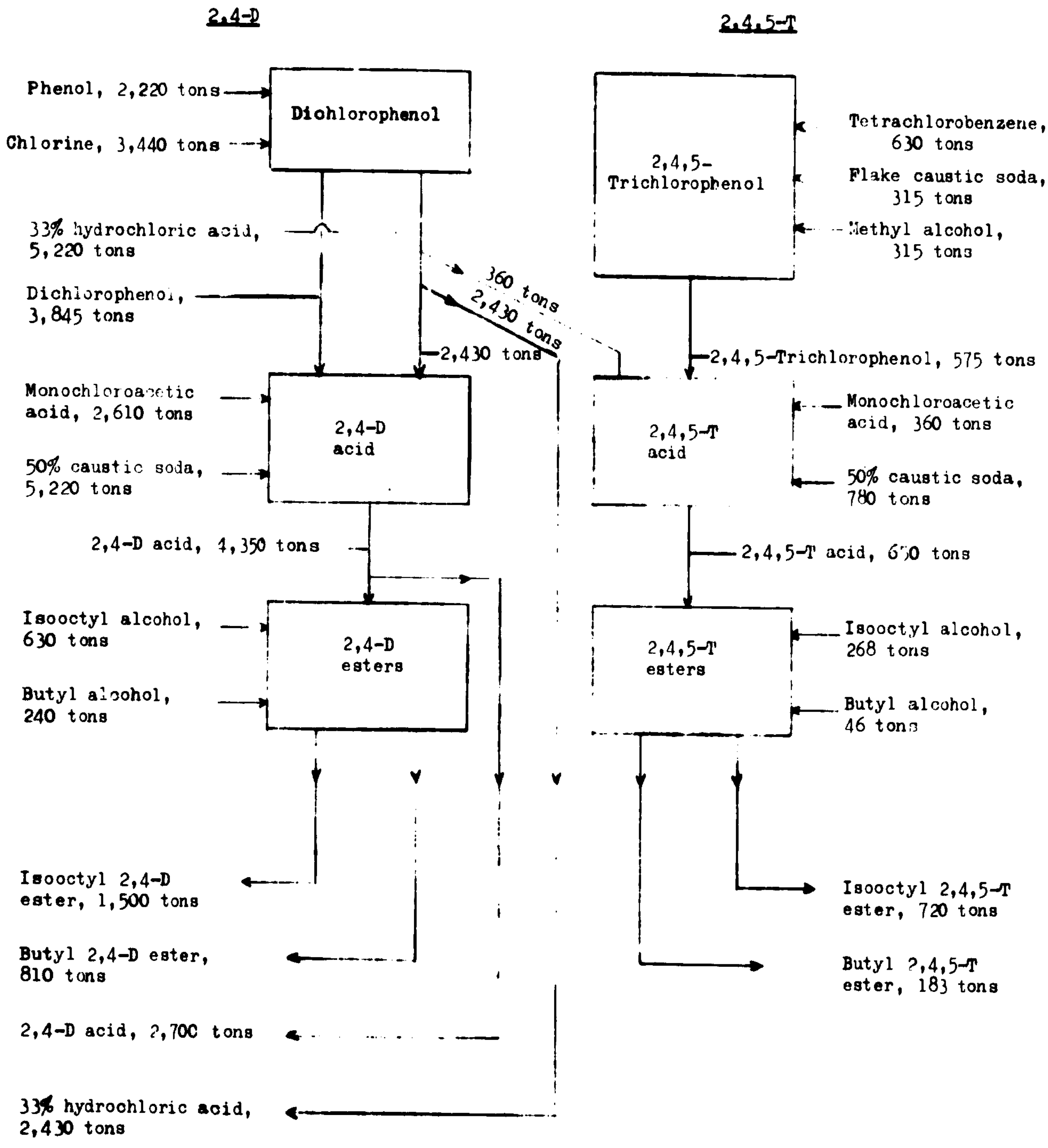

Figure I. Material flow diagram

I. ANALYSIS OF THE TZDK REPORT

A. General findings

Information on equipment or manufacturing processes is provided in this report, since none was given in the TZDK report. The importance to Turkey of an adequate supply of wheat herbicides is made clear in the TZDK report, and the estimate of raw material requirements is quite close to that reached by the expert. The capital cost estimate was, however, much higher (LT 126,832,922 for total fixed investment), but no attempt will be made here to analyze the discrepancy, owing to the difficulty of understanding the details given in chapter IV, page 3, of the TZDK report. The attempts to verify the market situation were not very successful, and this subject is covered below in the section on Market Projections. The chief question that arises is why the plant should be sized now to meet projected 1988 demand for 2,4-D.

Elaborate calculations were made to evaluate plant sites, and these appear to be generally sound. The chief area of disagreement concerns waste disposal sites, a subject which requires further consideration. For example, the open sea in general provides good protection in case of accidental spills, but the precise spot chosen in Aliaga was not a good one (in this connexion, see the sections devoted to plant location and waste water problems in 2,4-D manufacture).

The raw materials section of the TZDK report correlates well with the findings of the expert. Its one error consists in the inclusion of hydrochloric acid as a raw material instead of a by-product.

The production costs and sales prices are calculated to be:

	Cost	Sales price
2,4-D acid	LT 27,152/ton	LT 29,867/ton
2,4,5-T acid	LT 44,425/ton	LT 48,868/ton

However, these production costs are based on a 100% production rate that will not be needed for domestic needs until 1991 according to market projections. No analysis of the production cost is made for the initial years when the plant will operate at a fraction of its capacity. The report is also confusing in regard to actual expected production capacity. All figures used for production cost estimates are based on the assumption that the plant can operate at 100% capacity. But in the demand - supply projections (chapter I, page 8) an 80% capacity figure is used as the maximum expected production of the plant, and the TZDK has indicated that the 80% capacity figure is more realistic.

The calculations of net profit (chapter V, page 11) are misleading for the following reasons:

(a) The production rate is taken at 100% capacity, which exceeds both the expected capacity and the market requirements until 1988;

(b) Hydrochloric acid is credited at LT 10,000/ton, whereas it has been found that at Aliaga the market price was only LT 3,500/ton;

(c) The 2,4-D sales price of LT 29,867/ton is considerably higher than the current import price of $1,250/ton = LT 20,000/ton, but lower than the 1975 import price of LT 33,450/ton.

Table 2. Calculation of production requirements

Year	Demand a/ (in tons)		Gelibolu 2,4-D production a/ (in tons)	Balance needed (in tons)	
	2,4-D	2,4,5-T		2,4-D	2,4,5-T
1979	2,187	325	450	1,737	325
1980	2,460	367	900	1,560	367
1981	2,733	408	1,200	1,323	408
1982	3,006	449	1,200	1,806	449
1983	3,279	490	1,200	2,079	490
1984	3,553	530	1,200	2,353	530
1985	3,826	571	1,200	2,626	571
1986	4,100	611	1,200	2,900	611
1987	4,373	653	1,200	3,173	653
1988	4,646	694	1,200	3,446	694
1989	4,919	735	1,200	3,719	735
1990	5,193	775	1,200	3,993	775
1991	5,466	816	1,200	4,296	816
1992	5,739	857	1,200	4,539	857
1993	6,012	895	1,200	4,812	895
1994	6,286	939	1,200	5,086	939
1996	6,833	1,020	1,200	5,633	1,020

a/ From the TZDK report.

The TZDK report was based on the construction of a plant with a production capacity of 4,350 t/a of 2,4-D acid and 650 t/a of 2,4,5-T acid, assuming a 250 day year, but the plant was expected to operate at 80% capacity, with a production of 3,500 t/a of 2,4-D and 500 t/a of 2,4,5-T. The expert was requested by TZDK to use the same basis for plant design.

Table 2 shows that the 2,4-D section of the proposed plant would operate at only 40% of capacity in 1979 and not reach the target of 80% until 1988. If the Gelibolu 2,4-D plant is not built, the TZDK plant would operate at 50% capacity in 1979 and reach 80% capacity in 1984. It is not clear how much reliance can be placed on the Gelibolu plant operating as planned, but the State Planning Office confirmed that it had been issued a permit for 1,500 t/a, and also that it had asked to have its authorized output increased to 4,500 t/a. Table 2 also shows the 2,4,5-T section of the TZDK plant would operate at 50% capacity in 1979 and reach 80% capacity in 1984.

The possibility of exporting the surplus production prior to 1989 is difficult to predict. Until the price of basic raw materials such as acetic acid, chlorine and caustic soda in Turkey are substantially reduced, there is no possibility for Turkey to compete in the world market. Exports would therefore have to be heavily subsidized in order to help Turkey's foreign trade.

Attempts to verify the 1974 and 1975 demand figures in the TZDK report by comparison with import levels were unsuccessful. Data for 1975 could not be obtained, and the 1974 import data totalled 443 tons of active ingredient as compared with 942 tons recorded in the TZDK report.

B. Market projections

The TZDK feasibility study has a detailed estimate of the past and the projected use of 2,4-D and 2,4,5-T in wheat production. The following table shows the figures for the 1969-1974 period.

Table 3. Herbicide use during the 1969-1974 period

Year	Wheat-sown area (in dekares)	Area of herbicide use (in dekares)	Area of herbicide use (percentage)
1969	86,600,000	5,881,027	6.79
1970	86,000,000	6,631,599	7.71
1971	87,000,000	6,980,388	8.02
1972	87,300,000	6,672,554	7.64
1973	88,500,000	8,378,109	9.46
1974	87,500,000	9,645,811	11.02

The TZDK predicts that the percentage of the wheat area to which these herbicides will be applied will increase from 11% in 1974 to 100% in 1996, with the annual rate of increase decreasing uniformly from 33% in 1975 to 4% in 1996.

All of the 2,4-D and 2,4,5-T currently used in Turkey is imported. Zirai Mucadele Ilaclari Hammaddeleri A.S. in Gelibolu has a permit to produce 1,500 tons per year of 2,4-D acid starting in 1979.

The TZDK study was for the production of only 2,4-D and 2,4,5-T acids. But a check of imports showed that esters were being imported in 1975. The expert therefore added units to produce the butyl and isooctyl esters. Data on import prices show that the 2,4-D acid price usually has been at a more favourable relationship to world market prices than have been the prices for esters.

A discussion was held with the General Manager of Bayer Baykim and head of the association of formulators in order to supplement TZDK information on imports. It emerged from the discussion that the most common formulations had a 5 to 1 ratio of 2,4-D to 2,4,5-T, which is close to the 7 to 1 ratio of TZDK. Only 10% to 20% of the total esters would appear to be butyl (as compared with isooctyl), whereas the TZDK estimates 35% butyl (but this does not significantly affect plant design). The General Manager's estimate of the current market is 2,000 t/a of 2,4-D and 200 t/a of 2,4,5-T. This is significantly higher than the TZDK estimate of a total of 1,571 tons for 1976. He also estimated a 10% to 15% annual increase in the market for 2,4-D and 2,4,5-T, but considered it unnecessary to produce any isopropyl 2,4-D ester.

II. PLANT LOCATION

The TZDK study included a detailed calculation to de rmine the best plant site, taking into account freight costs, availability of labour, transportation facilities and power, waste disposal, and priority for underdeveloped regions. It concluded that the best site was Aliaga bay near Izmir.

Aliaga

The expert visited this area, first examining a selected site by a river north of Aliaga. This appeared unsuitable because of particularly sensitive conditions downstream involving hazards to cotton fields, a fishing area and a public beach. The Department of Water Resources later indicated that deep-well disposal anywhere near the coast is not feasible because of the possible infiltration of the waste into ocean water. The supply of cooling water at this site also appeared inadequate.

An attempt was then made to find a suitable site adjacent to the planned Petkim petrochemical complex at Aliaga. Of particular interest was a joint operation with Petkim to reduce the overhead costs of a small independent plant through the use of a small portion of Petkim's available electric power and cooling water. No suitable land close to their planned plant was found, and Petkim in Ankara later indicated that it had plans for the use of all its surplus land, and was itself in a tight situation with regard to cooling water. Moreover, its plans do not anticipate that chlorine or caustic soda will be available (in this connexion, see below the section on raw materials). A favourable factor is that the adjaoent refinery represents a market for 2,500 t/a of 33% hydro-ohloric acid at LT 3,500/ton.

A site near Aliaga is possible. It has an uncertain but possible supply of low cost chlorine and caustic that would save LT 13,600,000/year compared with the costs of Ekstas Holding, Yatirimlar A.S. Waste water treatment for this area is possible, but expensive. Difficulties are the addition of requirements for chlorine and caustic soda to Petkim's output at such a late stage, and the uncertain supply of cooling water.

Seriflikochisar

This site was interesting because of the planned building of an Ekstas chlorine-caustic plant here (see below the section on raw materials) and the possibility of waste water disposal by evaporation.

This site was visited and the situation was discussed with Ekstas. The following factors should be taken into account:

(a) Chlorine and caustic soda will be available, but at a high price;

(b) Electricity will be available from the line to be run to Ekstas from a hydroelectric generator;

(c) Cooling water from wells appears adequate;

(d) Adjacent land is available at LT $50/m^2$;

(e) Ekstas has already constructed and is operating a small carboxymethylcellulose (CMC) plant, has some experienced technical staff, and would be interested in a joint arrangement with TZDK, which could also include the chlorine-caustic plant;

(f) The immediate area is not suitable for waste disposal by evaporation. The Department of Water Resources has offered to look for a site in the general area, and this might produce an alternative to expensive incineration (see below the section on waste disposal);

(g) Waste disposal by a deep disposal well is a possibility, but an expensive one. This was discussed further with Turkish Petroleum Co. geologists, who drilled an exploratory well near the site in question, and with the Department of Water Resources;

(h) This site involves more freight costs for raw materials and products to be imported to the Izmir area. However, freight costs are relatively low, and in the long run a plant at this site would be advantageous for the central and eastern areas of the country.

III. RAW MATERIALS

Chlorine and 50% caustic soda

Ekstas plans to construct a chlorine-caustic plant at its existing CMC plant at Seriflikochisar. It has received tenders and expects to take a final decision on 10 October 1976. The plant will have a capacity of 9,000 t/a and start operation in 1978 or 1979. Ekstas may use 2,400 tons of this to make monochloroacetic, although it is difficult to see how this will be feasible unless the price of acetic acid is greatly reduced. The company also says it can sell 6,000 t/a to Seka at Eskisehir, at a price of LT 3,300/ton for chlorine f.o.b. plant. From its capacity of 10,000 t/a of caustic soda it could easily meet expected demand, but its price is high, LT 10,500/ton (on a 100% basis) for the 50% liquid.

Petkim Aliaga complex will produce 90,000 t/a of chlorine and 100,000 t/a of caustic soda. It plans to use all of this, except during the first 3 to 4 years when it expects its usage to be restricted by start-up difficulties in the naphtha section of the plant. If a request was made in time, it would consider expanding capacity, but this appears to be difficult.

Its prices would be LT 2,000/ton for chlorine and LT 7,000/ton for caustic, although the State Planning Office has indicated that the prices would be LT 2,500 and LT 7,800.

Acetic acid

This is produced at Aepazari by Asit Sanayii and sold at LT 21,000/ton. Two plants near Denizli expect to make acetic acid as a by-product of furfural, but their prices are even higher, LT 30,000 and LT 26,300/ton on a 100% basis, and their acetic will be only 37% to 38% (99% to 100% is needed). The United States price of acetic acid is $0.16/lb (LT 5,734/ton), and acetic anhydride is $0.22/lb (LT 7,885/ton).

Until acetic acid can be obtained at a much lower price than the LT 21,000/ton, the manufacture of monochloroacetic acid is economically unsound unless based on imported acidic acid.

Phenol

Both Petkim and the State Planning Office have indicated that there are no plans for Petkim to produce phenol. The current United States phenol price is $0.27/lb (LT 9,677/ton) delivered in tanks. TZDK has a quotation from the Verkaufsgesellschaft für Teerezeugnisse at DM 1,680 c.i.f. Istanbul (LT 11,172/ton).

Monochloroacetic acid

TDZK has a quotation from the Akzo company in the Netherlands of LT 12,880/ton c.i.f. Istanbul. This is less than the United States price of $0.40/lb (LT 14,336/ton).

Isooctyl alcohol

This is not made in Turkey. The United States price is $0.19/lb in tanks (LT 6,810/ton). Since no quotation is available for this product, a price of LT 9,000/ton has been used to allow for ocean freight from Europe.

Butyl alcohol

The imported esters have been the isobutyl esters. In the United States a mixture of n-butyl and isobutyl is commonly used. The United States price of n-butyl alcohol is $0.22, and that of isobutyl is $0.22.

No butyl alcohol is made in Turkey. A price of $0.21 (LT 7,526/ton) has been used, and this is adjusted to LT 9,800/ton to allow for ocean freight.

1,2,4,5-Tetrachlorobenzene

TDZK has a quotation from Bayer of DM 2,400/ton c.i.f. Istanbul (LT 15,700/ton). This seems to be a fair price, and it is unobtainable in the United States.

Methyl alcohol

TDZK has a price of LT 4,500/ton from Sagsa in Adana. This is $0.77/gal as against the current United States price of $0.43 in tanks f.o.b.

IV. WASTE DISPOSAL

A. Waste water disposal in 2,4-D manufacture

The disposal of the liquid effluent presents an unusually severe problem in the manufacture of 2,4-D. In the simplest 2,4-D process, about 15% to 20% of the chlorophenols produced in the first step are not converted into the 2,4-D acid and are left in the effluent in the form of their water soluble sodium salts. There seem to be only three plants that are still operating in this manner; two of these discharge their effluent into the sewage systems of large cities that have only primary sewage treatment, the third one discharges into a deep disposal well.

The first improvement step is to acidify the process water that contains most of the chlorophenols and thus cause the chlorophenols to separate out as a lower oily layer. The chlorophenols can then be disposed of by landfill or by incineration. Incineration requires special equipment and produces HCl gas that is absorbed in water and then neutralized. The acid waste waters are filtered to remove small amounts of 2,4-D acid and neutralized with limestone. The waste water may contain approximately 0.1% chlorophenols and also small amounts of several chlorophenoxyacetic acids.

Some of the phenols can be destroyed by chlorination to reduce further the chlorophenol content of the effluent. It should be possible to reduce them to 0.003% (30 mg/l by chlorination). To reduce the chlorophenol content to a maximum of 1 mg/l the effluent can be passed through vertical cylinders filled with an ion exchange agent. Periodically the absorbed chlorophenols are removed with a recycled dilute caustic soda solution. To reduce the chlorophenol content of the effluent to a minimum, biological treatment by aerobic bacterial action in trickling filters or aeration basins is probably the best method. Another possible method of removing chlorophenols is solvent extraction, but there seems to be no plant where this is done.

The waste water also contains considerable sodium chloride (about 0.8 kg/kg 2,4-D aoid) and sodium glycolate (about 0.2 kg/kg 2,4-D). The sodium glycolate is not toxic.

There is no definite regulation in the United States on the chlorophenol content of plant effluent, but in most locations 1 mg/l seems to be considered aooeptable. It is reported that fish are killed at 2 mg/l and that 0.0005 mg/l produoes a taste in water.

B. Waste disposal regulations

Turkish regulations for water discharged from a plant were checked. The applicable law is the 1973 "Law and Regulations of Water Production". The following provisions apply particularly to the 2,4-D plant:

(a) The pH of the water discharged may vary from 6.5 to 8.5;

(b) There must be no harmful smells;

(c) The maximum permissible chemical content in mg/l is:

Chlorides	170	
Free chlorine	0.01	
O-chlorophenol	0.015	(1 part in 67,000,000 parts water)
P-chlorophenol	0.06	
M-chlorophenol	0.06	
Phenol	0.2	(1 part in 5,000,000 parts water)
Butyl alcohol	0.2	
Na (sodium ion)	85	
Sulfates	90	
Butyl 2,4-D ester	1.3	
Isopropyl 2,4-D ester	0.8	
Isopropyl 2,4,5-T ester	1.7	
Isooctyl 2,4,5-T ester	16.7	

By comparison, the maximum permissible content of DDT and BHC in mg/l is:

DDT 0.0006 mg/l (less than 1 part in 10 billion)

BHC 0.002 mg/l

Crude dichlorophenol may contain up to 0.5% o-chlorophenol, so that if chlorophenols are not separated out for separate disposal, the waste water could contain 77 kg per day of o-chlorophenol. At the estimated 850 gal/min cooling water flow, the o-chlorophenol content would be 16 mg/l. The first waste water improvement step, as noted above, must therefore be to apply the o-chlorophenol regulation.

Even the salt (sodium chloride) content of the plant waste water would be several times as high as is permitted by the regulation of 85 mg/l of sodium ion, which is equivalent to 0.023% salt.

The amount of treatment necessary depends on the plant location. The cost of this treatment will correspondingly vary. The $1,000,000 allowed for this is an estimate of the cost of reducing the dichlorophenol content to 1 mg/l.

Both form the practical point of view of not creating any waste water problems, and from that of conforming to the unusually strict Turkish regulations, it would be desirable to site the plant where it would be possible to dilute the effluent by discharging it into a large river or into the ocean. The Water Resources Department says a deep disposal well would be permissible only in central Anatolia. Disposal by an evaporation pond is also a possibility in an area where the geography is suitable.

In evaluating proposals for the purchase of technology for this plant, the content of the waste water must be one of the most important concerns.

Meanwhile, further investigation of deep-well disposal possibilities and a search for a suitable site by the ocean or Marmara Sea should be carried out.

V. ECONOMIC AND FINANCIAL QUESTIONS

A. Capital investment

Capital investment is extremely difficult to estimate at this stage because of unknowns such as plant location and the waste disposal facilities that will be needed, and of the expert's unfamiliarity with equipment and construction costs in Turkey. However, the following estimate was made by using a factor based on the process equipment cost f.o.b. of 1,130,000 (in $):

Total plant (= 4 x process equipment cost)	4,520,000
Import freight	126,000
Waste disposal	1,000,000
Total cost	$5,646,000

However, the TZDK estimate of building costs was obtained, and was $1,800,000 higher than expected. Adding this to the above estimate gives a plant cost of $7,446,000.

An attempt is also made in table 4 below to estimate the plant cost by using the main cost categories. The total by this method is $7,780,000.

Table 4. Estimate of total plant cost by categories of expenditure

Item	Cost in LT	Cost in $	Total cost in $
1. Land	1,500,000		94,000
2. Site improvement	1,000,000		62,000
3. Buildings	45,000,000		2,813,000
4. Equipment			
(a) Transportation	2,000,000		125,000
(b) Utilities	1,500,000	50,000	144,000
(c) Office	500,000		31,000
(d) Laboratory and shop	400,000	75,000	100,000
(e) Process	3,000,000	943,000	1,130,000
5. Piping and labour for process equipment and electrical installation	9,040,000	565,000	1,130,000
6. Waste disposal	8,000,000	500,000	1,000,000
7. Engineering	800,000	300,000	350,000
8. 20% contingency on items No. 4 (b) to No. 6	4,500,000	517,000	798,000
Total	77,240,000	2,950,000	7,780,000

Although there happens to be little difference between the two totals, this cannot be taken to mean they are correspondingly accurate. At this stage a margin of ± 20% is the most that can be expected so far as accuracy is concerned.

For purposes of calculating depreciation, interest on investment, and foreign exchange, a figure of $7,800,000 or LT 125,000,000 has been used. Of this, 62% would be spent in Turkey.

The process equipment is estimated mainly for a United States-style plant. Some substantial equipment savings could be made by using simpler equipment and more labour, particularly in the case of the rotary vacuum filters and centrifuges, where a saving haps $150,000 could be made.

The plant design is based on an output of 4,350 t/a of 2,4-D acid and 650 t/a of 2,4,5-T acid as requested by TZDK. However, half of this capacity will not be needed for the first 5 years, so this may offer an opportunity to reduce the capital investment.

The estimated sizes for buildings should be rechecked, since when they were made it was assumed that building costs were low in Turkey, and the sizes may therefore be overestimated. The process building design is also affected by the climate at the plant location and by the technology used.

Estimates for items No. 1 to No. 4 (c) were made by TZDK using the expert's estimated requirements for process, maintenance, warehouse and laboratory building sizes. No engineering charge was made to buildings on the assumption that this is included in the cost of the buildings.

The following elements are not covered in table 4:

Interest on expenditures during construction
Training programme for personnal
Process technology

B. Manufacturing costs

Raw material costs for each product are given in table 5 below, with details shown in tables 6 and 7.

Total plant manufacturing costs are given in table 8, and the total costs for each product in table 10.

Table 5. Raw material costs for each stage of production

Product	Proportion of active ingredient (%)	Cost per ton of product (LT)	Cost per ton of product ($)	Cost per ton of active ingredient (LT)	Cost per ton of active ingredient ($)
2,4-D acid	100	22,339	1,396	22,339	1,396
Butyl 2,4-D ester	80	20,877	1,305	26,100	1,631
Isooctyl 2,4-D ester	67	18,652	1,166	26,840	1,678
2,4,5-T acid	100	33,809	2,113	33,810	2,113
Butyl 2,4,5-T ester	82	30,213	1,888	36,850	2,304
Isooctyl 2,4,5-T ester	69	26,809	1,676	38,800	2,425

First a calculation was made of the raw material costs for each stage of production, and these are shown in tables 6 and 7. One reason for calculating the raw material costs separately is that these are basic costs not affected by the variations in plant size, overhead costs, depreciation and interest charges. These costs can be reduced only by a decrease in raw material prices or by obtaining better process technology than estimated.

These costs include only the raw material components of the manufacturing cost. Active ingredient (A.E.) is a common term in the United States, and the Crop Protection Institute has some of its statistics in the form of active ingredient, which it calls "free acid". It will be noticed that the isooctyl esters are cheaper to manufacture than the butyl esters, but more costly in terms of the 2,4-D or 2,4,5-T acid component of the ester.

Table 6. Raw material costs[a] for 2,4-D products

Product and raw materials	Amount needed for product (kg/kg)	Rate of consumption (t/a)	Cost (LT/ton)	Cost (thousand LT/year)
2,4-D acid (4,350 t/a)				
Phenol	0.51	2,220	11,172	24,802
Chlorine	0.79	3,440	3,300	11,352
50% caustic soda	1.20	5,220	5,250	27,405
Monochloroacetic acid	0.60	2,610	12,880	33,617
			Total	97,176
				= 22,339 LT/ton
Isooctyl 2,4-D ester (1,500 t/a)				
2,4-D acid	0.67	1,000	22,339	22,339
Isooctyl alcohol	0.42	630	8,950	5,639
				27,978
				= 18,652 LT/ton
Butyl 2,4-D ester (810 t/a)				
2,4-D acid	0.80	650	22,339	14,520
Butyl alcohol	0.30	240	9,960	2,390
			Total	16,910
				= 20,877 LT/ton

a/ Raw material oosts do not inolude freight costs within Turkey.

The 2,4-D acid and its hydroohloric acid by-product are used and marketed as follows (t/a):

2,4-D acid produotion	4,350
Use for esters	1,650
Balance for sale	2,700

33% hydrochloric acid by-produot	
Net production from 2,4-D acid	2,790
Use for 2,4,5-T aci. production	360
Net for sale or to be neutralized	2,430

Table 7. Raw material costs[a] for 2,4,5-T products

Product and raw materials	Amount needed for product (kg/kg)	Rate of consumption (t/a)	Cost (LT/ton)	Cost (thousand LT/year)
2,4,5-Trichlorophenol (575 t/a)				
1,2,4,5-Tetrachlorobenzene	1.1	630	15,668	9,870
Caustic soda flake	0.55	315	6,200	1,953
Methyl alcohol	0.55	315	4,500	1,418
			Total	13,241
				= 23,027 LT/ton
2,4,5-T acid (650 t/a)				
2,4,5-Trichlorophenol	0.88	575	23,027	13,241
50% caustic soda	1.20	780	5,250	4,095
Monochloroacetic acid	0.55	360	12,880	4,637
33% hydrochloric acid	0.55	360	-	-
			Total	21,973
				= 33,809 LT/ton
Isooctyl 2,4,5-T ester (720 t/a)				
2,4,5-T acid	0.70	500	33,809	16,905
Isooctyl alcohol	0.37	268	8,950	2,398
			Total	19,303
				= 26,809 LT/ton
Butyl 2,4,5-T ester (183 t/a)				
2,4,5-T acid	0.82	150	33,809	5,071
Butyl alcohol	0.25	46	9,960	458
			Total	5,529
				= 30,213 LT/ton

a/ Raw material costs do not include freight costs within Turkey.

Table 8. Total manufacturing costs

Item		Cost (thousand LT/year)
Raw materials		130,034
Personnel		
Production labour and supervision		2,400
Maintenance		700
Warehouse and shipping		300
General plant		2,000
	Total personnel cost	5,100
Maintenance materials		3,000
Waste disposal expenses		3,000
Steam, water, electricity		2,000
Other general plant expenses		1,500
Depreciation		
10% on equipment		7,700
5% on buildings etc.		2,300
	Total depreciation	10,000
Interest on fixed investment		
125,000,000 x 13.75% (including tax)		17,200
Interest on working capital		
46,747,000 x 15%		7,000
	Total costs	178,834

Of the total cost given in table 8, the amount used for processing operations is 48,800,000 LT/year (see table 9).

There was not enough time and information available to make estimates of some items of plant expense. However, since 90% of the manufacturing costs is accounted for by raw materials, personnel, interest and depreciation, more detailed estimates are relatively unimportant at the current stage.

Working capital was taken as a one-month supply of raw materials plus a three-month supply of finished products. The products are used only during the wheat-growing season, and the demand in any season will vary according to weather conditions. The plan is to operate the plant steadily through the year, so that there will be a considerable accumlation of inventory during the slaok season. The actual seasonal buying pattern should be checked more thoroughly.

For the degree of accuracy needed at this stage it is not necessary to oalculate separately the various items of processing costs. The capital investment in process equipment is a good guide for a preliminary cost distribution, so this was used in the following table.

Table 9. Distribution of processing costs

Produot	Cost of process equipment (LT)	Proportion of total (%)	Processing cost (thousand LT/year)	Processing cost (LT/ton)
Diohlorophenol	84,800	48	23,424	5,385
2,4-D aoid	400,100			
2,4,5-Trichlorophenol	113,300	36	17,568	27,028
2,4,5-T acid	243,300			
Butyl 2,4-D ester Butyl 2,4,5-T ester	81,200	8	3,904	3,932
Isoootyl 2,4-D ester Isoootyl 2,4,5-T ester	83,200	8	3,904	1,759
Totals	1,004,000		48,800	

Table 10. Manufaoturing cost for each product

Product	Production rate (t/a)	Manufacturing costs (LT/ton)	(thousand LT/year)
2,4-D acid	2,700		
Raw materials		22,339	
Processing		5,385	
		27,724	74,855
Butyl 2,4-D ester	810		
Raw materials		20,877	
Processing (0.80 x 5,385) + 3,932		8,240	
		29,117	23,585
Isooctyl 2,4-D ester	1,500		
Raw materials		18,652	
Processing (0.67 x 5,385) + 1,759		5,367	
		24,019	36,029
Butyl 2,4,5-T ester	183		
Raw materials		30,213	
Processing (0.82 x 27,028) + 3,932		26,095	
		56,308	10,305
Isooctyl 2,4,5-T ester	720		
Raw materials		26,809	
Processing (0.70 x 27,028) + 1,759		20,678	
		47,487	34,191
Total			178,965

The total manufacturing cost given in table 10 is approximately the same as in table 8.

C. Economic viability

The following four cases sum up the detailed calculations and estimates made below. Specific figures for the individual cases appear in table 11.

Case 1. Production and sales for operations at 100% plant capacity compared with import costs at 1975-1976 average prices.

Case 2. Production and sales for operations at 100% plant capacity compared with imports at 1976 prices.

Case 3. Production and sales during the first five years of operations at the expected average production rates of 39.1% of 2,4-D capacity and 62.8% of 2,4,5-T capacity, compared with imports at 1975-1976 average prices.

Case 4. Production and sales at the expected average rates of the first five years compared with imports at 1976 prices.

Table 11. Estimated return on new plant

Case	Import costs	Cost of production (LT)	Gain or loss (LT)	
1	187,587,000	178,965,000	+ 8,622,000	(+ 4.6%)
2	137,506,000	178,965,000	-41,460,000	(-30%)
3	85,298,000	97,365,000	-12,067,000	(-14%)
4	65,538,000	97,365,000	-31,827,000	(-49%)

Assuming the $2,950,000 needed for importing equipment to build the plant is borrowed from abroad at 8% interest, then the foreign exchange balance in each case, compared with the cost of importing the products, will be:

Case 1: +$5,839,000

Case 2: +$2,709,000

Case 3: +$2,457,000

Case 4: +$1,222,000

Table 12 shows the 1975 and 1976 import prices paid for the products.

Table 12. 1975 and 1976 import prices

Product	1975 prices ($/ton)	1976 prices[a/] ($/ton)	Average prices ($/ton)	Average prices (LT/ton)
2,4-D acid	2,142	1,250	1,696	27,136
Butyl 2,4-D ester	2,163	1,310	1,737	27,792
Isooctyl 2,4-D ester	b/	1,300	1,724[c/]	27,584
Butyl 2,4,5-T ester	b/	d/	3,800[e/]	60,800
Isooctyl 2,4,5-T ester	3,443	3,380	3,412	54,592

a/ The reduction in import prices from 1975 to 1976 is greater for 2,4-D products than for 2,4,5-T products.

b/ No prices obtainable.

c/ Estimated by using the ratio of prices of butyl and isooctyl 2,4-D esters in 1976.

d/ No imports in 1976.

e/ Estimated by using the 1974 ratio of the prices of butyl and isooctyl 2,4,5-T esters.

Table 13 contains a comparison of the above 1975-1976 average import prices with the estimated manufacturing costs at 100% capacity given in table 10.

Table 13. Comparison of estimated manufacturing costs and 1975-1976 average import prices

Product	Import costs (LT/ton)	Manufacturing cost (LT/ton)	Import costs (LT/year)	Manufacturing cost (LT/year)
2,4-D acid	27,136	27,724	73,267,000	74,855,000
Butyl 2,4-D ester	27,792	29,117	22,512,000	23,585,000
Isooctyl 2,4-D	27,584	24,019	41,376,000	36,029,000
Butyl 2,4,5-T ester	60,800	56,308	11,126,000	10,305,000
Isooctyl 2,4,5-T ester	54,592	47,487	39,306,000	34,191,000
Total			187,587,000	178,965,000

Table 13 therefore shows that the net gain by manufacturing is 8,622,000 LT/year (=4.6%).

Using the 1976 import prices, the total import cost is 137,506,000 LT/year, or a loss by manufacturing of 41,460,000 LT/year. The manufacturing cost is then 30% higher than the importation cost.

The above figures are based on operation at 100% capacity. However, aooording to the TZDK market projection, this rate of production will not be needed until 1991 (see table 2). For the first five years of operation, the projected demand (after subtracting the expected private industry production at Gelibolu) is an average of 1,701 tons/year of 2,4-D and 408 tons/year of 2,4,5-T. If the plant operates below its capacity during the first years, the manufacturing cost per ton is included in the amount of fixed costs to be applied to the smaller production. An estimated 67% of the processing cost (see table 9) would be a fixed cost. This amounts to 32,700,000 LT/year.

The estimated production and import costs were based on the anticipated average net demand for the first five years (1979-1983). On this basis, for 2,4-D products the plant would operate at 39.1% (=1,701/4,350) capacity, and for 2,4,5-T products, at 62,8% (=408/650) capacity. Assuming that 67% of processing costs are fixed, the 2,4-D processing cost increase is:

$$0.67 \times 1/0.391 = 1.71$$
$$0.33 \times 1 = \underline{0.33}$$
$$2.04 \times \text{cost at } 100\% \text{ capacity}$$

The 2,4,5-T processing cost increase is:

$$0.67 \times 1/0.628 = 1.07$$
$$0.33 \times 1 = \underline{0.33}$$
$$1.4 \times \text{cost at } 100\% \text{ capacity.}$$

Re-calculating the cost data in tables 10 and 13 gives the new manufacturing and import costs contained in table 14 below.

Table 14. Revised manufacturing and import cost estimates for 1979-1983

Product	Tons per year	Manufacturing cost (LT/year)	Import cost (LT/year)
2,4-D acid	1,056	35,190,000	28,656,000
Butyl 2,4-D ester	317	11,950,000	8,810,000
Isooctyl 2,4-D ester	586	17,346,000	16,164,000
Butyl 2,4,5-T ester	115	7,676,000	6,992,000
Isooctyl 2,4,5-T ester	452	25,203,000	24,676,000
Total		97,365,000	85,298,000

Table 14 therefore shows manufacturing cost to exceed import cost by LT 12,067,000, or 14%.

At 1976 import prices the average cost of imports for the first five years is reduced by 23% to LT 65,538,000/year. This is LT 31,827,000/year less than manufacturing costs.

D. Foreign exchange

Foreign exchange cannot be estimated without knowing how much foreign capital and what interest rate would be used to finance plant construction. However, an estimate based on operation at 100% capacity is given below.

1. Imported raw materials	$5,449,000
2. Estimated annual cost of supplies imported for maintenance, waste treatment etc.	200,000
	$5,649,000
3. If the funds spent outside Turkey for plant construction are covered by an 8% foreign loan, the annual interest is $2,950,000 x 8% =	$ 236,000
Total per year	$5,885,000

By comparison with the foreign exchange needed to import the products at the average 1975-1976 prices, i.e. LT 187,587,000 = $11,724,000 (see table 11), the annual gain in foreign exchange as a result of building the plant is $5,839,000/year.

Using 1976 prices for the products, the import costs amount to $8,594,000, or a foreign exchange saving of $2,709,000/year.

If the plant operates during the first five years at 39.1% capacity for 2,4-D and 62.8% capacity for 2,4,5-T, at 1975-1976 prices the following results are obtained:

Imported raw materials	$2,438,000
Other imported supplies	200,000
Interest 8%	236,000
	$2,874,000
Import costs	$5,331,000

The saving on foreign exchange is now $2,457,000/year.

If the plant operates at the above 39.1% and 62.8% capacities and if 1976 import prices are used for the products, then:

Import of products	$4,096,000
Raw materials etc., as above	2,874,000
Foreign exchange saving	$1,222,000/year

VI. CONCLUSIONS AND RECOMMENDATIONS

The data in this report can now be studied by an economist who could recommend whether the gain in foreign exchange for 2,4-D and 2,4,5-T manufacture is sufficiently attractive to offset the subsidy that would be needed to make up for the higher cost of domestic manufacture compared to import prices. Although the figures in this report are in some cases only rough estimates, in total the estimates are believed to be accurate enough for such a decision.

If this decision is favourable then several aspects should be further studied in order to forestall potential problems and to explore ways and means of reducing the capital and/or operating costs.

A. Conclusions

1. Based on 1976 and average 1975-1976 import prices, and assuming that the $3,000,000 needed for imported equipment and services to build the plant is obtained as an 8% long-term foreign loan, the estimated foreign exchange savings resulting from the replacement of imports by local production could vary from $1,200,000 to $5,800,000, depending on the level of plant operations as a percentage of total capacity.

2. The proposed scale of production could be reduced about 50% in the initial installation, with space left to add additional units as needed in future years.

3. No definite site for the plant has been selected. The proposed site at Aliaga seems unsatisfactory from the point of view of water supply and waste disposal, while the site at Seriflikochisar, west of Tuz Gölü, should be further studied before a final decision is taken. The waste disposal situation needs much more investigation. The $1,000,000 estimated for this might be reduced to between $100,000 and $200,000 if deep well disposal is favourable at Ekstas or a similar site. Perhaps some 2,4-D companies have developed technology that would reduce this cost. On the other hand, it is also possible that, although this is a figure that has twice been estimated for comparable plants in the United States, it might turn out to be much more expensive in Turkey.

4. The market for the hydrochloric acid by-product could represent a substantial cost saving. Using the delivery price of LT 3,500/ton Petkim refinery is paying, the 2,340 t/a could bring in LT 8,190,000 per year.

5. A major problem is the lack of experienced chemical engineers. For this reason a turn-key type of plant has been assumed. If experienced engineers were available, then it would be possible to reduce the capital cost very substantially by contracting only for know-how, purchasing the equipment directly from suppliers, and sub-contracting the construction work to Turkish firms. This would also make possible more flexibility in adjusting the size and design of the plant to meet changing conditions.

6. Inquiries need to be made to locate the best available technology.

B. Recommendations

1. A study should be made of steps which might be taken to integrate this plant with another plant so as to reduce both capital investment in general plant facilities and operating and overhead costs. Two private companies, Ekstas and Koruma, are interested in discussing this, and other possibilities are Petkim in Aliaga or certain state-owned companies, such as paper or fertilizer companies. This recommendation is made only as a general principle, since the expert is not familiar with chemical plants in Turkey. The alternative of the installation of a smaller initial plant might also be considered.

2. The experience of the Turkish Petroleum Co. in drilling an exploratory well near Seriflikochisar should be studied in relation to the deep-well disposal possibilities in this area. The Water Resources Department has indicated that upon receipt of an application it would look for a site for an evaporation lake in the Seriflikochisar area. This proposal should be followed up.

3. Both the market for hydrochloric acid by-product and the export market to Middle East countries should be studied more thoroughly.

4. If experienced chemical engineers cannot be recruited in Turkey, then some form of joint venture should be considered, as mentioned in recommendation No. 1 above.

5. With regard to raw materials requirements and the capital cost for process equipment, companies producing 2,4-D and 2,4,5-T should be contacted to learn if they have any technology to license that might substantially reduce costs.

6. As mentioned above in the section on capital investment, consideration should be given to the use of equipment requiring less capital but more labour in the manufacturing process.

7. A study should be made with a view to providing better estimates of 2,4-D and 2,4,5-T world market prices that can be expected in the next few years, and of the forecast development of the market in Turkey. These prices should then be used as a basis for the economic study of the proposed plant.

Annex I

PROCESS DESCRIPTIONS

Brief outlines of the manufacturing process for each item are included in this annex together with block flow diagrams. No separate diagram for 2,4,5-T acid was made since it is almost a duplicate of the 2,4-D process.

There is some variation in process details among various manufacturers. The processes described are those which seem to be the most common. Some minor changes in the processes and in the equipment lists have been made to avoid disclosure of proprietary know-how.

Product specifications were not investigated, but these processes will provide at least the normal commercial quality, and probably better results than some of the material being imported.

One point that must be remembered is that no drying facilities for 2,4-D acid have been included. The planned product is a moist crystalline material containing 10% water. This is very useful to the formulators preparing the amine solutions, since it is necessary to add water in the amine formulations.

A description of some alternative processes in commercial use is included at the end of this annex.

A. Basic processes

2,4-Dichlorophenol

Phenol is chlorinated to diohlorophenol (DCP) by a batch process in the liquid phase. The product is mostly the 2,4 isomer, and by using a catalyst a product of the following composition oan be obtained:

2,4-Diohlorophenol	92%
2,6-Dichlorophenol	6%
O-Monoohlorophenol	0.5%
2,4,6-Trichlorophenol	1.5%

Molten phenol is charged to eaoh chlorinator and a small amount of oatalyst added. Liquid ohlorine from a tank is fed to a steel, steam-jacketed chlorine evaporator. The ohlorine gas is fed to each chlorinator through a sparger pipe to diffuse the gas into the liquid phenol. The chlorination reaction is exothermic. The heat of reaction is removed by cooling water in the jackets of the chlorinators.

The chlorine is completely absorbed in phenol. The HCl gas by-product contains traces of chlorophenols which are mostly removed by scrubbing the HCl gas. The HCl gas is then absorbed in a standard falling-film HCl absorber to produce hydrochloric acid for sale. The HCl absorber included in this plant design is for the production of 33% acid, but higher strengths can easily be produced from this gas stream by designing the absorber accordingly. The hydrochloric acid is of good commercial quality, and high purity acid can be produced by using high purity water for the absorbtion and addition of a second scrubber.

The crude DCP containing about 92% of the 2,4 isomer can be used without further purification to produce 2,4-D, and the following outline is based on this procedure. Alternative purification methods are discussed below in the section devoted to alternative processes.

2,4,5-Trichlorophenol

This is made by the reaction of 1,2,4,5-tetrachlorobenzene with flake caustic soda, with methyl alcohol being used as a reaction medium. It can be done on either a batch or a semi-continuous basis.

A jacketed, agitated, steel autoclave designed for 500-1,000 psig is used for the reaction. After the completion of the reaction the methanol is distilled off and is then redestilled and used again. The next step is to steam out the small amount of trichloroanisole which is formed. This is recovered and recycled. Either before or after the anisole stripping, most of the sodium chloride present is filtered out, washed and discarded.

The excess caustic soda present is neutralized with hydrochloric acid and the resulting solution of 30% to 40% sodium 2,4,5-trichlorophenate is ready to be used in the 2,4,5-T reactor. Two very serious problems have arisen in the manufacture of 2,4,5-trichlorophenol. An extremely toxic material, commonly called dioxin, is formed in small amounts unless proper operating conditions are strictly followed. In trace amounts this is teratogenic, causing birth defects, in larger amounts it causes skin disorders commonly called chloracne, and in yet larger amounts affects the liver and can cause death. A second and related problem is that the reaction is exothermic and can get out of control, rupturing the autoclave, and the accompanying high temperatures can form dioxin.

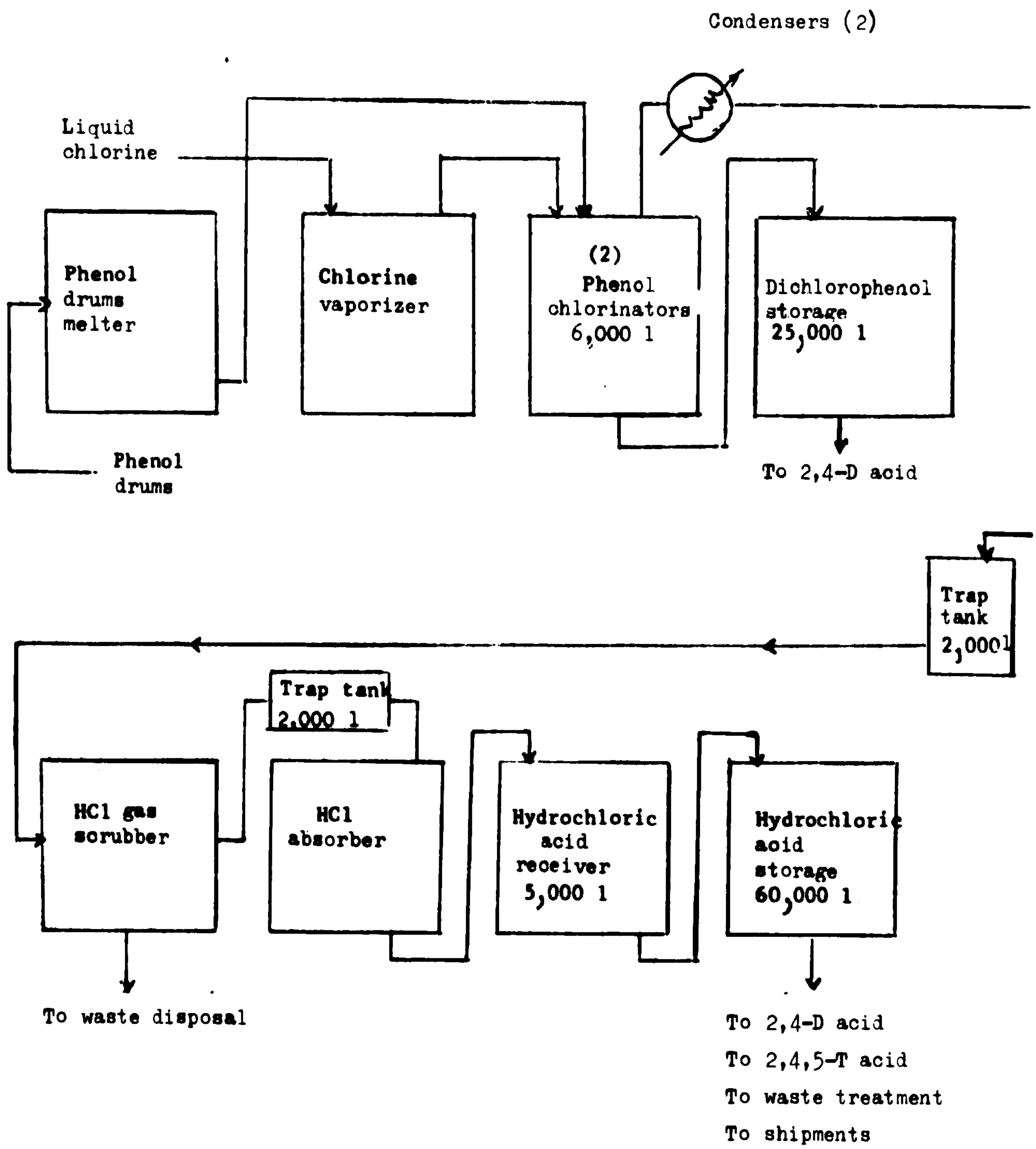

Figure II. Dichlorophenol production process

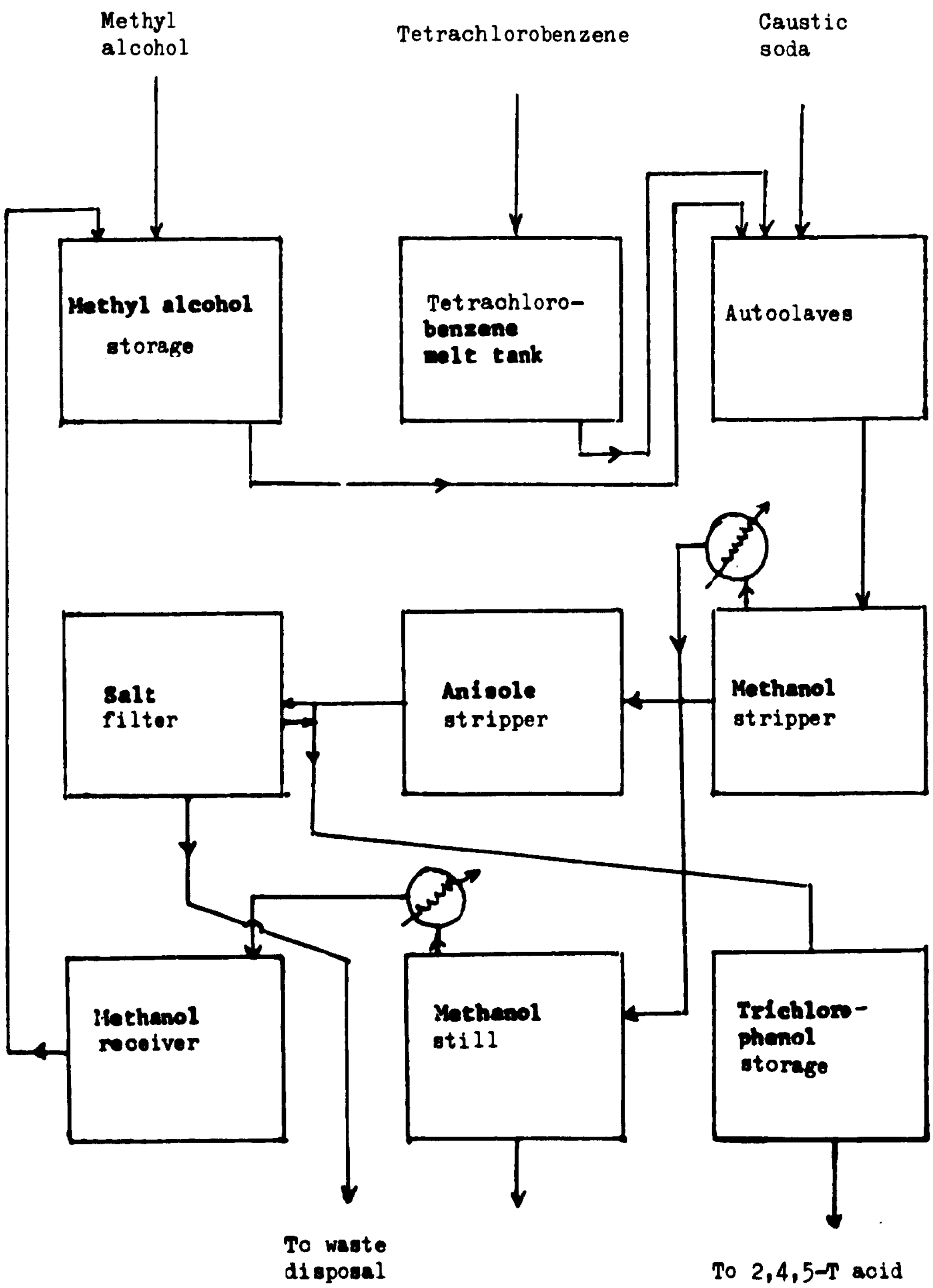

Figure III. 2,4,5-Triohlorophenol production prooess

Autoclave ruptures occured at three plants in the United States between 1950 and 1960. In the late 1950s a severe outbreak of chloracne in a German plant led to research there which identified the presence of dioxin as the cause, and led to the development of the plant operating procedure necessary to prevent its formation. In the 1960s two United States plants had severe operating problems when they tried to operate beyond their equipment capacity to meet the temporary large military demands as a defoliant in Viet Nam.

The expert does not know whether the disaster that happened during the summer of 1976 at the Hoffmann-La Roche plant in Italy was caused by inadequate design safeguards or careless operation, but he has been informed that the plant does not plan to resume trichlorophenol production.

Although it seems clear that 2,4,5-Trichlorophenol can be safely manufactured, the expert does not know whether the experienced chemical manufacturing personnel are currently available in Turkey to make such a project risk-free.

<u>2,4-D acid</u>

2,4-D acid manufacture consists of the chlorination of phenol to produce dichlorophenol, the reaction of dichlorophenol with monochloroacetic acid and caustic soda to produce 2,4-D sodium salt, and acidification of the 2,4-D salt to produce 2,4-D acid. Chlorine gas is bubbled into liquid phenol and the HCl gas by-product is absorbed in water to produce 33% hydrochloric acid. The chlorination is stopped when the phenol has been almost all converted to dichlorophenol. About 92% of this dichlorophenol is the 2,4 isomer; the balance is 2,6-dichlorophenol isomer that is subsequently discarded as waste material.

Dichlorophenol, monochloroacetic acid and 50% caustic soda are reacted in a vessel having an agitator of special design and under carefully controlled conditions of temperature and pH to form a thick slurry of 2,4-D sodium salt. An important objective in this reaction is to minimize the hydrolysis of monochloroacetic acid to glycolic acid. This slurry is cooled, filtered and the solid 2,4-D sodium salt on the filter is washed with sodium chloride solution. The filtrate which contains sodium chloride, sodium glycolate and the sodium salt 2,6-dichlorophenol is discarded.

The 2,4-D sodium salt is slurried in water and acidified with hydrochloric acid (using some of the hydrochloric acid from the phenol chlorination). The resulting slurry of 2,4-D acid is centrifuged. The 2,4-D acid is washed on the centrifuge to yield a product containing 90% 2,4-D acid and 10% water.

The wet 2,4-D acid is packaged in fibre drums with polyethylene liners. Except in the case of export shipments, it is not economical to dry the 2,4-D acid since it is much easier to remove the 10% water during the esterification process than it is to buy and operate an expensive 2,4 dryer. The wet 2,4-D acid is also easier to handle because it is not dusty.

All steps in the 2,4-D process are carried out on a batch basis. The fumes of dichlorophenol are particularly objectionable and all vessels are connected to a fume scrubber.

The filtrate from the centrifuge contains about 10% NaCl. A portion of this filtrate is neutralized with NaOH and used for the wash water on the rotary filter mentioned in the second paragraph.

The filtrate from the rotary filter is treated to recover some of the 2,4-dichlorophenol that is recycled to the 2,4-D reactors.

2,4,5-T acid

The basic chemical process for 2,4,5-T is essentially of the same type of that for 2,4-D. However, the production capacity for 2,4,5-T is smaller due to the nature of the 2,4,5-T crystals; thus, using the same size vessels one can only produce one third to one half the amount of 2,4,5-T as compared with 2,4-D using the same size vessel in any one batch.

2,4,5-trichlorophenol or sodium 2,4,5-trichlorophenate solution is reacted with monochloroacetic acid and 50% caustic soda. The resulting sodium salt is filtered and washed in the same manner as 2,4-D. The filtrate is not discarded but is acidified with hydrochloric acid in order to recover the unreacted trichlorophenol which is used again as raw material.

The acidification and centrifugation steps are the same as those for 2,4-D acid; however, the wet 2,4,5-T acid obtained from the centrifuge contains 25% to 30% water.

Fumes from the 2,4,5-T process are less objectionable than from 2,4-D, but the same fume scrubber system is used. The liquid waste contains less chlorophenols and is easier to handle than the effluent from 2,4-D manufacture.

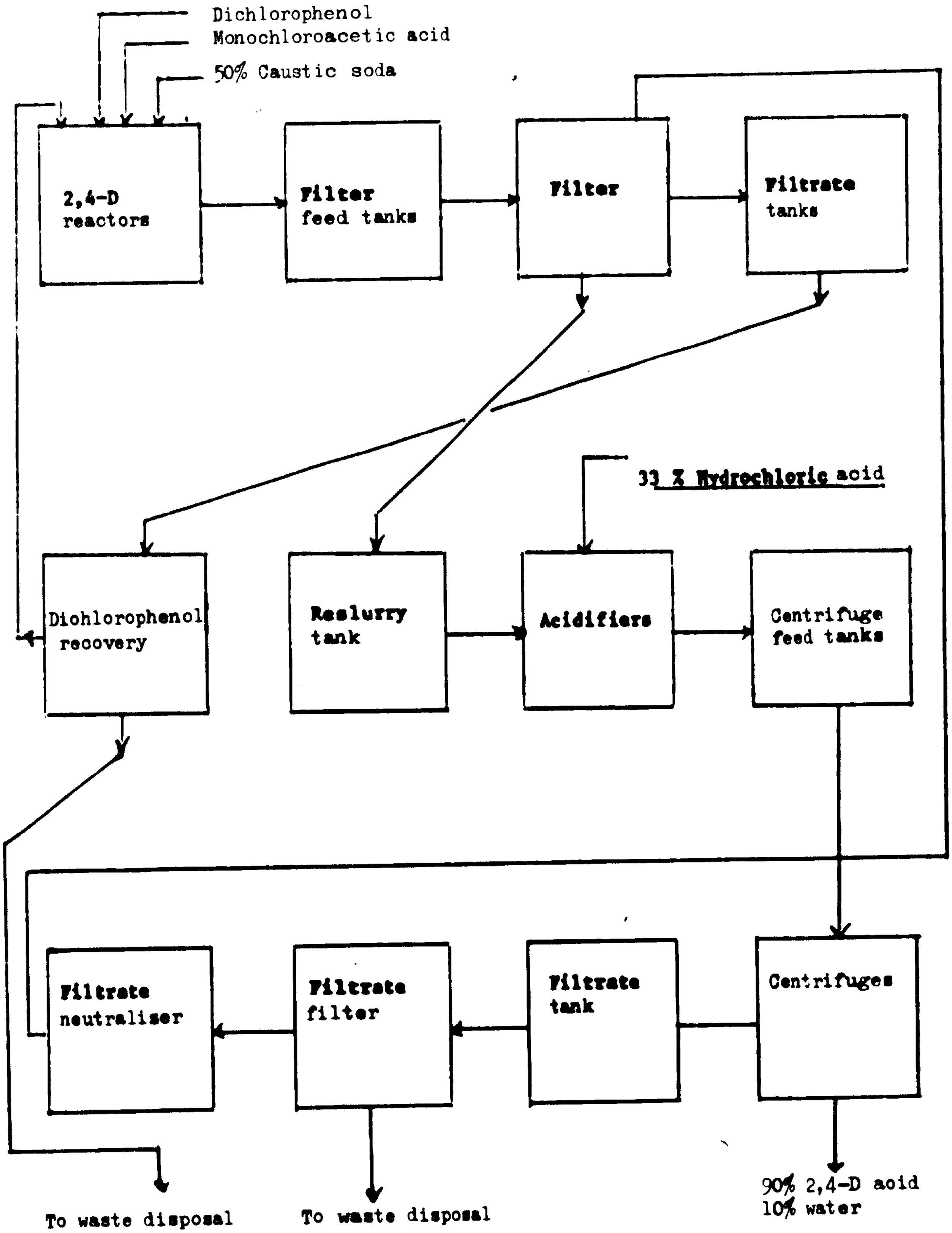

Figure IV. 2,4-D acid production process

B. Alternative processes

1. The dichlorophenol may be distilled in a fractionating oolumn and thus obtain a 98% to 99% 2,4-dichlorophenol purity. In this case all of the unreacted dichlorophenol may be recovered by acidifying the filtrate from the rotary filter, separating the lower layer of dichlorophenol and recycling it to the reactor. This improves the raw material usage, but the distallation equipment and operation is expensive. The 2,6-dichlorophenol separated out by distillation may be used to make pentachlorophenol or discarded.

2. Instead of filtering the product from the 2,4-D reactors, the unreacted chlorophenols may be removed by reducing the pH to 5 with hydrochloric acid and then steam-distilling out the phenols.

3. Where only esters are needed, as in the case of 2,4,5-T in this project, a method sometimes employed is to react the monochloroacetic acid with the butyl or isooctyl alcohol, then react this product with the sodium salt of the 2,4,5-trichlorophenol.

4. The acidification, washing and separation of 2,4-D and 2,4,5-T acids can be done with the acid in a molten phase. In this case the product is a hot liquid which can be charged in that form to the esterifiers or dried and flaked to produce dry 2,4,5-T acid.

5. Instead of a rotary vacuum filter a Nutsch type vacuum filter can be used. Instead of a centrifuge, a Nutsch filter or a rotary vacuum filter can be used. Carbon steel reactors can be used instead of stainless steel.

6. If the selling price of hydrochloric acid is higher than the purchase price of sulfuric acid, sulfuric acid is used for the acidification step.

7. If purified 2,4-dichlorophenol is used as in process No. 1 described above, the ratio of monochloroacetic to dichlorophenol charged to the reactors is reduced, thereby decreasing the amount of monochloroacetic needed per unit of product.

Butyl 2,4-D and 2,4,5-T esters

These two esters are made in exactly the same manner and with the same equipment.

The esterifier is charged with the acid and an amount of butyl alcohol considerably in excess of the theoretical amount. A small amount of a catalyst such as benzene sulfonic acid, phosphoric acid or sulfuric acid is added.

This mixture is heated and boiled as vigorously as possible. The condensed vapors consisting of water and butyl alcohol are separated in a decanter; the lower water layer flows continuously to a receiver and the upper butyl alcohol layer returns to the esterifier.

When a test indicates the esterification is nearly complete, the butyl alcohol overflow from the decanter is switched to a receiver. When condensate flow stops, a vacuum is applied to distill off the remaining small amount of butyl alcohol. When distallation stops, the batch is cooled to about 40°-50°C, then the mixer is stopped for about 1/2 hour. The catalyst layer is drained from the bottom of the mixer. The batch is then pumped to storage through a pressure filter that has been pre-coated with Filter-aid.

The water layer from the decanter is distilled in a small still having a fractionating column in order to recover the 20% of alcohol dissolved in it.

<u>Isooctyl 2,4-D and 2,4,5-T esters</u>

These two esters are made by exactly the same method and with the same equipment. Equimolar quantities of the acid and of isooctyl alcohol are charged to an esterifier and heated, with the water that distills off being condensed and collected. There is no condensate returned to the esterifier. A catalyst is not necessary but may be used to speed up the esterification. A vacuum is used to help speed up the water removal.

After several hours a test is made to check that the alcohol and the acid are a 1-1 ratio, and more of either one is added if necessary. When a test shows the esterification is finished, the batch is cooled to 40°-50° and filtered to storage.

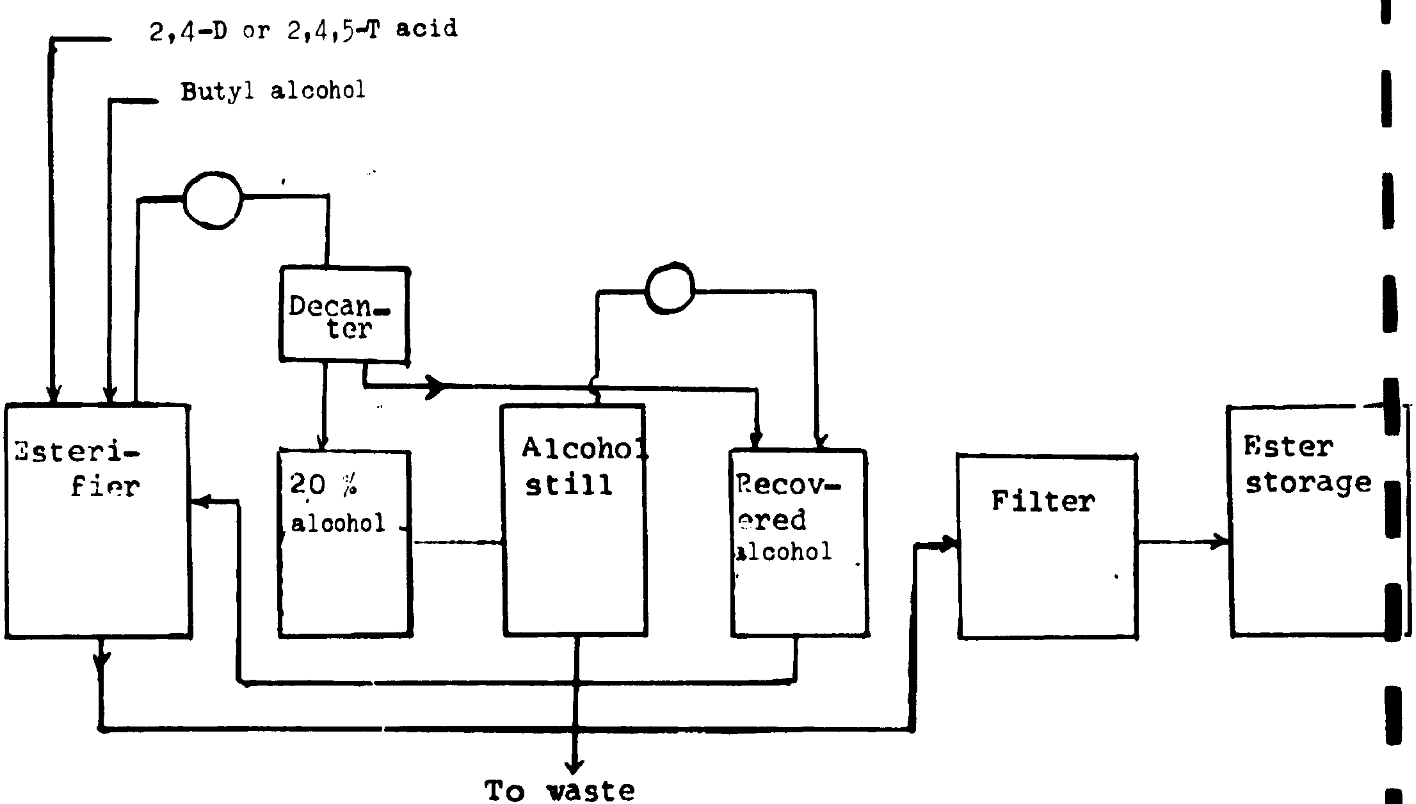

Figure V. Butyl 2,4-D and 2,4,5-T esters production process

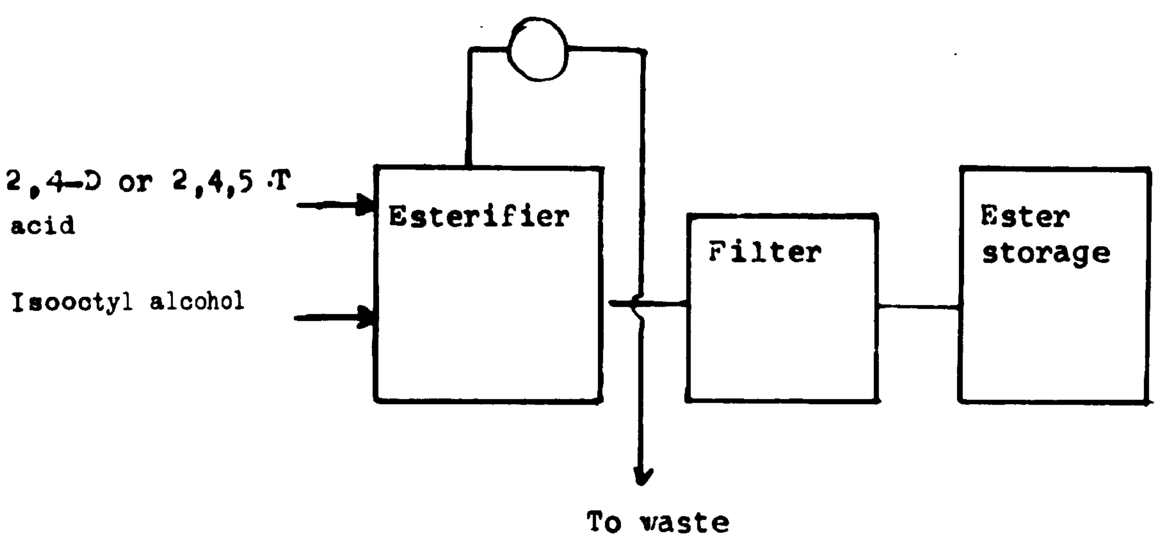

Figure VI. Isooctyl 2,4-D and 2,4,5-T esters production process

Annex II

PROCESS EQUIPMENT COST SUMMARY AND LISTS

Process equipment cost summary

	Local equipment costs (LT)	Imported equipment costs ($)	Total costs ($)
2,4-Dichlorophenol	707,000	40,600	84,800
2,4,5-Trichlorophenol	554,000	76,700	111,300
2,4-D acid	935,000	341,700	400,100
2,4,5-T acid	453,000	215,000	243,300
Butyl esters	195,000	69,000	81,200
Isooctyl esters	147,000	74,000	83,200
(+ 5% for export packaging)		41,000	41,000
(+10% for ocean freight)		85,000	85,000
	2,991,000	943,000	1,130,000
			= LT 18,079,000

2,4-Dichlorophenol equipment list

	Cost (LT)	Cost ($)
Hot room for melting drums of phenol	30,000	
Phenol pump, steel, 3 hp, 50 gpm		800
Phenol feed tank, 1/4" steel, 300 l	12,000	
Chlorine evaporator		2,500
Chlorine pressure controller		2,000
Phenol chlorinators (2), 1/2" steel, jacketed, 6,000 l	200,000	
Chlorinator condensers (2), Karbate, 60 sq ft		5,000
Trap tanks (2), 1/4" steel, 500 l	4,000	
DCP pumps (2), steel and alloy, 3 hp, 50 gpm		2,000
Gas-scrubbing column, steel, 1 m diameter x 6 m high	20,000	

	Cost (LT)	Cost ($)
Packing for gas scrubbing column	10,000	
Trap tank 1/4" steel, 2,000 1	9,000	
HCl absorber, Karbate, 1,000 lb HCl/h		20,000
Steel supports for HCl absorber	15,000	
33% HCl tank, polyester, 500 1	20,000	
Pump for 33% HCl (3), RL or polyester, 5 hp, 100 gpm		4,500
33% HCl storage tanks (4), steel, 20,000 1	300,000	
DCP storage tank, 3/8" steel, 25,000 1	80,000	
Chlorine rotameters (2)		1,000
Temperature recorders (3), 2-pen		1,500
Circulating pump, 316 SS, 2 hp, 25 gpm		1,500
Scrubber reservoir tank, 3/8" steel, 2,500 1	16,000	
Fume-scrubbing column, pyrex, packed, 6" diameter		1,000
Rotameter for HCl absorber		300
Temperature regulators (2), self-contained, 1/2" steam valves		500
Totals	707,000	40,600

2,4,5-Trichlorophenol equipment list

	Cost (LT)	Cost ($)
Tetrachlorobenzene melt tank, steel, nickel coil, 4,000 1	50,000	5,000
Tetrachlorobenzene pump, steel, jacketed, piston type, 5 gpm		3,000
Autoclave, steel, jacketed, agitator, 2,200 gal		30,000
Autoclave condenser, steel, 100 sq ft		1,500
Methanol stripper, steel, jacketed, agitator, 8,000 1	50,000	3,000
Slurry pump, steel, 5 hp		1,500
Methanol condenser, 2.00 sq ft		1,500
Distillate receiver, steel, 5,000 1	1,500	
Salt filter		5,000
Filtrate storage tank, 1/4" steel, 6,000 1	20,000	

	Cost (LT)	Cost ($)
Filtrate pump, steel, 3 hp		1,200
Steam stripper, 3/8" steel, 10,000 l	50,000	
Stripper condenser, steel, 200 sq ft		1,500
NaTCP pumps (2), steel, 5 hp		2,500
Anisole receiver, steel, 8,000 l	6,000	
Anisole pump, steel, 2 hp		1,200
Anisole storage tank, 1/4" steel, 8,000 l	20,000	
NaTCP storage tanks (2), 3/8" steel, 40,000 l	200,000	
Crude methanol tank, steel, 2,000 l	20,000	
Methanol pumps (3), steel, 2 hp		3,600
Methanol still pot, 3/8" steel, 100 sq ft	30,000	
reboiler, 5,000 l	30,000	1,500
Methanol still column, steel, 18" diameter x 16' high	40,000	
Methanol receiver, steel, 4,000 l	12,000	
Methanol storage tank, steel, 15,000 l	30,000	
Fume scrubber	26,500	6,000
Methanol meter		1,000
Flow meters (5)		2,500
Temperature recorders (2)		800
Temperature controllers (3)		3,000
Pressure recorder		400
Pressure controller		1,000
Total	554,000	76,700

2,4-D acid equipment list

	Cost (LT)	Cost ($)
50% caustic storage tanks (2), steel, 30,000 l	120,000	
50% caustic pump, steel, 5 hp, 50 gpm		1,100
50% caustic feed tank, 1/4" steel, 3,000 l	12,000	
DCP measuring tank, 3/8" steel, 3,000 l	18,000	
2,4-D reactors (2), 316 SS, 30 hp agitator, jacketed, 10,000 l		75,000
2,4-D reactor condensers (2), steel, 50 sq ft	20,000	
Filter feed tanks, 3/8" steel, jacketed for 25 psi, 8,000 l	150,000	
Agitator gear reducer and motor for filter feed tanks (2)		4,000
Reactor pumps (2), 316 SS, 7 1/2 hp, 75 gpm		3,000
Filter feed tank pumps (2), steel, gear type, 5 hp		2,000
Rotary vacuum filter, steel with stainless trim, 8' diameter x 7' long, and including:		40,000
50 hp vacuum pump Vacuum receivers Filtrate and wash liquor pumps Spray nozzles and headers		
Enclosure and discharge chute for rotary vacuum filter	15,000	
Slurry tank, 1/4" steel, 12,000 l	80,000	
Agitator, gear reducer and motor for slurry tank		3,000
Pump for slurry tank, steel, 3 hp, 50 gpm		1,000
DCP caustic soda mix tank, 3/8" steel, jacketed, 3,500 l	40,000	
Agitator, gear reducer and motor for DCP caustic soda mix tank		1,500
Pump for DCP caustic mix, steel, 3 hp, 40 gpm		700
Acidulators (2), RL steel, 10 hp agitators, 20,000 l		30,000
Acidulator pumps (2), RL steel, 5 hp, 75 gpm		3,300
Centrifuge feed tank, RL steel, 7.5 hp agitator, 8,000 l	90,000	2,000
Centrifuge feed pump, RL steel, 5 hp, 30 gpm		1,100
Centrifuges (2), RL steel, 48" diameter x 24" high, bottom discharge		110,000

	Cost (LT)	Cost ($)
Filtrate receiver, polyester or RL steel, 2,000		1,100
Filtrate pump, RL steel, 3 hp, 30 gpm		1,100
33% HCl measuring tank, RL steel or polyester 4,000 l	20,000	
Filtrate collecting tank, polyester or RL steel, 12,000 l	50,000	
Neutralizing tank for brine, RL steel or polyester, 4,000 l	40,000	
Agitator, gear reducer and motor for neutralizing tank		1,800
Brine filter, pressure, 316 SS, 30 sq ft		6,000
Brine filter pump, polyester, 3 hp, 30 gpm		1,300
Brine tank, polyester, 2,000 l	15,000	
Brine feed pump, polyester, 2 hp, 30 gpm		1,200
50% caustic measuring tank, steel gauge glass, 5,000 l	5,000	
Fume scrubber 2-stage, 4" water suction, 10,000 cfm	100,000	5,000
20% caustic tank for fume scrubber, 3/16" steel, 2,500 l	10,000	
Caustic pump for scrubber, steel, 7 ½ hp		12,000
DCP recovery unit	150,000	10,000
pH controllers for reactors (2)		4,000
pH meters (2), portable		500
Tank level indicators, manometer type		3,000
Temperature recorders (5), 2-pen, 12" round chart		3,000
Rotameters for caustic steel (3)		800
Water meters (2), batch		1,200
Weigh scale		2,000
Bagging equipment		10,000
Totals	935,000	341,700

2,4,5-T acid equipment list

	Cost (LT)	Cost ($)
50% caustic feed tank, 1/4" steel, 1,000 l	7,000	
2,4,5-T reactor, 316 SS, 20 hp agitator, jacketed, 8,000 l		68,000
Reactor condenser, steel, 50 sq ft	20,000	
Reactor pump, 7.5 hp, 50 gpm		1,500
Filter feed tank, 3/8" steel, jacketed, 7,000 l	120,000	
Agitator for filter feed tank		2,500
Filter feed pump gear, steel, 5 hp		2,000
Rotary vacuum filter, steel with stainless trim, 6' diameter x 6' long, and including:		30,000
40 hp vacuum pump Vacuum receivers Filtrate and wash liquor pumps Spray nozzles and headers		
Enclosure and discharge chute for rotary filter	12,000	
Slurry tank, 1/4" steel, dished bottom, open top, agitator support, 6,000 l	50,000	
Agitator with gear-reducer motor for slurry tank		2,000
Pump for slurry tank, steel, 3 hp, 20 gpm		1,000
Acidifier, RL steel, 10 hp agitator, 20,000 l		15,000
33% HCl feed tank, polyester, 1,200 l	15,000	
Acidifier pump, RL steel, 5 hp, 5 gpm		1,500
Centrifuge feed tank, RL steel, 5 hp agitator, 4,000 l	50,000	2,000
Centrifuge 48" diameter x 24" high, RL steel, bottom discharge		55,000
Filtrate receiver, polyester, 2,000 l	30,000	
Filtrate collecting tank, polyester, 12,000 l	50,000	
Brine neutralizing tank, RL steel or polyester agitator, 3,000 l	30,000	1,600
Brine filter, pressure, 316 SS		6,000
Brine filter pump, SS, 2 hp, 20 gpm		1,200
50% caustic feed tank, steel, 500 l	5,000	
Alkaline filtrate storage tank, 3/8" steel, 10,000 l	40,000	
Filtrate pump, steel, 2 hp		900

	Cost (LT)	Cost ($)
Filtrate acidifier, GL steel, Hastelloy C agitator, 2,000 l		12,000
33% HCl feed tank, polyester, 500 l, with:	10,000	
Trichlorophenol receiver, 1/2" steel, 1,000 l	14,000	
Recovered trichlorophenol pump, 316 SS, 1 hp		1,100
Weigh scale for 2,4,5-T acid, 500 kg		2,000
pH controller for reactor		2,000
pH motors (2), portable		500
Tank level indicators, manometer type		3,000
Temperature recorders (3), 2-pen, 12" round chart		2,000
Rotameter for caustic		300
Water meter, batch		600
Total	453,000	215,000

Equipment list for butyl 2,4-D and butyl 2,4,5-T esters

	Cost (LT)	Cost ($)
Butyl alcohol storage tank, steel, standard design, 40,000 l	75,000	
Butyl alcohol pumps (2)		1,800
Butyl alcohol meter		600
Esterifier, GL steel, agitated, jacketed, 1,500 gal		35,000
Esterifier condenser, Karbate, 150 sq ft		5,000
Decanter, GL steel, 100 gal		1,000
20% alcohol receiver, 1/2" steel, gauge glass, 1,000 l	15,000	
20% alcohol pump, SS		1,000
20% alcohol recovery still, reboiler, column, condenser		5,000
Recovered alcohol receiver, 1/4" steel, gauge glass, 1,000 l	7,000	
Butyl ester pumps (4)		4,800
Butyl ester receiver tank, 1/4" steel, 5,000 l	18,000	
Butyl ester filter		2,500
Butyl 2,4-D ester storage tank, steel, standard design, 20,000 l	40,000	

	Cost (LT)	Cost ($)
Butyl 2,4,5-T ester storage tank, steel, standard design, 20,000 l	40,000	
Temperature recorder		400
2 stage vacuum jet		1,000
Tank level indicators (3)		900
Batch make-up tank		10,000
Total	195,000	69,000

<u>Equipment list for isooctyl 2,4-D and 2,4,5-T esters</u>

	Cost (LT)	Cost ($)
Isooctyl alcohol storage tank, steel, standard design, 40,000 l	75,000	
Alcohol pump		900
Alcohol meter		600
Isooctyl 2,4-D esterifier, agitated, 200 gal		10,000
Esterifier condenser, Karbate, 100 sq ft		3,000
Receivers (2), GL steel, 100 gal		2,000
Ester pumps (2)		2,400
Isooctyl 2,4,5-T esterifier, GL steel, agitated, jacketed, 1,000 gal		30,000
Esterifier condenser, Karbate, 75 sq ft		2,500
Vacuum jet, single stage		700
Vacuum jet, 2-stage		1,000
Ester receiver tank, steel, gauge glass, 8,000 l	20,000	
Ester receiver tank, steel, gauge glass, 4,000 l	12,000	
Ester filter pumps (2)		2,800
Ester filters (2)		5,000
Ester storage tanks (2), steel, standard design, 20,000 l	40,000	
Temperature recorder		400
Tank level indicators (3)		900
Ester storage tank pumps (2)		1,800
Batch make-up tank		10,000
Total	147,000	74,000

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