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ENVIRONMENTAL POLLUTION FROM FERTILIZER PRODUCTION IN INDIA - SOME CASE STUDIES[1]

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ENVIRONMENTAL POLLUTION FROM FERTILIZER PRODUCTION IN INDIA - SOME CASE STUDIES

INTRODUCTION

Fertilizer production occupies a key place in the agrarian economy of India. After independence in 1947, fertilizer production industry received a considerable boost-up in the country as a principal activity. The production processes of fertilizers are based on naptha, natural gas, coal and furnace oil gasification, depending upon the availability of the raw materials. Every industry has an inevitable contribution to the environmental pollution and the fertilizer industry is no exception to the rule. There have been several instances of environmental pollution, varying from minor to severe ones, arising from the fertilizer industries in the country. The extent of pollution depends upon the age of the plant and the technological process(es) adopted in the manufacture.

An analysis of the environmental pollution problems normally faced by the fertiliser industry is presented in the paper together with the cost economies of the control measures in the case studies of 4 typical plants in the country.

STATUS OF FERTILIZER DEMAND AND PRODUCTION IN INDIA

Although agriculture is the principal activity in the country engaging about 126 million out of its total population of 551 million, the food production is not adequate enough to meet the internal demands and the emergencies. Food shortage is a staggering problem in the country.

The statistics relating to the total food production and area under various crops are given in Tables 1 & 2 respectively. The average yields per hectre, as per 1970-71 figures, for rice, wheat and other foodgrains work out to be 1134, 1299 and 870 kg respectively. These

Table 1. Area under principal crops in India

(Million hectares)

Crops	1950-51	1960-61	1970-71
Rice	30.8	34.1	37.4
Wheat	9.7	12.9	17.9
Other Cereals	37.7	45.0	46.1
Pulses	19.1	23.6	22.4
Foodgrains	97.3	115.6	123.9
Sugarcane	1.7	2.4	2.7
Oilseeds	10.7	13.8	15.5
Cotton	5.9	7.6	7.6
Jute	0.6	0.6	0.8
Total	213.5	255.6	274.1

Source: DAVP, India (1974)

Table 2. Agricultural Production in India

Commodity	Unit	1950-51	1960-61	1969-70
Rice	Million tonnes	22.11	34.64	40.43
Wheat	"	6.83	11.00	20.09
Jowar	"	6.25	9.81	9.72
Bajra	"	2.68	3.27	5.33
Other Cereals	"	7.98	10.71	12.24
Pulses	"	9.22	12.75	11.69
Total foodgrains	"	55.05	82.21	95.50
Oilseeds	"	5.02	6.87	7.61
Sugarcane (in terms of gur)	"	7.05	11.40	13.44
Cotton (lint)	Million bales*	2.87	5.24	5.23
Jute	"	3.51	4.13	5.61

* one bale weighs 180 kg
Source: DAVP India (1972)

averages are 30 to 40 percent less as compared to the yields in the developed countries. Extreme dry climate, lack of nutrients in the soil due to intensive cultivation over years without replenishment, improper management of farms, lack of proper equipment, prevalence of plant diseases, inadequate plant protection from insects and limited use of high yielding varieties are some of the inhibitive factors affecting food production.

During the last 25 years of independance, there has been a rising tempo in the agricultural production. The land under cultivation has increased from 214 million hectares in 1950-51 to 274 million hectares in 1970-71 together with increase in the range of crops grown (Table 1). The financial outlays for the production of fertilizers and hybrid seeds have also been increasing during these years. In fact, the growth of the fertilizer industry has been fantastic during these years, being 60-fold in terms of the investment (Tables 3 & 4). The imports have registered a steep fall over this period

Table 3. <u>Growth of fertilizer industry in India</u>

Period	Capacity as at the end of the period ('000 tonnes) N	P$_2$O$_5$	Investment (Rs. million) Public sector	Private sector	Total
1. Upto the end of March 1952	16.5	19.8	180	20	200
2. 1951-56	98.8	45.5	370	30	400
3. 1956-61	238.4	82.5	570	30	600
4. 1961-66	542.9	218.7	1450	300	1750
5. 1966-67	1024.0	412.0	1000	1500	2500
Total			3570	1880	5450
6. 1969-74	5150.0	235.0	7500	5500	13000
7. 1974-79	7750.0	420.0	N.A.	N.A.	8000
8. 1979-81	9250.0	490.0	N.A.	N.A.	5500

N.A. Not available

Source: Times of India Directory & Year Book (1975)

apparently due to intensive indigenous production of the fertilizers (Table 5). The total investment during the Third Five Year Plan period

Table 4. Total fertiliser production in India

(Million tonnes)

Year	Target	Actual
1966-67	1.57	1.20
1967-68	2.15	1.17
1968-69	2.80	1.67
1969-70	2.80	1.99
1970-71	3.30	2.18
1971-72*	4.03	2.60

* Provisional

Source: Times of India Directory & Year Book (1973)

Table 5. Annual imports of fertilisers in India

('000 tonnes)

Year	N	P	K	Total
1968-69	847	138	200	1185
1969-70	667	94	164	925
1970-71	477	32	226	735

Source: Times of India Directory & Year Book (1973)

stood at Rs.1750 million. At the end of 1966-67, the total investment in the industry mounted to Rs.5450 million including Rs.1880 million in the private sector. The estimated investment by the end of 1973-74 is Rs.13000 million for a production capacity of 5.15 million tonnes of nitrogenous and 0.235 million tonnes of phosphatic fertilisers.

In respect of fertiliser consumption, however, India falls behind all other developed countries (Table 6). In order to reach the

Table 6. Country-wise consumption of fertilisers during the year 1971-72

Country	N	P_2O_5	K_2O	Total
				(kg/hectare/year)
Asia	6.25	2.72	2.02	10.99
China (Taiwan)	189.58	44.12	68.65	302.35
Japan	135.76	105.10	104.95	345.81
Rep. Korea	122.34	51.96	30.45	204.75
India	6.87	1.66	0.92	9.45
Philippines	6.75	4.80	4.26	15.81

Source: Times of India Directory & Year Book (1973)

rate of fertiliser consumption of Japan, India will have to increase its consumption rate by 20 times in nitrogen, 60 times in P_2O_5 and 115 times in K_2O. In general, India will have to increase the fertiliser consumption 35 times to be able to achieve the rate comparable to that of Japan. The rate of investment correspondingly will have to be increased by 35 times if the price indices are expected to be stea-dy. With inflation, these figures will have to be adjusted accordingly. The crucial aspect is not of the investment but of the actual construction and commissioning of the units. In order to achieve self-reliance in food production India will have to undertake a massive investment of approximately Rs.480 billion in a short period of 10 years or alternatively will have to import the fertilisers.

There are over 60 fertiliser factories of varying sizes in the private and public sectors with an installed capacity of about 6.4 million

Table 7. Production capacities of various fertiliser factories in India*

Name of factory		Capacity in terms of N ('000 tonnes/year)
Projects in production		
A. Public Sector		
1. Fertiliser Corporation of India		
(a) Sindri		80
(b) Nangal		80
(c) Trombay		81
(d) Gorakhpur		80
(e) Namrup		45
2. FACT (Alwaye)		82
3. Neyveli lignite		70
4. Hindustan Steel (Rourkela)		120
5. Madras Fertilisers		184
6. Others (from Coke Oven Plants)		12
	Total	824
B. Private Sector		
1. GSFC, Gujarat		216
2. IEL, Kanpur		200
3. DCM, Kota		110
4. Coromandel		80
5. E.I.D. Parry		16
6. New Central Jute		10
7. Others (from Coke Oven)		8
	Total	640
TOTAL CAPACITY IN PRODUCTION (A + B)		1,464
Projects under implementation		
A. Public Sector		
1. Fertiliser Corporation of India		
(a) Durgapur		152
(b) Namrup (Expansion)		152
(c) Barauni		152
(d) Talcher		229
(e) Ramagundam		229
2. FACT (Cochin Phase I)		152
3. IFFCO Kandala, Gujarat		215
	Total	1,281
B. Private Sector		
1. Zuari Agro, Goa		175
TOTAL CAPACITY UNDER IMPLEMENTATION (A + B)		1,456

* The data relates to the year 1971

Source: Times of India Directory & Year Book (1973) tonnes per year (1971-72). Many of these, however, produce fertilisers as a subsidiary to their main products. Out of the 35 public limited concerns manufacturing fertiliser(s) as the main product, 8 manufacture nitrogenous fertilisers and others produce phosphatic fertilisers (Tables 7 & 8). The major growth is in the public sector which has larger units and account for 58 percent of the total installed capacity.

Table 8. <u>Data on capacity vis-a-vis production of various fertilizers</u>

('000 tonnes/year)

Type of fertiliser produced	1971-72		
	No. of units	Installed capacity	Actual production
Ammonium sulphate	13	978	622
Ammonium phosphate	2	186	96
Calcium ammonium nitrate	2	800	410
Double salt	1	122	27
Nitro-phosphate	1	270	204
Urea	10	1878	1257
Ammonium chloride	2	69	32
Di-ammonium phosphate	1	108	55
Superphosphate	28	1300	759
Triple superphosphate	1	27	9
Urea ammonium phosphate	1	260	257
Complex NPK	2	401	77
Total	64	6399	3765

Source: Times of India Directory & Year Book (1973)

ENVIRONMENTAL POLLUTION PROBLEMS FROM FERTILIZER PLANTS

The process technology and the equipment of the fertiliser plants are imported, either completely or partially, from countries like, Germany, France, USA or Japan. The environmental pollution control measures and the required equipment, however, have been neglected in most of the cases and rarely up-to-date technology was offered. These aspects ought to have been thought of and included in the planning stages themselves.

For want of the provision of control measures, the wastes from the fertiliser industry create environmental pollution in all the three forms viz., air, liquid and solids. The types of pollutants normally encountered in the fertiliser factory are briefly summarised below:

Air Pollution

(1) Oxides of Sulphur:- These are released to the atmosphere during the production of steam, naptha desulfurisation, manufacture of sulphuric acid and other [illegible] which require heat generation.

(2) Fluorides:- This pollutant is released during acidulation, or thermal processing of phosphate rock. The other processes normally resulting in the emissions of fluorides are: manufacture of normal superphosphate, run-of-pile triple superphosphate, wet process phosphoric acid, and the production of granular triple superphosphate.

(3) Ammonia:- During the production of mono- and di-ammonium phosphate certain amounts of ammonia are lost from the process in the ammoniator,

reactor, dryer and cooler vent gases. These are released as gaseous ammonia and may be removed by scrubbing with a recycled water slurry or recovered by scrubbing with phosphoric acid. Ammonia plant compressor and valve gland leakages also release gaseous ammonia to the air.

(4) Ammonium chloride:- This is evolved as a fine sub-micron fume during the manufacture of various NPK fertilisers. It requires high energy scrubbing for effective removal.

(5) Ammonium nitrate:- This, too, is evolved as a fine sub-micron fume from NPK plants and requires high energy scrubbing for removal. The energy requirements are, however, less than those required for removal of ammonium chloride fumes.

(6) Nitric oxides:- These fumes are generally evolved in the production of nitric acid in the contact type plant. A tall packed tower providing scrubbing with water can be used for their removal. Alternatively, these oxides can be converted by means of scrubbers or tail gas catalytic reducers to other forms and removed conveniently.

The average values of various air pollutants from fertiliser industry are shown in Table 9 which gives a fair idea of the pollution potential of this industry.

Table 9. Comparative statement of gaseous effluents*
Emissions Kg/Tonne of product as surveyed by NEERI

Plant	Ammonia plant		Urea Plant			Complex fertiliser			Sulphuric acid	
	SO_2	NH_3	Urea dust	NH_3	SO_2	Dust	F.	NH_3	SO_2	Acid mist
A*	8.9	2.22	N.A.	2.22	0.67	0.56	0.025	N.A.	7.5	1.22
B*	11.0	1.67	18.0	13.5	0.67	0.[illegible]	0.025	N.A.	13.5	3.75
C**	5.0	N.A.	3.54	1.[illegible]	N.A.	1.[illegible]	N.A.	0.45	No.plant	No plant
D***	8.3	2.0	9.8	5.6	0.67	0.33	0.025	0.45	10.4	2.5

*Based on actual emission survey, **Supplied by the factory as per performance of the control equipment, ***Theoretical calculation on data supplied by the factory.

Water Pollution

An average-sized fertiliser factory produces a large quantity of wastewater ranging from 2 to 6 mgd. The wastewater contains a variety of polluting substances such as:

(i) Carbon slurry (where partial oxidation method is used in the gassification step or in coal gassification plant)

(ii) Scrubber wastes depending on the process used for gas purification, such as:

  (a) Monoethanolamine (MEA)

  (b) Arsenic (as As_2O_3)

  (c) Potassium carbonate (K_2CO_3)

  (d) Caustic (NaOH)

(iii) Ammonia-bearing wastes from ammonia and urea synthesis units;

(iv) Urea and ammonia-bearing wastes from the urea synthesis units;

(v) Ammonium sulphate waste from the manufacture of ammonium sulphate;

(vi) Phosphates and fluoride containing wastes from phosphoric acid plant;

(vii) Ammonium phosphate and ammonia from ammonium phosphate plant;

(viii) Acidic spillages from sulphuric acid plant;

(ix) Acid from regeneration of cation exchange units;

(x) Alkali from regeneration of cation exchange units;

(xi) Cooling waters; and

(xii) Domestic sewage.

Table 10 shows the range of the average values of the pollutants in the wastewaters from the fertiliser industry in the country. It gives a fair idea of the water pollution potential of the industry.

Table 10. Water pollution status of a fertilizer industry

Pollutant	Average concentration in the combined waste (mg/l) range	Sources of pollutant	Pollution aspects
1. Ammonia	700(as N) - 1800	Ammonia plant and urea plant	Toxicity to fish and aquatic life, fish kills, eutrophication.
2. Urea	800 - 1200	Urea plant	Toxicity of ammonia after hydrolysis, eutrophication of water bodies.
3. Arsenic	0.5 - 6.00	Gas purification plant in ammonia and urea manufacture	Causes back-foot disease in humans of accumulative poison, affects plants and crops.
4. Phenols, aldehydes, oils and fats.	200 - 10000	Gas compressor houses in ammonia and urea manufacture, coal gas scrubbing.	Suppresses dissolution of oxygen in water, floats on water and forms ugly and irridescent slime; coal gas scrubbing. Toxic to fish, causes water treatment problem for drinking water supplies.
5. Phosphate	20 - 1000	Phosphoric acid and complex fertilizer units	Along with ammonia cause algal blooms which increase cost of water treatment.
6. Fluoride	10 - 200	Scrubber effluents in phosphoric acid and superphosphate manufacture	Causes dental and skeletal fluorosis, hatching of eggs in fish, damage to plants.
7. Carbon slurry	500 - 1000	Gas scrubbing plants.	Blocks sunlight, turns waters unsightly

Solid wastes

Solid wastes from the fertiliser industry comprise mostly of: (i) Arsenic trioxide and carbonate in the potassium carbonate sludge which is removed from the vetrocoke process for generation of carbon dioxide. Arsenic trioxide containing sludge ranges from 6 to 16 gm/tonne of urea produced. It is highly toxic and difficult for disposal. (ii) fluorides from the super phosphate plants; (iii) calcium sulphate from the phosphoric acid plants; and (iv) dust collected from handling plants and control equipment which cannot be recycled.

TECHNICAL EVALUATION OF CONTROL MEASURES

The National Environmental Engineering Research Institute (NEERI), Nagpur is actively engaged in the development of economic and efficient indigenous know-how on pollution abatement procedures. It has conducted investigations in a number of fertilizer plants in the country to assess the pollution potential; to develop methods of treatment and to suggest remedial measures and improvements in the existing plants to achieve better environmental pollution control. A list of these factories is given as Appendix I. Besides the survey and the investigations of the existing plants, the Institute has also rendered assistance for the proposed plants as regards the site selection, design of control equipment etc.

CASE STUDIES

Case studies of four select fertilizer factories are presented below in detail for appraisal of the existing environmental pollution status and the NEERI's effort in evolving suitable procedures for pollution control together with the associated costs.

PLANT 'A'

The plant is located inlands about 120 km from sea on a river in western India. The capacities of the various units are given below

Units	Capacity (tonnes/day)	
1. Liquid ammonia (anhydrous)	960	
2. Urea (a) Fertiliser grade	1100	
(b) Technical grade	10	
3. Sulphuric acid	470	
4. Phosphoric acid (as P_2O_5)	185	
5. Complex fertiliser (a) ammonium phosphate	470	800
(b) di-ammonium phosphate	370	
or		
(c) ammonium sulphate phosphate	800	

Water pollution

The effluent amounting to 17180 m^3/day (3.77 mgd) predominantly contain free and mixed ammonia, urea, oil, grease, fluorides, phosphates, arsenic etc (Table 11). Ammonia is toxic to fish even in low concentrations. Arsenic is highly toxic to human beings and plants. Oil and grease are know to create unsightly conditions.

NEERI conducted a sanitary survey of the two rivers receiving the wastewaters which showed that the rivers were heavily polluted over a distance as much as 11 km from the point of confluence of the two rivers.

Table 11. Analysis of combined liquid effluent (Plant 'A')
Average flow = 3.77 mgd

Period		pH	Total solids (mg/l)	Total Nitrogen (mg/l)	Ammonia Nitrogen (mg/l)	Urea Nitrogen (mg/l)	Phosphate (PO_4 mg/l)	Fluoride (F) (mg/l)	Arsenic (As) (mg/l)
1970	Max	9.4	6280	1598	952	648	185	17.0	2.6
January	Min	8.5	3380	952	602	350	20	3.7	0.27
	Ave		4280	1254	778	475	82	10.3	1.1
	Max	10.2	10420	5580	1982	3808	280	35.6	3.2
February	Min	7.5	2800	450	315	157	10	1.7	0.5
	Ave		5375	1705	880	845	52.5	17.4	1.35
	Max	8.6	6440	2212	984	1288	200	34.0	3.0
March	Min	7.0	1790	384	388	28	20	6.0	1.7
	Ave		3873	881	539	522	38.0	18.3	2.35
Overall average			5100	1278	782	614	78.7	15.3	1.57

Observations on the existing treatment units showed that the procedure of mixing up the factory effluent with the sewage after treatment of the latter in an oxidation pond and their discharge into a watercourse which meets the river after a distance of 2 km is far from satisfactory.

After a detailed literature survey, laboratory investigations and pilot scale experiments, NEERI proposed the following treatment and disposal alternative schemes for the factory effluents together with the associated cost estimates:

Scheme	Brief Description	Cost estimates (Rs. in lakhs)*	
		Capital	Recurring/ year
I	Ammonia removal by air strippers and disposal into river	45.0	2.1
II	Ammonia removal by simple lagooning and disposal into the river	25.0	2.4
III	Ammonia removal by nitrification and disposal into the river	52.0	5.28
IV	Ammonia removal by nitrification and denitirification and disposal into the river	46.0	1.25
V	Storage in tanks and disposal of untreated effluent into the river during monsoon	54.5	5.0
VI	Pumping the effluent for irrigation	65.0	0.50

* One lakh = 100,000

All these schemes are technically feasible. The choice, however, will depend upon the local factors such as land availability and the capital and running costs involved.

Besides the above treatment and disposal alternatives, the treatment by oxidation pond also appeared feasible. This mode of treatment is known for the least capital costs and very low running costs. However, the land requirements are considerably higher than any of the schemes proposed above. The particular factory has initiated this treatment method on a small scale under the guidance of NEERI to get an idea of the estimates of the ammonia removal efficiency and the land requirements before a final decision could be taken.

Air Pollution

The total emissions from individual units discharged per day are shown in Table 12. The sulphuric acid plant had no controls for sulphur dioxide or sulphur trioxide with low stack height of 22 meters. The complex plant also had no dust controls. The emissions from the plant caused a severe damage to the mango crops in a radius of about 5 kilometers. The damage was more intensive in the north-west and south-east directions since the wind was predominant in these directions during winter and summer and monsoon months respectively. The estimated loss of mango crops alone run into thousands of rupees.

Remedial measures

Based on the extensive survey of the factory, NEERI suggested the following remedial measures:

		Cost (Rs)
(i)	Installation of acid mist eliminator on H_2SO_4 plant	8[illegible],000
(ii)	Utilisation of the ammoniacal effluent from the plant to scrub the sulphur dioxide, and also for conversion into ammonium sulphate	65,000
(iii)	Increase in the stack height from 22 meters to 40 meters (whose foundations could not take a heavier load)	----

Table 12. Products and emissions from different units of Plant 'A' (Tonnes/day)

Products plant	Production capacity			Existing emissions				Expansion emissions				Total emissions			
	Existing	Expansion	Total	SO_2	NH_3	NO_x	Dust	SO_2	NH_3	NO_x	Dust	SO_2	NH_3	NO_x	Dust
Ammonia	450	560	1010	4.0	1.0	-	-	4.0	2.0	-	-	8.0	3.0	-	-
Urea	450	560	1010	4.0	1.0	-	-	4.0	2.0	-	-	8.0	3.0	-	-
Complex fertiliser	800 (800)	1200	2000	0.6	-	11 kg (fluor des) + 0.65	3.5	-	-	17 kg (fluorides)	2.0	0.6	-	28 kg	1.5
H_2SO_4	410	60	470	5.0			0.5 acid mist	Absorption process under installation			70 kg/ day acid mist	5.0	-	-	-
Steam generation	70	-	70	4.0	0.8	0.65	3.65	-	-	N.A.	N.A.	4.0	0.6	N.A.	N.A.
Total				15.6	2.8	0.65	3.5	8.0	4.0	-	-	25.6	6.6	-	-

Observations

1. Stack height only 22 meter for H_2SO_4 plant. No mist eliminator
2. Severe damage to mango orchard around 3 km radius of the plant particularly eastern and northern side.

Suffice it to say that on implementation of these recommendations, the concentrationsof various gaseous pollutants at the ground level were brought down to 10 percent of the earlier values.

Solid wastes disposal

The factory has problem of solid waste disposal especially of calcium carbonate sludge with arsenic trioxide contained in the evaporated concentrators from the GVC process.

The plant produces 12 gms of arsenic containing sludge per tonne of urea and had accumulated these wastes in a concrete godown in 100 kg bags packed individually for over a period of 8 years. Ultimately it was disposed off by the plant authorities as approved by the Government by putting into 40 gallons drums and gunniting them with 5 mm thick cement and dumping them off about 150 km off the coast line with a spacing of approximately 100 meters between each drum, at places with water depth of approximately 30 meters.

PLANT 'B'

This plant is located in a large city suburb surrounded by residential areas north side of a harbour. The installed capacities of the existing units and those under expansion are given below:

Units	Capacity (tonnes/day)
1. Ammonia (anhydrous)	350
2. Urea	300
3. Complex fertiliser (DAP)	300
4. HNO_3	280
5. H_2SO_4	200
6. Methanol	60

Water pollution

The total volume of the effluents from the plant amounts to 27,300 m^3/day (6 mgd). The average concentrations of the major polluting constituents are given below:

Substance	Concentration (mg/l)
Ammonia	1500.0
Arsenic	7.0
Oils	200.0
Fluorides	300.0

The effects of the wastewater discharges have not been studied in detail as it flows into the sea north of a harbour and a creek estuary since sea water affords considerable dilution because of the tide movements. Mortality of fish and other aquatic organisms was reported in the vicinity of the discharges.

Air pollution

This plant has relatively poor air pollution control measures. Sulphur dioxide and sulphur trioxide from H_2SO_4 plant are discharged from a very low stack height of 22 meters without any controls. Similarly, NO_x, NH_3 and particulates are also fairly high due to inadequate control. The emissions are given in Table 13.

The factory is surrounded by a residential area. In view of the complaints, an air quality survey was conducted and causes of complaints were studied by NEERI wherein it was found that SO_3 mist was the main source of pollution. Air quality data is presented in Tables 14 and 15.

Table 13. Products and air pollutant emissions from Plant 'B' (tonnes/day)

Product plants	Production capacity	Existing emissions			
	Existing	SO_2	NH_3	NO_x	Dust
Ammonia	350(300)	3.3	0.5	-	-
Urea	300	-	4.0	-	4.8
Complex fertilizer (DAP)	900(800)	0.6	-	21 Kg fluorides	0.5
HNO_3	330	-	-	2.1	-
H_2SO_4	300	2.7	-	-	0.75 (acid mist)
Methanol	100	1.0	-	-	-
Steam generation	60 tonnes furnace oil (3% S)	3.6	-	0.5	-
Total		11.2	4.5	2.6	5.3

Figures in bracket indicate production rate at the time of stack sampling.

Table 14. Air quality data for Plant 'B'

Pollutants	Total no. of observations made	Threshold concentration below which most observed values lie, ppm	Occurrence of high concentration	
			No. of occurrences	Maximum values observed - ppm
Sulphur dioxide	180	0.02	30	0.15
Nitrogen dioxide	180	0.01	12	0.06
Ammonia	108	0.30	30	1.7
Hydrogen sulphide	180	0.005	28	0.07

Table 15. Sulphur dioxide concentrations at the downwind sampling station

Day	Sulphuric acid plant under controlled operation (ppm)	Sulphuric acid plant closed (ppm)
1	0.017	0.020
2	0.025	0.003
3	0.021	Nil
4	0.006	0.007
5	0.004	0.010

NEERI made the following recommendations:

				[illegible]
	(i)	continuous operation of the sulphuric acid plant,		
	(ii)	increased capacity for the sulphuric acid storage	Rs.	1,50,000
	(iii)	installation of acid demisters	"	5,00,000
and	(iv)	increased stack height for discharge from 20 meters to 50 meters	"	5,00,000

Further, discharges from ammonia compressors, urea plant and NO_x plant were studied and better operational and corrective measures were recommended to prevent leakages from pump glands of ammonia, arsenic etc (Rs. 6,00,000).

The recommendations are under implementation.

Solid wastes

Since its inception, this plant is discharging 18 gms of sludge per tonne of urea and this waste flows along with its effluent continuously into the sea where it is diluted by the tidal action. Very recently, an objection has been raised to this. Steps are being taken under NEERI's recommendations for installation of concentrators for the arsenic containing solid waste. Ultimate disposal will be into the sea in the form of drums with cement granditing at a distance of 200 km away from the coastal area.

Total cost of this process will be Rs.80,000/- out of which the evaporator would cost about Rs.40,000/- for the masonary concrete pans and about equal amount for the packing and storage facilities. There will be no operational costs on this except for employing 4 people who will gather the wastes from the pans and pack it with necessary precautions. The salary will amount to Rs.10,000/- per year.

PLANT 'C'

This is one of the largest plants located on a gulf with installed capacity as under:

	Units	Capacity (tonnes/day)
1.	Ammonia	1100
2.	Urea	1800
3.	Sulphuric acid	470
4.	Phosphoric acid	185
5.	DAP/NPK	500/800

The plant is located at a very critical place near a gulf which is a harbour and a valuable fishing ground for the local people.

Water pollution

The average characteristics of the combined effluent from the factory are given below

Table 16. Characteristics of combined effluent

Flow before the treatment — 16482 m^3/day

Flow after the treatment — 14802 m^3/day

Constituent	Before treatment		After treatment	
	kg/day	mg/l	kg/day	mg/l
Ammonia	2513	152	833	56
Urea	4126	250	4116	278
Chromium	96	5.8	96	6.5
Phosphate	384	23.4	384	26

The difference in the combined flow before and after the treatment is due to the reuse of treated effluent from the process condensate (ammonia plant) which amounts to 1680 m^3/day.

The factory will be discharging about 16482 m^3 of effluent per day containing 2513 kg of ammonia (0.23 percent of the quantity produced) 4116 kg of urea (0.26 percent), 96 kg of chromium and 384 kg of phosphates. The losses in ammonia and urea are very low as compared to about 1.3 per cent of ammonia and 0.6 percent of urea reported in other plants. The factory itself has proposed treatment measures for removal particularly of oil, arsenic and ammonia.

The suggested treatment, however, was not adequate to protect fishing grounds, harbour structures and aquatic life. Also no treatment for chromium bearing cooling water blowdown was provided. Hence the chromium content in the combined effluent (6.[illegible] mg/l) is higher than the prescribed limit (IS:2490 1963) of 1 mg/l. Further, the combined effluent from the demineralisation plant being acidic is proposed to be neutralised by the factory with lime or sodium hydroxide. In the scheme proposed by NEERI this is taken care of intrinsically. The treatment and disposal alternatives include the following recommendations:

(i) steam stripping of wastes for process units,

(ii) fixation of ammonia and neutralisation with acidic waste,

(iii) removal of chrome by acid and lime treatment, and

(iv) concentration of VC process sludge by concentration drying and controlled sea disposal.

Air pollution

The actual emissions of various air pollutants are given in Table 17.

Table 17. Products and emissions from Plant 'C' (tonnes/day)

Product plants	Production capacity	Emissions				
		SO_2	NH_3	Dust	Acid mist	Fluorides
Ammonia	1100	9.13	2.2	-	-	-
Urea	1600	-	8.96	15.68	-	-
Complex fertiliser	600	0.87	0.24	0.46	-	0.014 kg
Sulphuric acid	470	4.83	-		1.18	-
Phosphoric acid	165	-	-		-	0.666
Total		14.83	11.40	16.14	1.18	0.680

This plant has well controlled emissions except ammonia and sulphuric acid plants which show higher discharges per unit of production. Urea dust flow is also higher amounting to about 16 tonnes per day. The factory has been advised by NEERI:

(i) to install additional wet scrubbers for urea and the complex fertilizer dust, and

(ii) to increase the chimney height to 75 meters later for the sulphuric acid plant when felt necessary.

Detailed cost estimates, however, were not prepared.

Solid wastes

This plant has no problem for solid wastes disposal. It already has an evaporator concentrator and also mechanised packing system. The cost of disposal is included in water pollution control equipment by the factory at the planning stage. The sludge containing arsenic is lowest of all the plants studied amounting to about 6 gm/tonne of urea produced.

PLANT 'D'

This plant is located near a sea beach on the west coast. It was constructed and commissioned during 1978. The capacities of various units are given below:

	Unit	Capacity (tonnes/day)
1.	Ammonia	600
2.	Urea	1140
3.	Complex fertilizer (NPK)	535

The phosphoric acid (180 tonnes/day) is being imported.

Water pollution

The effluents from various units except the urea plant (6700 m^3/day) will be disposed after chemical treatment into the sea. The effluent from the urea plant (3500 m^3/day) is utilised on 120 hectares of land for irrigation purposes which is satisfactory.

The characteristics of the effluent to be discharged to the sea are given in the Table 18.

Table 18. Characteristics of effluents discharged to sea

Characteristics	Treated effluent	I.S. 2490
1. Total suspended solids mg/l	Approx 30	100
2. Particle size	Less than 200 micron	Less than 850 micron
3. pH	5.5 - 9.0	5.5 - 9.0
4. Temperature, °C	30	40
5. B.O.D. mg/l	2.6	30
6. Oils and grease mg/l	max 1.7	10
7. Phenolic compounds mg/l	max less than 1	10
8. Cyanides as CN mg/l	max less than 0.1	0.2
9. Sulphides as S	less than 1.0	2.0
10. Alpha emitters Beta " μc/ml max	10^{-7}	10^{-7} 10^{-6}
11. Insecticides	Nil	Nil
12. Total residual chlorine, mg/l	max less than 0.5	1.0
13. Fluorides, arsenic, etc mg/l	less than 2.0 * (As 0.75)	Less than 2.0

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* At the time of sampling and analysis, the actual arsenic values ranged between 2.0 - 6.0 mg/l.

The effluent disposal system was designed and constructed by the factory. The discharge point is located at a distance of 100 meters from the low water shore line and at a depth of 3 meters below high water and 1 meter below the low water levels. Sea pollution survey has not been carried out.

Air pollution

The emissions from this factory are shown in Table 19.

Table 19. Production and emissions from Plant 'D' (tonnes/day)

Product plant	Production capacity	Emissions					
		SO_2	NH_3	Dust	SO_3	Fluorides	NO_x
Ammonia	660	3.3	N.A.	-	-	-	-
Urea	1140	-	1.435	4.03	-	-	-
Complex fertiliser	550	N.A.	0.235	0.755	-	N.A.	-
Steam generation		15.8	-	-	3.28	-	N.A.
		19.1	1.67	4.785	3.28	-	-

This is one of the best controlled plants in the country for the discharge of pollutants. The stacks are designed with heights from 30 meters to 60 meters so as to give a maximum concentration between 75 to 100 μg/hr of sulphur dioxide at wind velocities of 1-3-8 & 10 meter/hr.

NEERI, therefore, had nothing to recommend as additional control measures.

Solid wastes

The plant produces about 10 gm of sludge per tonne of urea produced. The original proposal was to provide an evaporator, but somehow the management did not follow up the recommendation from the plant suppliers and had started discharging arsenic trioxide containing sludge along with the liquid wastes. This resulted in arsenic concentrations as high as 6 mg/l as against the manufacturers recommendation of 0.75 mg/l. In 1972, this factory had a severe accident due to the burst of the glands packing in the recycling pumps resulting in massive arsenic concentration of 50 mg/l with a heavy fish kill on the beach and the plant was forced to be closed down. At the request of the Government, NEERI undertook an investigation and recommended immediate separation of the arsenic wastes, its evaporation and concentration followed by bag packing of the solid wastes for sea disposal. Factory has already implemented the suggestion and the cost of this operation works out to Rs.20/- per day. This is included in the estimates for water pollution control prepared for the plant.

ACCIDENTS AND EPISODES OF SEVERE POLLUTION IN THE CASE STUDY PLANTS

After its commissioning in 1965-66, Plant 'A' had not even provided for any treatment process nor did it had proper disposal system of liquid effluent such as a channel to drain away the liquid effluents. This resulted in flooding of the large low lying areas around the plant with gypsum pond effluent full of arsenic and ammonia etc. During the same period, it had also a breakdown in the ammonia compressor resulting in very high discharges of concentrated ammonia in the liquid effluent. This resulted in the death of cattle on a large scale. After investigation NEERI suggested construction of an outfall channel as well as the treatment processes.

In Plant 'B' a probe was conducted by NEERI into the causes of sudden discharge of SO_2 and SO_3 in areas around the plant. The condensers between the consecutive contact units of sulphuric acid plant were corroded due to intermittent operations and entry of oxygen with perforations resulting in emissions of large quantities of sulphur trioxide and acid fumes causing severe damage and complaints from the residents in the vicinity which is a populated zone. NEERI suggested continuous operation with addition storage with suitable control to prevent such occurrences.

In Plant 'C' which is located on a sea-coast, very recently the operators discontinued the use of concentrators for the arsenic waste inadvertently, increasing the arsenic content in the effluent to [illegible] mg/l as against 0.75 mg/l in the originally controlled discharge. Simultaneously, the factory had a breakdown on the vetrocoke liquid circulation pump. This discharge was mixed with the combined effluent and put into the sea resulting in a very high fish kill near the point of discharge at the beach. The Government, therefore, had to order for shut down of this plant and a probe into the cause. NEERI, as one of the principal members for the investigation, identified the source of discharge and recommended strict usage of the concentraters to prevent such an episode. Only after a written guarantee from the plant owners and operators for implementations of NEERI recommendations, the Government allowed the plant to be recommissioned in November 1975.

Yet another instance may be quoted where phenol removal unit in a coal based plant was out of order resulting in gross pollution in an important river of the country. The activated sludge units were improperly operated resulting in eventual breakdown. NEERI recommended to modify the operational pattern with standby capacity to prevent recurrence.

These episodes indicate a pathetic situation in the fertiliser industry in India on account of improper operation of the plants, and lack of proper maintenance of equipments. This is so mostly due to ignorance or unawareness of the factory authorities about the possible environmental pollution hazards. This condition has not only resulted in gross pollution but also a considerable economic loss to the plant owners.

COST ECONOMICS

Costs for the provision of water, air and solid waste pollution control measures and their operation for these case studies are given in Table 20.

Table 20. Cost of pollution control per tonne of product @

Plant	Air Pollution Rs./day	Water & Solid wastes pollution Rs./day	Total Rs./day	Production tonne/day	Increase in cost Rs./tonne	% increase*
Plant 'A'	2700	1200	3900	1900	2.05	0.2
Plant 'B'	5120	2160	7280	1200**	6.05	0.6
Plant 'C'	5800	N.A.	N.A.	2200	2.64	0.3
Plant 'D'	3600	2800	6400	1875	3.62	0.4
					Average	0.45

* Based on prevailing average market price of urea and complex fertiliser at Rs.1000 per tonne. ** This plant also sells 100 tonnes of H_2SO_4 and 60 tonnes of methanol per day. Not included for calculating pollution cost.

@ This data do not include recovery benefits for NH_3

The costs for air pollution control appears to be almost one and half to twice that of water and solid wastes pollution control per tonne of production. The overall costs for control range from Rs.2 to 6 per tonne of the fertilizers i.e. 0.2 to 0.6 per cent with an average of 0.4 per cent. These costs are extremely low and a small fraction of the normal fluctuation in the production costs as well as the margin of profit for the factory. Therefore, there is no reason why the factories cannot economically incorporate the control measures.

The case studies, however, do not include the factories that are old and small in size where the profits are very marginal and capital investment low. It will be necessary to undertake a study for assessment of cost economies of environmental pollution control measures for these factories separately.

STATUS OF ENVIRONMENTAL POLLUTION CONTROL IN INDIA

The present case study represents typical examples of the extent of environmental damage to the vicinity of the 4 fertiliser factories. There are over 60 major fertiliser factories of various capacities spread in different parts of the country. Added to these are large refineries, petrochemical complexes, synthetic fibre manufacture and chemical industries and several others which cause severe pollution in many pockets of the country.

ENVIRONMENTAL POLLUTION CONTROL EFFORT IN THE COUNTRY

There are several organisations actively engaged in the field of environmental engineering in the country. Their role is briefly described below

(1) NATIONAL ENVIRONMENTAL ENGINEERING RESEARCH INSTITUTE

The Government of India constituted the Council of Scientific and Industrial Research (CSIR) to promote the growth and development of science and technology to attain the national goals. The NEERI, a national laboratory under the CSIR is vested with the development of economic and efficient methods for environmental pollution control, well suited to the conditions, resources and economy of the country. Within a short span of 15 years the Institute has set in [illegible] and R & D projects and has made major contributions to the development of indigenous methodology.

With a view to ameliorate the environmental pollution problems arising out of the Fertiliser Industries, NEERI has developed technology of pollution control which covers oxidation ponds and the activated sludge process, air pollution control equipments, [illegible] scrubbers etc. The Institute also renders [illegible] by way of preparation of specifications and the documents for industries to construct the control equipment. NEERI has also the organised services like training, publications and documentation for dissemination of information on the economics of the processes developed by the Institute.

(2) [illegible] OF THE ENVIRONMENTAL PROTECTION & CONSERVATION, MINISTRY OF SCIENCE & TECHNOLOGY

This is the apex body in the field of environmental protection. The role of this organisation is to investigate the major projects at the initial stages of licensing and planning and to recommend and approve locations of the factories in connosence with the national policies. It also coordinates interministerial issues on environmental pollution control.

(3) INDIAN STANDARDS INSTITUTION

This organisation is affiliated to the Ministry of Industries and has a principal role in laying down the norms for various effluents so that the ambient environmental air and water quality standards are maintained. NEERI is actively associated with the ISI in this important task. About 73 standards are already laid down on the environmental protection uptill now and another [illegible] are in the making.

(4) MINISTRY OF WORKS & HOUSING, GOVERNMENT OF INDIA

The Central Public Health & Environmental Engineering Organisation (CPHEEO) under the Ministry has an active role in formulation and implementation of the air and water pollution control legislation. Water pollution control act has come into force very recently (May 23, 1974) and air pollution control bill is in the process. These bills provide for control of effluent discharges both gaseous and liquid, at the various factories and authorise the creation of agencies with financial and legal powers for vigilance on implementation of standards laid down. These agencies will also be responsible for overall management of the environmental pollution control of water and air, particularly around the human settlements as well as industrial establishments.

(5) EQUIPMENT MANUFACTURERS

India has now a considerable experience over a period of 20 years in the field of environmental engineering and has also manufactured many of the control equipments either entirely indigenously or in collaboration with their American, British or German counterparts. There are about 16 firms both in the public and private sectors engaged in manufacture and supply of the equipment. In this regard, the country is almost self-sufficient.

SUMMARY AND CONCLUSIONS

The manufacture of fertilisers is given a top priority in the country to meet the urgent needs of food production. There are already over 60 fertiliser factories, small and large in size, under production and some 20 units are in the planning stage. These factories have liquid wastewater discharges and gaseous emissions of various magnitudes which cause gross pollution of the environment unless adequate treatment and control measures are adopted. The Instituteslike NEERI and ISI have a critical role to help pollution abatement by laying down standards and developing such indigenous competent know-how, which will find ready acceptability and in the design of control equipment. In spite of the fact that costs for control measures are just marginal, as shown in case studies, instances of pollution have been taking place primarily for the following factors.

1. Purchase of turn-key plants from the foreign firms who, in a bid earn the contract, invariably neglect the control equipment to bring down the cost.

2. Unawareness of the hazards of environmental pollution by the factory owners and control authorities.

3. Lack of legislation and guidance by the Government. Until recently, no comprehensive legal provisions were made to protect the environment except for the smoke nuisance act which was enforced in few cities. The act is absolete now to meet the stringent controls.

4. Lack of proper operation and maintenance both of the plant and the existing control equipment either due to non-availability of the spare parts or delayed replacement or operation by untrained staff. It will be pertinent to quote here that losses in India on account of nitrogen by way of ammonia are 1 to 3 percent of the productions which are 5 to 10 times those in other countries. This costs to the country a severe drain of foreign exchange.

5. Improper location of the plant vis-a-vis residential areas with complete disregard to the environmental factors such as meteorology, topography etc.

6. Lack of technical guidance on the requirements of the control measures.

RECOMMENDATIONS

The experience of the already industrialised nations has amply shown that the control of environmental pollution is attained more economically through prevention rather than cure. The philosophy of environmental pollution control is that control measures must be provided for at the planning stage of the industrial project as a [illegible].

[illegible] environmental pollution [illegible] existing as well planned plants as it is for the national effort as well as international effort. Out of the experience gained on the subject, the followings suggestions are made.

NATIONAL LEVEL

1. Legislation:- The government should create legal [illegible] local, state, central and federal levels to enforce [illegible] mental conservation measures. This will include [illegible] for the minimum [illegible] minimum [illegible] in industries and [illegible] water quality

2. Technical guidance:- [illegible] classification of the industries according [illegible] and nature of pollution and preparation of guidelines for [illegible] and discharge points etc will be invaluable for the enforcement of [illegible]ation.

3. [illegible]:- Local factors such as topography, climatology and meteorological conditions should be considered as a guide for the plant location. [illegible] land use planning will not only minimise the damage to the environment but also reduce the needs of strict pollution control and its cost. This is particularly essential for developing countries like India where the financial resources are admittedly scarce.

4. **Training:-** Training courses and technical assistance to the plant staff for operation and maintenance of the plant and control equipment should be provided. The training should also be conducted for the [illegible] to enlighten them on all [illegible] which cause [illegible].

5. [illegible] institutions and to establish laboratories to undertake [illegible] analysis and development of control techniques.

INTERNATIONAL [illegible]

[illegible] is all the more important in the case of environmental [illegible] control. Unfortunately, developing countries do not have adequate resources to meet the nation's science and technology needs. International collaboration to pool the knowledge and experience all over will go long way to solve the formidable problem of environmental pollution in the developing countries.

International collaboration is needed in the following areas:

1. **Dissemination of information:-** This can be well done through establishing reference centres in different countries at the institutes and the research laboratories which are a national resource in the field of environmental engineering. These will act as focii for encouraging free exchange of information from developed to developing countries.

2. **Promotion of scientific knowledge on control measures:-** This can be done in the following ways:

(a) exchange of scientific personal among countries;

(b) provision of fellowships for long-term studies as well as for short-term orientation;

(c) organisation of courses for technical personnel;

(d) stimulation and assistance for specific research;

(e) organisation of exhibitions of scientific instruments and achievements;

(f) preparation of an international guide on environmental protection measures for assisting countries in developing national standards; and

(g) organisation of international meetings and conferences on various aspects of environmental pollution

8. Collaboration amongst different agencies.- It is encouraging that there are a number of international agencies such as UN, UNEP, WMO, WHO and specially UNIDO which are engaged in the global task of environmental pollution control. Besides, there are voluntary organisations also like International Clean Air Congress, International Water Pollution Control Federation whose activities have an important bearing on the environmental pollution control. Collaboration among the agencies concerned should be fostered since it will be of great benefit particularly to the developing countries in this field.

ROLE OF UNIDO

UNIDO has a leading role for promoting the international effort to help industrialisation and at the same time to ameliorate the problems of the environmental pollution in terms of damage to population, vegetation and other economic development of the countries. The possible areas for UNIDO's leadership are:

1. Establishment of committees or working groups to review the scientific evidence for assessment of the environmental pollution from industries in general and fertiliser industry in particular,
2. Exchange of qualified technical personnel amongst developing and developed countries,
3. Encouragement for and financing of special training programmes,
4. Dissemination of available literature and abstracts through establishment of reference centres for UNIDO in various institutes engaged in environmental pollution control. Similar activities have already been started by the WHO, WMO and UNEP,
5. Stimulation of research and development projects and provision of the financial assistance and arrange for international collaboration wherever required,
6. Preparation of international guides on environmental pollution measures needed for industries to assist the developing countries.

The environmental pollution problems need solutions to be devised in such manner as to suit the local conditions. Turnkey solutions do not have much of place in this field. What is important, therefore, is to build up capability of a country to solve the problems by themselves. The International collaboration should be oriented towards assisting nations to build up this capability.

UNIDO shall have served a major of their purpose if they achieve this goal through consolidated efforts in pooling together the knowledge and expertise wherever available to put it to the advantage of those nations who need it from time to time. Every country will be looking forward to the UNIDO to help them in the form of technical, financial and other assistance so build up their own competence and be self-reliant.

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APPENDIX - I

List of the fertiliser plants for which NEERI conducted investigations on environmental pollution is given below.

(1) The Gujarat State Fertiliser Company Limited,
Baroda,
Gujarat.

(2) Fertiliser Corporation of India,
Trombay,
Bombay,
Maharashtra State.

(3) Zuary Agro Chemicals Limited,
Goa Fertiliser Unit,
Vascoda Gama,
Goa.

(4) Southern Petrochemical Industries Corporation,
Tuticorin,
Tamil Nadu, Madras

(5) Fertiliser Corporation of India,
Namrup,
Assam.

(6) Fertiliser Corporation of India,
Barauni,
Bihar.

(7) Ralli Chemicals, Super Phosphate Factory,
Magwara,
U.P.

(8) Fertiliser Corporation of India,
Gorakhpur,
U.P.

(9) Sahu Chemicals & Fertilisers,
Shahpuri,
Varanasi,
U.P.

The data from unpublished investigational reports on the above factories are used in the paper.

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