ENVIRONMENTAL MANAGEMENT IN THE INDIAN FERTILISER INDUSTRY

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CERTIFICATE

Certified that the thesis **ENVIRONMENTAL MANAGEMENT IN THE INDIAN FERTILISER INDUSTRY** is the record of bona fide research work carried out by Mr.M.P.Sukumaran Nair under my guidance. The thesis is worth submitting for the Degree of Doctor of Philosophy in Social Sciences.

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DECLARATION

I declare that the thesis **ENVIRONMENTAL MANAGEMENT IN THE INDIAN FERTILISER INDUSTRY** is the record of bona fide research work carried out by me under the supervision of Dr.C.A. Francis, Professor, School of Management Studies, Cochin University of Science and Technology. I further declare that this thesis has not previously formed the basis of the award of any degree, diploma, associateship, fellowship or other similar title of recognition.

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INTRODUCTION

Development of the fertiliser industry is very important to improve agricultural productivity and enhance food production to feed the increasing population. Growth of fertiliser industry, however, causes serious environmental problems. Environmental considerations, therefore, assume importance in respect of fertiliser and several other industries.

The process involved in the production of fertilisers generates effluents and the emissions contribute to environmental degradation such as green house effect, stratospheric ozone depletion, acid rain and acidification, eutrophication, soil degradation, technological hazards, chemical mists etc., with potential damage to human race. Thus, on the one hand we have the dire necessity to increase fertiliser production for maintaining food security while on the other hand the consequential environmental issues are to be tackled effectively to avoid damages. Environmental management assumes paramount importance in this perspective to address the numerous issues relating to pollution control, safety etc., and to minimize the degradation of the environment on account of developmental activities.

Objectives of the Study

The objectives of this study are:

1. to identify key issues in environmental protection in the production of fertilisers,

2. to assess the extent to which the national and international norms/guidelines regarding pollution control and environmental management in fertiliser plants are implemented in the fertiliser industry in India,
3. to identify the reasons for the non-compliance, if any, to those norms and guidelines by the fertiliser firms in India,
4. to understand the problems encountered in Environmental Management in Indian fertiliser plants, and
5. to suggest, on the basis of the above, guidelines for an environmental policy that will foster development of fertiliser industry in the country with out degrading the environment.

Importance of the Study

The growth of the fertiliser industry in the country all these years has been guided by the necessity of increasing production. This has led to serious environmental degradation of water resources, soil and air around these plants. Worldwide the focus of pollution control in the chemical industry has shifted from end of pipe treatment to avoiding pollution, clean technology and sustainable development. Hence, there is a necessity that environmental considerations shall play a substantive role in the future development of the industry. Despite the importance and urgency of the problem, no comprehensive work has so far been done in India on the whole issue with a view to develop a national level policy guidelines for the industry from the environmental angle. This study is an attempt to fill up the above gap by addressing the issues from the engineering and management angles.

Scope and Methodology

This study has been confined to the large scale sector of the Indian fertiliser industry.

The core of the study is based on detailed primary data collected from a representative sample of the fertiliser firms.

There are 29 major fertiliser manufacturing firms in India, of which 10 are in the public sector, 17 in the private sector and 2 in the co-operative sector. Twelve firms produce both nitrogenous and phosphatic fertilisers, 12 produce only nitrogenous fertilisers and 5 only phosphatic fertilisers. These firms have 72 operating plants in total, of which 54 are nitrogenous and 18 phosphatic plants. The entire requirement for potassium is met by imports.

Of the 54 nitrogenous and 18 phosphatic fertiliser plants, a sample of 15 plants from six firms has been taken for the detailed study based on vintage and technology, the most important factor with regard to pollution control and environmental management. The firms selected are Rashtriya Chemicals and Fertilisers Ltd., Mumbai; Fertilisers And Chemicals Travancore Ltd., Cochin; and Madras Fertilisers Ltd., Chennai from the public sector; Indo Gulf Fertiliser Corporation Ltd., Jagadishpur and Tata Chemicals Ltd., Babrala, from the private sector and Krishak Bharati Co-operative Ltd., Hazira, from the co-operative sector.

The Best Available Techniques (BAT) of European Fertiliser Manufacturers' Association (EFMA) is used for comparing the environmental performance of Indian plants under study.

Primary data pertaining to the study was collected from the sample using a questionnaire and through personal discussions with the concerned executives. A series of discussions and interviews on the various issues under study were conducted among a group of experienced people from different plants coming under Indian fertiliser industry. The viewpoints on relevant environmental issues from industry operators abroad and practicing professionals in fertiliser sector are obtained through an opinion poll using a specially designed questionnaire. The sources of secondary data were journals, publications on safety and environmental issues, information available from manufacturing companies through print versions or on the web, seminar presentations and such documentations, industry association databases and so on.

Literature Survey

There have been some studies on certain environmental aspects of fertiliser production as noted below. The '*Fertiliser Manual*' published by United Nations Development Programme (UNDP), 1980 and later revised and updated in 1998, trace the history of fertilisers, major fertiliser processes and contain a chapter on Pollution Control and Environmental Factors highlighting the effluents and emissions from these units and discuss the trends in pollution control approaches being adopted.

The '*Fertiliser Handbook*' published by The Fertiliser Institute (USA, 1982) intended to underscore the importance of fertilisers, its manufacture and cover the environmental aspects in general.

Technology and Manufacture of Ammonia by Samual Strelzoff examines practically every unit operation of ammonia production from various feedstock and contains necessary information, data and methodology for optimised design and operation of large capacity plants.

Catalyst Handbook edited by Martyn V. Twigg contains details about the various catalysts employed in ammonia manufacturing and contained useful information on catalyst development and manufacture, plant design and operation. Conversion and yield heavily depend on the efficiency of the catalytic reactions and it also help to proceed intended reactions to completion and avoid unwanted side reactions contributing to environmental problems.

Three great works on *Ammonia, Nitric Acid, Phosphoric Acid* edited by A.V.Slack provide first hand theoretical and practical information relating to development of technologies for these plants, various process designs currently available, thermodynamic implications, design details and challenges being confronted in operating plants and point to the directions in which new developments are likely to take place.

Fertiliser Manufacture by M.E. Pozin presents a detailed account of the various nitrogenous and phosphatic fertilisers commonly in use, their processes of production, environmental impacts and mechanisms adopted in plants for control.

Phosphates and Phosphoric Acid, Raw Materials, Technology, and Economics of the Wet Process by P. Becker gives a vivid account of the technology, process and environmental impacts of phosphoric acid production.

Pollution Control in Fertiliser Production edited by Charles A. Hodge, Neculai N. Popovici addresses nearly every aspect of pollution control of chemical fertiliser industry—covering current and emerging technologies for raw materials production, end products, and by-products. The book also explores the most advanced techniques for reducing noxious emissions in the environment and reviews the technologies needed to renovate existing facilities and methods for converting effluents and by-products to useful products.

Handbook of Pollution Control Processes edited by Robert Noyes is a concise but thorough overview of state-of-the-art technology for pollution control processes and highlight appropriate technology for decontamination and destruction of pollutants.

Manufacture of Sulfuric Acid by Werner W. Duecker and James R. West gives a detailed description of the process and technology involved in the manufacture and the environmental management of plants producing sulphuric acid.

Air Pollution by Arthur C. Stern is an excellent treatise on the various sources of air pollution, its mitigation and control. The book also contains various models of dispersion of pollutants in air and suggest design criteria and considerations for plants for effective containment of air pollution.

The European Fertiliser Manufacturers' Association (EFMA), Belgium, in response to the European Union directive on integrated pollution prevention and control, has brought out 8 booklets on *Best Available Techniques* (BAT) covering the processes for production of ammonia, nitric acid, sulphuric acid, phosphoric acid, urea and urea ammonium nitrate, ammonium nitrate and calcium ammonium nitrate and NPK compounded fertilisers by the mixed acid and nitro phosphate routes. These booklets contain industry perceptions and standard practices necessary to operate plants efficiently and safely.

Natural Capitalism: Creating the Next Industrial Revolution by Paul Hawken, Amory Lovins, L. and Hunter Lovins proposes a new approach for environmental management of our production systems by which natural resources could be made more productive and at the same time environmental concerns are minimized yielding benefits both for today's stakeholders as well as future generations and has a particular relevance to the fertiliser industry.

Major Hazard Control: A Practical Manual, published by the International Labour Organization, Geneva, contains techniques and methodologies for assessment and control of industrial hazards. It also outlines procedures for inspection hazardous installations, accident investigation, site selection etc.

The *Mond Index*, published by Imperial Chemical Industries PLC, UK, provides explanation and examples of a set of procedures developed for rapid hazard assessment of chemical process plants.

The Fire and Explosion Index-Hazard Classification Guide published by The Dow Chemical Co., UK, is a useful guide for assessing the damage potential of any operation in which flammable, combustible or reactive material is stored, handled or processed.

The Central Labour Institute, India has brought out a publication, *Guidelines on Inspection of Major Accident Hazard Installations*, to guide inspectors of factories in carrying out inspection of major accident hazard installations, emphasising methods for identifying areas in the plant that can give rise to a serious accident and risk to safety of personnel both onsite and offsite.

Loss Prevention in the Process Industries by Frank P. Lees is a versatile work in three volumes covering hazard and risk analysis in the process industries in its entirety and suggest numerous methods risk mitigation and containment within acceptable limits for safe operation of plants.

The Chemical Manufacturers' Association, USA, has published *Process Safety Management—Control of Acute Hazards* with a view to review and evaluate the systematic approaches to process safety analysis and help members select process safety methods which are most beneficial to their particular circumstances and develop more effective steps.

The *Risk Analysis in Process Industries* published by the Institution of Chemical Engineers (IChemE), UK contains methods for quantified risk analysis for promotion of safety in chemical process industries. The above book is the outcome of an international study group set up by the European Federation of Chemical Engineering in 1980.

Technical guidance for Hazard Analysis and *Hazardous Materials Emergency Planning Guide* are two important documents published by the US Environmental Protection Agency (EPA) contain techniques and methodologies for hazard analysis and contingency planning for mitigation of the harmful impacts of accidental releases etc., for planners.

Major Industrial Hazards—their Appraisal and Control by John Withers, is a planners guide intended for practitioners in the industry and for regulatory authorities. The book provides an introductory appreciation of the key elements, which need to be taken into account while attempting risk assessment of major installations.

Environmental Engineers' Hand Book by Bela G. Liptak, and F.N. David Liu in three volumes is a complete source book for designing pollution control and environmental management systems for all kinds of chemical plants and processes.

The Environment Impact Assessment—A Manual, published by the Ministry of Environment and Forests, Government of India, is a comprehensive document covering Environment Impact Assessment methodology including baseline studies, identification of key issues and consideration of alternatives, impact analysis, remedial measures and regulatory requirements.

Environmental Management, Law and Administration by Paras Diwan and Parag Diwan is a comprehensive work on the legal implications of the various facets of environmental law, administration and issues pertaining to environmental management.

The *Report of the International Study Group on Risk Analysis*, published by the Institution of Chemical Engineers, UK (1985) reviews the techniques employed when carrying out risk analysis for the promotion of safety in process industries for useful application in fertiliser industries.

A World Bank technical paper *Techniques for Assessing Industrial Hazards*, developed by Technica Ltd., UK, provide guidelines for identifying potential hazards of new and existing plants or processes in chemical and energy industries and for assessment of the consequence of the release of toxic flammable and explosive materials to the atmosphere. Most of the fertiliser raw materials are petroleum products that are highly inflammable and storage and handling of these products carry a high-risk potential.

The International Fertiliser Development Centre (IFDC), Alabama, USA, along with European Fertiliser Manufacturers Association (EFMA), the International Fertiliser Industry Association (IFA), The Fertiliser Institute (TFI), the United Nations Environment Programme (UNEP) and the United Nations Industrial Development Organization (UNIDO) has organized a series of workshops to examine the impact of fertiliser production and use on the environment, which include:

1. Environmental Impact of Ammonia and Urea Production Units (India, 1991)
2. Phosphate Fertilisers and the Environment (USA, 1992)
3. Nitric Acid Based Fertilisers and the Environment (Belgium, 1993)
4. Environmental Challenges of Fertiliser Production–an Examination of Progress and Pitfalls (USA, 1997) and
5. International Workshop on Current Environmental Issues of Fertiliser Production (Czech Republic, 1999).

These workshops, in view of the significant progress that has been made in achieving an increased level of environmental stewardship within the fertiliser industry and the special dynamics of the industry discussed the issues encountered in responding to existing and emerging environmental challenges among a wide representation of fertiliser manufacturers, engineering and scientific community, managers and policy planners and evolved remedies for the problems confronted in large-scale production processes.

The UNEP technical report on *Mineral Fertiliser Production and the Environment* (1998) provided guidelines on how environmental objectives might be achieved in the production of fertilisers by means of integrated industrial and environmental policies.

An inter-regional meeting on safety in the design and operation of ammonia plants under the joint auspices of United Nations Industrial Development Organization (UNIDO) and the Fertiliser Association of India (FAI) was also organized in India during 1976.

The Fertiliser Association of India (FAI) organized a group discussion on '*Emergency Preparedness and Disaster Management in Fertiliser Industry*' (1995) to create overall awareness on the risk emanating from fertiliser plants and improve the state of preparedness to deal with emergency situations.

An *Innovative High Risk/High Priority Anhydrous Ammonia Study: Tampa Bay* (1995) was organized by the US Environment Protection Agency to enquire into the safety of ammonia installations catering to fertiliser plants in the Florida coast.

FAI has developed and published a comprehensive *Safety Manual* (1996) for fertiliser plants in India.

'*Environmental Management*' a noted work by G.N. Pandey which covers pollution control in fertiliser industry also is intended to educate planners as well as executives working in the industry especially for developing a feel for the necessity of integrating environmental protection with development for balanced environmental management.

Reliability and Risk Assessment by J.D. Andrews and T.R. Moss gives a comprehensive description of the main probabilistic methods employed in reliability and risk assessment focusing on process plant operations.

Several publications on safety and environmental issues, information available from manufacturing companies through print versions or on the web, Seminar presentations and such documentations, Industry association databases, reports of Planning Commission, Directorate of Economics and Statistics, Government of India, major industry journals such as *Hydrocarbon Processing* (Gulf Publishing Co., US), *Chemical Engineering Progress* (American Institute of Chemical Engineers, US), *Chemical Engineering* (McGraw Hill, US), *Hydrocarbon Asia* (AP Energy Business Publications, Singapore), *Nitrogen, Phosphorous and Potassium, Sulphur* (all CRU Publishing, UK), *Chemical Processing* (Putman, US) etc., relevant publications from the Fertiliser Association of India (FAI), Ministry of Chemicals and Fertilisers, Government of India, Ministry of Environment and Forests, Government of India, World Bank, International Fertiliser Development Center (IFDC), International Fertiliser Industry Association (IFA), The Fertiliser Institute (TFI), United Nations Environment Programme (UNEP), United States Environment Protection Agency (USEPA), European Fertiliser Manufacturer's Association (EFMA) etc., provided source of secondary data for the study.

The above studies cover different aspects relating to safety and environmental issues of fertiliser plant operation in general and in certain cases specific to certain units only. A comprehensive study analyzing the various issues in environmental management and covering the whole of the industry was not attempted so far. This study is expected to cover the gap.

Limitations of the Study

The study is confined to the environmental management issues pertaining to the production of mineral fertilisers. It does not cover the implications of its use in the environment. The extent of the study is limited to the current practices prevailing in the industry and systems available at hand in the various units for meeting the quality and quantity regulations of the pollution control authorities. The study does not cover the impact of projects under implementation and future plans for better environmental control in the units. It is also assumed that installed pollution control facilities are always diligently operated. Further the study covered only the large-scale sector of the industry

Organisation of the Thesis

The research report is laid out in nine chapters. The introductory chapter describes the objectives of the study and its importance, the methodology and the limitations of the study.

The second chapter is devoted to establishing the intricate relationship between population, food security and fertiliser requirement to boost agricultural production.

The third chapter briefly reviews the growth and development of the fertiliser industry in India and highlights the environmental challenges being confronted.

The fourth chapter gives an outline of the fertiliser manufacturing processes currently in vogue in the country and the environmental problems arising out of these processes by way of emissions, effluents, solid waste etc., and reviews methods being adopted to control their adverse impacts.

The fifth chapter deals with the current practices and developments in environmental management and control strategies being adopted internationally in fertiliser manufacturing plants worldwide.

The sixth chapter outlines the legal framework of environmental protection as applied to fertiliser units.

The seventh chapter describes the importance of environmental management systems being adopted by several units, such as ISO 14000, Environmental Impact Assessment and Environmental Audits in Indian fertiliser plants.

The eighth chapter examines the environmental performance of the selected units vis-à-vis the best available practices, conformity with statutory stipulations and international standards.

The last chapter suggests, based on findings of the above analysis, elements of an environmental policy, to support the growth and development of fertiliser production in the country and enhance our food production with out large-scale environmental problems.

Chapter 2

POPULATION, FOOD SECURITY AND THE ENVIRONMENT

A large number of people around the world live in poverty and malnutrition indicating the need to increase food production. A recent UN study (Population Division, 2000) shows that it is certain that the world population will continue to grow significantly over the next half a century. Consequently, the demand for food also will follow a similar trend. It is well known that the growth rate in these two sectors do not go hand in hand but assume marked deviations—population increases in geometric proportions and food production follow the arithmetic trend. When Thomas Malthus published his *Essay on the Principle of Population* two hundred years ago, it seemed self-evident that human population growth would be periodically checked by famine, if not by pestilence and war. Despite 18th Century hopes for the "perfectibility" of man and for a brave new "scientific" world, where the application of reason would diminish the incidence of war and enhance the ability of medicine to defeat pestilence, it was impossible to see how agricultural production could be expanded sufficiently rapidly to accommodate the exponential nature of unconfined population growth.

In the developing world, 790 million people do not have enough to eat, according to the UN estimates (FAO, 2000). This is lower by 40 million compared to figures for 1990-92. At the World Food Summit in 1996, world leaders pledged to reduce the number of people affected by starvation to around 400 million by 2015. At the current rate of an average reduction of 8 million undernourished people a year; there is little scope of achieving the proposed goal by the targeted date.

According to *The State of Food Insecurity in the World* (FAO, 1999), the current reduction does not indicate uniform progress throughout the world. Indeed the data reveal that, in the first half of this decade, just 37 countries achieved a reduction in the number of undernourished, totaling 100 million people. Across the rest of the developing world, the number of hungry people actually increased by almost 60 million.

In the words of Norman Borlaug, "let us all remember that world peace will not and cannot be built on empty stomachs. Deny farmers access to modern factors of production—improved varieties, fertilisers and crop protection chemicals—and the world will be doomed, not from poisoning, as some say, but from starvation and social chaos" (Borlaug. N., 1997).

The State of Food Insecurity in the World (FAO, 1999), also points out that hunger is not limited to the developing nations. The report presents the first assessment of the number of undernourished people in the developed world, finding 8 million in the industrialized countries and 26 million in the countries in transition.

The "Earth Summit" held in Brazil in 1992 observed: "The world's capacity to feed a growing population is uncertain, ...agriculture has to meet the challenge mainly by increasing food production on land that is already in use, and avoid encroachment on land that is only marginally suitable for cultivation" (UNCED, 1992).

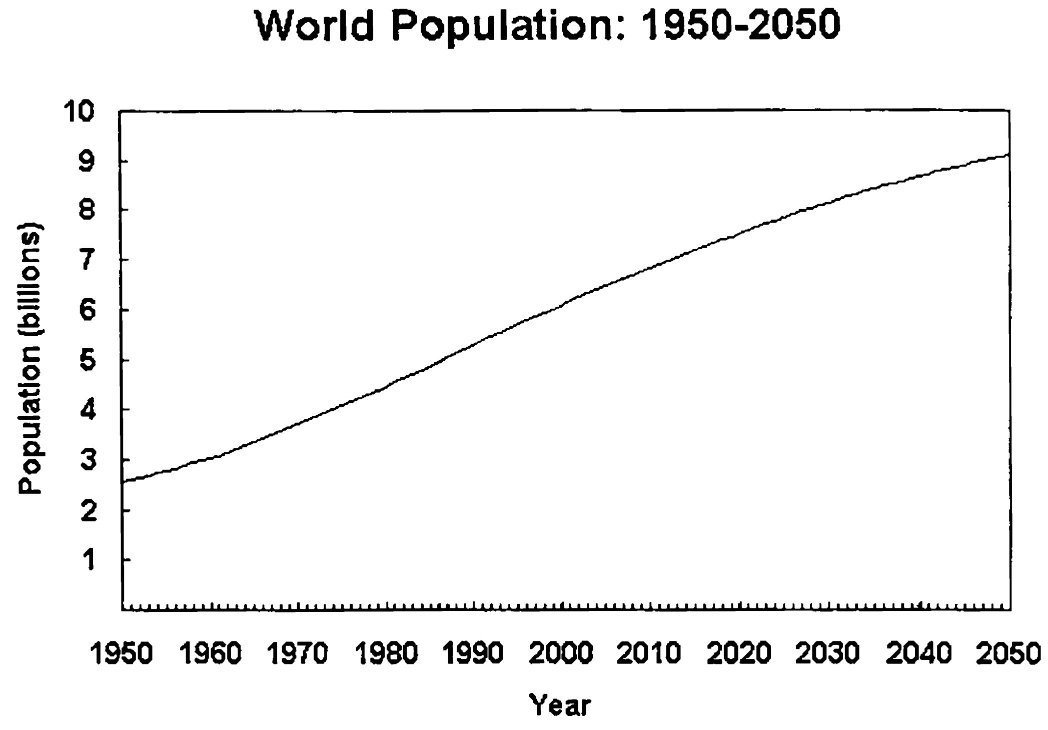
India could virtually eliminate urban poverty in a decade if it could sustain an annual economic growth averaging 6.4%. But the report also foresees growing disparities between Indian cities and the countryside where 74% of people live (NCAER, 1997). Agricultural growth is stagnant. All these suggest that any prescription to combat hunger essentially call for a two pronged approach of achieving reduction in population growth rate as well as increasing food production.

Population Growth

The world's population grew slowly till 1900 and thenceforth growth accelerated and reached 6.2 billion by 2000 (Fig.2.1). Developing countries with 77% of the world's people accounted for much of that growth. Population is now increasing at about 1.7% per year corresponding to a doubling time of 40 years (UN Population Division, 2000).

Today in India, we have 1 billion people, i.e. 16 per cent of the world's population on 2.4 per cent of the globe's land area. If current trends continue, India may overtake China in 2045, to become the most populous country in the world (NPP, 2000). While global population has increased threefold during this century, from 2 billion to 6 billion, the population of India has increased nearly five times from 238 million to 1 billion in the same period (Table 2.1). India's current annual increase in population of 15.5 million is large enough to neutralize efforts to conserve the resource endowment and environment.

The impact of population growth on development is evident from a study of the Human Development Index (HDI) of the countries. This is based on education, per capita income and years of life expectancy. The developed countries have a high Human Development Index, 95 out of 100. Their population growth rate is 0.25 per cent a year, the lowest in the world. At the other end of the scale is sub-Saharan Africa, with a population growth rate of 2.25 per cent a year, only slightly more than India's. Its rating on the index is 45 out of 100, the lowest in the world.



Source: U.S. Census Bureau, International Data Base 5-10-00.

Fig.2.1: Growth of World Population

Table 2.1

Population: India (1901-2001)

Census Year	Population (million)			Annual Growth rate %
	Rural	Urban	Total	
1901	212.5	25.9	238.4	
1911	226.2	25.9	252.1	0.56
1921	223.2	28.1	251.3	-0.03
1931	245.5	33.5	279	1.04
1941	274.5	44.2	318.7	1.33
1951	298.6	62.5	361.1	1.25
1961	360.3	78.9	439.2	1.96
1971	439	109.2	548.2	2.2
1981	523.9	159.4	683.3	2.28
1991	628.7	217.6	846.3	2.14
2001 (proj)	741.7	285.3	1027.0	1.93

Source: *Fertiliser Statistics, 2000-2001.*

India's rating is around 55 out of 100, and its population growth is 1.7 per cent a year. Had our population growth rate been, say 1.4 per cent a year, we would have been much higher in the index scale, and life would not have been so grim (WDR, 2000).

Food Supply

In the early 1960s our country was not self-sufficient in food production and today we are capable of meeting our requirements through domestic production. During the period 1950-1984, the introduction of high-yield crops and energy intensive agriculture ushered the Green Revolution, leading to increased crop production (Table 2.2). Worldwide food grain output increased by a factor of 2.6 in this period increasing linearly, within the fluctuations. Except for parts of Africa, production exceeded population growth throughout the world. Per capita production has now slowed and appears to be declining

The latest FAO Assessment of Food Insecurity in the World estimates the incidence of undernourishment in the developing countries in 1995-97 at 790 million persons (18 per cent of their population) (FAO,1999). This number has remained high, it was 960 million in 1969-71 (37 per cent of the population). Progress towards meeting the World Food Summit's target of halving the numbers of undernourished persons from the 830 million of 1990-92 by no later than 2015, has been slow so far. At the current pace, the target would not be met by 2015 (FAO,1999). Nevertheless, the decline in the relative incidence of undernourishment (a halving of the percentage of the population affected) has been a significant achievement.

Table 2.2

Production of Food Grains: India 1951-2001

Year	Production (million tonnes)	Average yield (kg/hectare)
1950-51	50.8	522
1955-56	68.6	605
1960-61	82	710
1965-66	72.3	629
1970-71	108.4	872
1975-76	121	944
1980-81	129.6	1023
1985-86	150.4	1175
1990-91	176.4	1380
1995-96	180.4	1491
1999-2000	196	1697

Source: *Fertiliser Statistics, 2000-2001.*

Considerable improvement is seen in the per capita food consumption in terms of kcal/person/day. The world average of this variable grew 17 per cent in the past three decades, to 2760 kilo calories (kcal) predominantly in the developing countries whose average grew 28 percent. The industrial countries and the transition economies have achieved fairly high levels of per capita consumption already in the mid-1960s. This progress in the aggregate of the developing countries has been decisively influenced by the significant gains made by the seven most populous countries with a population of over 100 million (China, Indonesia, Brazil, India, Pakistan, Nigeria and Bangladesh). There are currently still 33 countries that have per capita food consumption below 2200 kilo calories, most of them in sub-Saharan Africa (FAO, 1999)

Despite recent improvements to its food supply, India is not producing enough food to adequately feed its people, says a researcher who analyzed food balance sheets, census population data, government surveys, food composition statistics, and estimates of the population's biological requirements. While the country's food production has increased substantially in the past fifty years, the overall quantity has barely kept pace with population growth (Hopper, 1999). India's experience of famine indicates the need for an active involvement of Government in boosting agricultural productivity. Millions starved to death in West Bengal as recently as 1943 (Uppal, 1984). At the end of the 19th Century, more than six million people died in two successive famines. In the mid-1960s, a succession of monsoon failures caused many observers to despair of India's prospects. Like Malthus, they were unable to envisage the revolutionary technologies, which were even then emerging from agricultural research. Without the "Green Revolution", disaster would undoubtedly have struck India long before now. By 2025, India's population could increase by nearly 40% over its mid-1990s level. Allowing for increased per capita food demand, it is estimated that this will necessitate an annual grain supply of about 300 million tonnes, compared with about 210 million tonnes in 2001.

Since further agricultural land expansion is not feasible, farming intensity and average crop yields must be considerably increased, if large food imports are to be avoided.

There are a number of factors help to increase food production, but there are a number of constraints also that make it difficult. Constraints include currently available and utilized extent of arable land, rate of land degradation, and the limitations of water and biological resources.

Determinants of Agricultural Productivity

For most of the world's population, grain is the primary source of nutrition. It is thus a useful measure in estimating future food needs. Marine sources now provide only between one per cent and two per cent of the world's supply of food. Agricultural production has generally grown faster in the developing countries than in the developed countries, though from a much lower yield base. New technologies—improved plant varieties, fertilisers and plant protection chemicals, modern farming techniques—have been largely responsible for the growth in crop yields, together with an expansion of irrigation and multi-cropping. Over the last 50 years, the increase in agricultural production has been achieved mainly by increasing crop yields: the agricultural area has expanded relatively little. In 1960, the global area under arable and permanent crops was about 1.4 billion hectare. By 1990, this had expanded by eight per cent to 1.51 billion hectare. In 1960, world cereal production was about 830 million tonnes. By 1999, this had increased to 2064 million tonnes (FAO, 1999).

In the past, the balance between population and food supplies has been maintained by a combination of natural resource depletion and technological innovation. It is certain that, in its present form, relying for energy as it does on fossil fuels, this balance cannot be maintained indefinitely.

The total amount of land suitable for agriculture world over is about 8 billion acres. Of that, 3.8 billion acres are under cultivation and, with the growth of various developmental projects, the availability of land for agricultural use is shrinking .The amount of water available for irrigation is also dropping. Without excessive fertilization, one acre of land is needed to feed one person: therefore, the human population has already exceeded the number supportable without chemical fertilisers. As chemical fertiliser manufacturing is based on the use of crude oil, models simulating world trends predict serious shortages in the next Century (Liptak 1996).

The loss of productive soil has occurred as long as crops have been cultivated. Soil is a natural body synthesized in profile form from a variable mixture of broken and weathered minerals and decaying organic matter which covers the earth in a thin layer and which supplies when containing the proper amounts of air, water, mechanical support in part sustenance for plants (Buckman & Brady, 1969).

Lal and Pierce (FAO, 2000) report that land degradation has now become a major threat to the sustainability of world food supply. This loss arises from soil erosion, increase in salinity, water logging, and urbanization, construction etc. Nutrient depletion, over cultivation, overgrazing, acidification, and soil compaction contribute as well. Many of these processes are caused or are aggravated by poor agricultural management practices. Taken together or in various combinations, these factors decrease the productivity of the soil and substantially reduce annual crop yields and also reduce crop productivity in the long run.

Soil erosion, a problem throughout the world, is the most serious cause of degradation of arable land, owing to its adverse effect on crop productivity. The major cause is poor agricultural practices that leave the soil without vegetative cover to protect it against water and wind erosion. Soil loss by erosion is extremely serious because it takes from 200 to 1000 years, averaging about 500 years, to form 2.5 cm (1 inch) of topsoil under normal agricultural conditions. Throughout the world current soil losses range from about 20 to 300 tonnes per hectare per year with substantial amounts of nitrogen and other vital nutrients also lost. Top soil is being lost at 16 to 300 times faster than it can be replaced.

The low level equilibrium yields achieved under a permanently rain fed or irrigated agriculture were shifted upwards due to technological improvements such as crop rotation, higher levels of manure application to improve and maintain soil fertility

Water Resources

Water is the major limiting factor for world agricultural production. To supply this much water to the crop, assuming no use of irrigation, it require 10 million liters (1000 mm) of rain fall per hectare, that too must be reasonably evenly distributed during the year and especially during the growing season. About 16% of the world's cropland is under irrigation. Much of the world's irrigated land is being damaged by salinization and water logging from improper irrigation techniques. Serious salinization problems already exist in India, Pakistan, Egypt, Mexico, Australia and the US. Another damaging side effect of irrigation is the pollution of river and stream waters by the addition of salts. Pressures from growing populations have strained water resources in many areas of the world. The prospect for future expansion of irrigation to increase food supplies, worldwide and in the US, is not encouraging because per capita irrigated land has declined about 6% since 1978. Greatly expanded irrigation is a difficult, and probably unsustainable solution to the need for expansion of agriculture output because of the rapidly accelerating costs of irrigation.

Agricultural Technologies

There are numerous ways by which cropland productivity may be raised that do not induce injury over the long term and are "sustainable". If these technologies were put into common use in agriculture, some of the negative impacts of degradation in the agro-ecosystem could be reduced and the yields of many crops increased. These technologies include energy-intensive farming, livestock management and fertiliser sources ,soil and water conservation, crop varieties and genetic engineering, maintaining biodiversity , improved pest control and irrigation.

Plant Nutrient Depletion

As early as 1840 Justus von Liebig who laid the foundation of modern fertiliser industry stressed the value of mineral elements in plant nutrition and the necessity of replacing them to maintain soil fertility. He formulated a mineral theory that "the crops on a field diminish or increase in exact proportion to the diminution or increase of the mineral substance conveyed to it in manure" (Hignett, 1982).

An important scientific contribution was Liebig's philosophy: "Perfect agriculture is the true foundation of all trade and industry—it is the foundation of the riches of Nations. But a rational system of agriculture cannot be formed without the application of scientific principles for such a system must be based on an exact acquaintance with the means of vegetable nutrition. This knowledge we must seek through chemistry" (Leibeg, 1840).

Leibeg propounded the "Law of the Minimum', which is still a useful concept despite its lack of quantitative exactness. This law states that if one of the nutritive elements of the soil or air be deficient or lacking in availability, growth will be poor even when all others are abundant. If the deficient element is supplied growth will be increased in proportion to the amount supplied up to the point where the supply of that element is no longer the limiting factor. Increasing the supply beyond this point is not helpful because some other element is now minimum supply and becomes the limiting factor (Hignett, 1989). "The loss of soil fertility in many developing countries poses an immediate threat to food production and could result in a catastrophe no less serious than from other forms of environmental degradation". "Agricultural soils lose their fertility by plant nutrient depletion and, in some cases, plant nutrient exhaustion, a real and immediate threat to food security and to the lives and livelihoods of millions of people. The loss of fertility reduces yields and affects water holding capacity, leading to greater vulnerability to drought" (FAO, 1992).

The FAO has stated "after land and water, fertilisers are probably the most important input leading to increased yields. They were responsible for some 55% of the increase in yields in developing countries between 1965 and 1976" (FAO, 1981). The nutrient content of commonly used mineral fertilisers are shown in Table 2.3.

Table 2.3

Important Fertilisers and their Nutrient Content (per cent)

Fertiliser type	Common Names	N	P_2O_5	K_2O	S
Nitrogen Fertilisers	Ammonium Sulphate	21	0	0	23
	Ammonium Nitrate	33-34.5	0	0	0
	Calcium Ammonium Nitrate	20.4-27	0	0	0
	Urea	45-46	0	0	0
Phosphate Fertilisers	Single Super Phosphate	0	16-20	0	12
	Triple Super Phosphate	0	46	0	0
	Diammonium Phosphate	18	46	0	0
	Ground Rock Phosphate	0	20-40	0	0
Potash Fertilisers	Muriate of Potash (Chloride)	0	0	60	0
	Sulphate of Potash	0	0	50	18

Source: *International Fertiliser Industry Association Database, 2001.*

Fertilisers are produced from naturally occurring raw materials and hence increased fertiliser production means additional pressure on nature, which will have tremendous environmental consequences. These include emissions and effluents containing pollutants that contribute to global and local environmental problems. Sustainable agriculture thus demands balanced application of fertilisers with minimum adverse environmental impacts during every stage of its production and use. Thus, a technically sound, economically viable, environment friendly, practically feasible and socially acceptable management policy is needed to ensure sustainable and high agricultural productivity.

It is interesting to examine how global food production may be increased to provide for a population expected to double by about 2050. Increasing current food production more than proportional to population growth is required so as to provide most humans with an adequate diet. The success of the Green Revolution lay primarily in its increased use of fertilisers, pesticides, and irrigation as well as use of improved seed verities. It increased the energy-intensiveness of agricultural production many folds. Modem developments in genetics and plant breeding helped to design plants species that could tolerate high levels of fertiliser use and improving the harvest index.

The Revolution has been implemented in a manner that has not proved to be environmentally sustainable. The technology has enhanced soil erosion, polluted groundwater and surface-water resources, and increased pesticide use has caused serious public health and environmental problems . Opportunities exist to reduce these negative environmental and social impacts. Research is underway at most of the International Crop Research Centres to make the revolution more environmentally and socially sustainable.

Since 1980, there has been some improvement in world crop yields with the rate of increase in total grain production declining slightly. Grain production has increased roughly linearly since the early 1950s. Area under grain cultivation reduced by 8% worldwide since 1981 (FAO, 2000). However, there are a number of important obstacles to a large, further expansion of the energy intensive practices that underlay the expansion based on the Green Revolution, including economics, technology adoption, and environmental degradation.

According to Dr.Swaminathan. fertiliser is the key to securing the food need of more than 1.3 billion Indians by the year 2025. No country has been able to increase agricultural productivity without expanding the use of chemical fertilisers. Working on a conservative population forecast of 1.3 billion by 2025, India would need 30 to 35 million tonnes of Nitrogen (N), Phosphorous (P) and Potassium (K) from chemical fertilisers in addition to 10 million tonnes from organic and bio-fertiliser sources, to produce the minimum food grain need of 300 million tonnes. Scientists have found that there was growing evidence of the increasing deficiency of phosphate and potash in soils, aggravated by the disproportionate application of higher doses of N in relation to P and K. Sulphur has been identified as crucial for optimizing the yield from oilseeds, pulses, legumes and high-yielding cereals (Swaminathan, 1997).

Fertilisers have played a very eminent role in Indian agriculture also. From a meager 0.13 million tonnes in 1955-56, fertiliser consumption has increased dramatically over the last four decades to reach 14.3 million tonnes in 1996-97 (Rao & Srivastava,1998). As a consequence of the growing demand for food grain, fiber, fuel and fodder to meet the needs of an ever increasing population, fertiliser consumption is increasing annually. The contribution of fertilisers to total grain production in India has been remarkable i.e., from one per cent in 1950 to 58 per cent in 1995. The contribution of fertiliser to additional food production was still higher *ie.*, about 60 per cent (Velayudham, 1998).

World fertiliser consumption increased steadily from 1920/21 to the present times and showed a phenomenal growth during the period 1951 to 1995 (Table 2.4

and Fig.2.2). The present concern is to ensure the sustainability of crop yields, a safe environment and profitability for the poor farmer with increased fertiliser use.

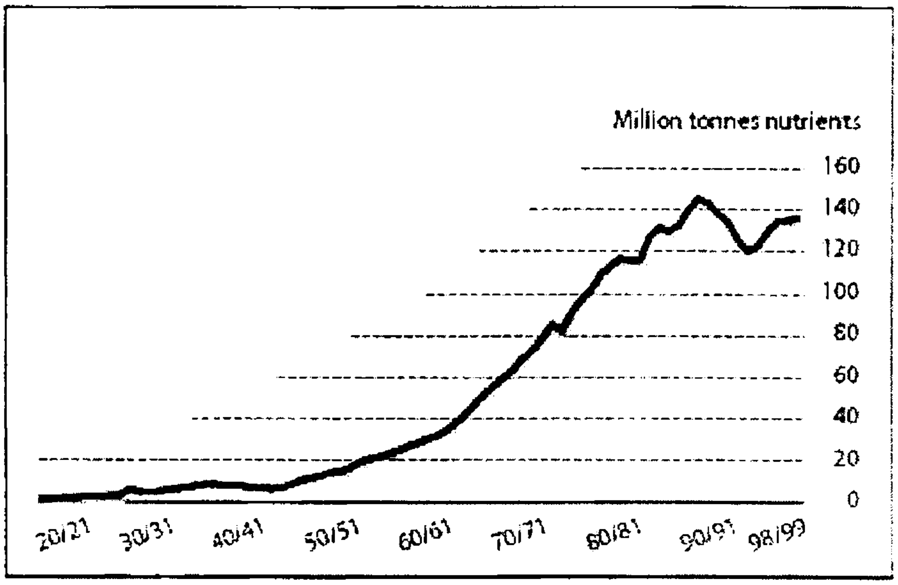
Table 2.4

World Fertiliser Consumption

(million tonnes nutrients)

Year	N	P_2O_5	K_2O	Total
1920/21	--	1.73	--	1.73
1930/31	1.3	2.77	1.39	5.46
1960/61	10.83	10.73	8.48	30.04
1970/71	31.75	21.11	16.29	69.15
1980/81	60.78	32.04	24.39	117.21
1990/91	77.56	36.07	24.61	138.24
1998/99	82.18	32.88	21.87	136.93

Source: *International Fertiliser Industry Association Database, 2001.*



Source: *International Fertiliser Industry Association*, 2001.

Fig.2.2: World Fertiliser Consumption

A study by Dr.R.N.Prashad revealed that over 7.7 lakh tonnes of nitrogen were removed by plants from soil taking in to account of the present level of food grain production while 10.6 lakh tonnes were added annually (Prashad, 1997).

"Past and current failures to replenish soil nutrients in many countries must be rectified through the balanced and efficient use of sources of plant nutrients and through improved soil management practices. While some of the plant nutrient requirements can be met through the application of organic materials available on the farm or in the community, such materials are insufficient to replenish the plant nutrients removed from the soils. It is critical that fertiliser use be expanded in those countries where a large share of the population is food insecure. One of the largest environmental problems in Africa today is the gradual decline in fertility of much of the soil" (Pinstrup *et al.*, 1997).

Impact of Fertilisers on Soil Structure

Some think that the use of mineral fertilisers has an adverse effect on soil structure. Evidence from very long-term experiments indicates that this is not the case. The aggregating action from enhanced root proliferation and greater amount of decaying residues from well fertilised crops makes soils more friable, easier to cultivate and more receptive to water. Organic carbon contents that become lower under inadequate, fertilisation appear to recover when adequate fertiliser is applied. Adequate fertilisation also contributes to greater biomass production tending to protect soil from erosion and providing greater quantities of residue critical to soil aggregation. We therefore conclude that long-term, high-input agriculture has a strong positive effect in improving agronomic properties of soils (Buol & Stokes, 1997).

There is a necessity for the community that the growing population is to be fed properly. Taking all constraints and favorable factors to achieve this end it is essential that crop productivity is to be enhanced at the same time maintaining the sustainability of agriculture. Damages already done to the biological and physical environment, on which we depend for food production has to be reversed to bring back ecological balance and minimize further damages. Controlling these damaging activities and increasing food production must now receive priority if humanity is to avoid harsh difficulties in the decades ahead.

The biggest danger to the world's natural environment today is low yield agriculture (Denis, 1997). Attempts to markedly expand global food production would require massive programmes to conserve land, efficient use of plant nutrients and efficient use of fresh water. The rates of food grain growth required to increase the per capita food available, in the light of present projections of population growth, are greater than have been achieved under any but the most favorable circumstances in developed countries.

Among these efficient production and balanced application of mineral fertilisers are of paramount importance and would require a highly organized global effort-by both the developed and the developing countries.

This implies that there will have to be a substantial increase in fertiliser production in future. There would, therefore, be a growing threat to environmental quality unless proper preventive measures are taken.

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Chapter 3

FERTILISER INDUSTRY IN INDIA

With over one billion people, India is the second most populous country in the world. During 1999-2000, the food production achieved an all time high record of 208.9 million tonnes. The targeted production of food grains by the end of Ninth Plan was 231 million tonnes (Ministry of Agriculture, 1999).

The productivity of our fields is low compared to other countries (Tewatia R.K *et al.*, 1992). In addition, the cultivable land resource is shrinking year by year because of various alternate uses. To meet the food, fiber, fuel, fodder, and other needs of the growing population, the productivity of agricultural land has to be necessarily improved with increased use of agricultural inputs like quality seeds, fertilisers, water, agro-chemicals etc., for better crop yields. Among the different agricultural inputs and practices required for good production, the use of the fertilisers together with quality seeds and water are the most important.

The large-scale use of fertilisers in India started in the late 1960s, after the introduction of high yielding varieties, which pioneered the "Green Revolution". The important fertilisers currently being used are Urea, Di-Ammonium Phosphate (DAP), Single Super Phosphate (SSP) and Muriate of Potash (MOP). These fertilisers supply mainly nitrogen (N), phosphorous (P) and potassium (K) whereas the requirement of other essential nutrients is largely met only from soil and to some extent from organic manures. Currently, about 16 million tonnes of N, P_2O_5 and K_2O are being used annually as fertilisers, which corresponds to an average NPK use of 87 kilograms per hectare (kg/ha). Considering the level of crop production during 1996-97 in India, the annual nutrient removal from soil is about 26 million tonnes, whereas supply from chemical fertilisers is around 14 million tonnes thus leaving a gap of about 12 million tonnes (IFA, 1999).

The fertiliser consumption per hectare of cultivated land in India is much lower than that of China or the US and it needs to be increased in future, to attain the required food grain production.

Table 3.1

Fertiliser Consumption 1999-2000 (per capita)

(kilograms/hectare)

United States	111
China	271
World	94
India	106

Source: *Fertiliser Statistics, 2001.*

The nutrient use efficiency of applied fertilisers indicates the extent to which it is absorbed by the plants. In India the use efficiency in respect of various nutrients are as follows:

Table 3.2

Nutrient Efficiency in India

(Per cent)

Nutrient	Efficiency
Nitrogen	30—50
Phosphorus	15—20
Potassium	70—80
Zinc	2—5
Iron	1—2
Copper	1—2

Source: *Tandon HLS, 1995.*

The above situation indicates that there is scope for attaining higher efficiency levels through balanced application. This would also reduce pollution from leaching of excess nutrients to the environment.

The Indian fertiliser industry had a very humble beginning in 1906, when the first manufacturing unit was set up in Ranipet near Chennai with a production capacity of 6000 metric tonne (MT) of Single Superphosphate per annum. The Fertilisers And Chemicals Travancore Ltd. (FACT) at Cochin in Kerala and the Fertiliser Corporation of India Ltd., Sindri in Bihar, were the first large sized fertiliser plants to be set up in the forties and fifties with a view to establishing a base for industrialization and achieving self-sufficiency in food grains. The Green Revolution in the late sixties gave an impetus to the growth of the fertiliser industry in India. The eighties witnessed a significant addition to the fertiliser production capacity.

In India, there are 54 major nitrogenous and 18 phosphatic fertiliser plants besides 83 single super phosphate plants with an installed capacity of 11.068 million tonnes of N and 3.747 million tonnes of P_20_5. These plants produced 10.87 million tonnes of N and 3.41 million tonnes of P_20_5 during 1999-2000 (FAI, 2000).

The total installed capacity of fertiliser production in the country, which was 10.5 million tonnes of nitrogen, and 2.95 million tonnes of phosphate during 1998, has risen to 11.72 million tonnes of nitrogen and 3.8 million tonnes of phosphate by 2001 (Table 3.3).

The rapid buildup of fertiliser production capacity in the country in the eighties has been achieved because of a favorable policy environment following the Retention Pricing Scheme and substantial investments made over the years in the public, co-operative and private sectors.

Table 3.3

Fertiliser Capacities, Production and Consumption in India

(million tonnes)

Year	Capacity		Production		Consumption	
	N	P	N	P	N	P
1951-'56	0.1	0.106	0.077	0.0124	0.108	0.013
1956-'61	0.121	0.128	0.112	0.0537	0.212	0.0531
1961-'66	0.47	0.274	0.238	0.119	0.575	0.133
1966-'69	0.855	0.434	0.563	0.213	1.209	0.382
1969-'74	1.947	0.581	1.05	0.325	1.829	0.65
1974-'79	3.274	1.117	2.173	0.778	3.42	1.106
1980-'85	5.241	1.722	3.917	1.318	5.486	1.886
1986-'90	8.147	2.716	6.747	1.795	7.386	3.014
1990-'95	8.844	2.834	7.944	2.557	9.507	2.932
1995-'96	8.998	2.924	8.769	2.593	9.882	2.897
1996-'97	9.332	2.948	8.593	2.578	10.301	2.976
1997-'98	9.987	3.165	10.083	3.058	10.901	3.913
1998-'99	10.571	3.206	10.477	3.181	11.353	4.112
1999-'00	11.068	3.748	10.873	3.407	11.592	4.798
2000-'01	11.719	4.717	11.004	3.748	10.92	4.214

Source: *Fertiliser Statistics, 2001.*

The large size fertiliser plants in the country are distributed in the public, co-operative and private sectors of the economy and manufacture a wide range of nitrogenous and phosphatic/complex fertilisers including urea, DAP and complex fertilisers (Table 3.4).

Table 3.4

Sector wise Installed Capacity

(million tonnes)

Sector	Installed Capacity		
	Quantity	N	P
Public	12.391	4.32	0.827
Private	17.59	4.401	2.302
Co-operative	6.20	2.348	0.5192

Source: *Fertiliser Statistics, 2001.*

Besides, there are seven units producing low analysis straight nitrogenous fertilisers. Among the large units, nine of them produce ammonium sulphate as a by-product. Apart from these there are 83 small-scale units producing single super phosphate.

There are around 25 chemical fertiliser materials in use in India today coming under nitrogenous, phosphatic, potassic, or complex category depending upon their nutrient content (Table 3.5). Urea and calcium ammonium nitrate (CAN) are the major nitrogenous fertilisers. Single superphosphate (SSP) is the main phosphatic fertiliser, while the main complex fertiliser is diammonium phosphate (DAP) (FAI, 1999).

Table 3.5

Fertiliser—Product wise Installed Capacity

('000 MT)

Product	Quantity	N	P
Urea	20067.3	9231.0	0.0
Ammonium Sulphate	771.5	162.0	0.0
Calcium Ammonium Nitrate	942.5	235.6	0.0
Ammonium Chloride	128.0	32.0	0.0
DAP	3646.5	656.4	1677.4
SSP	6262.8	0.0	1002.0
NP 20:20	613.5	122.7	122.7
NPK 15:15:15	300.0	45.0	45.0
NP 20.8:20.8	361.0	75.1	75.1
NPK 17:17:17	840.0	142.8	142.8
NPK 10:26:26	602.0	60.2	156.5
NPK 12:32:16	455.0	54.6	145.6
NPK 14:35:14	96.5	13.5	33.8
NPK 9:19:19	300.0	57.0	57.0
NP 28:28	251.0	70.3	70.3
NP 16:20	170.0	27.2	34.0
NP 23:23	372.5	85.7	85.7
Total	36180.2	11071.0	3647.9
Complexes Total	40541.7	11825.1	4616.3

Source: *Fertiliser Statistics, 2001.*

Fertiliser consumption increased from 16.8 million tonnes during 1998-'99 to 18.13 million tonnes during 1999-'00. The consumption of Nitrogen (N) increased from 11.35 million tonnes during 1998-'99 to 11.62 million tonnes during 1999-'00. The consumption of Phosphate (P) increased from 4.1 million tonnes during 1998-'99 to 4.8 million tonnes during 1999-'00. The consumption of potassium (K) increased from 1.31 million tonnes during 1998-'99 to 1.7 million tonnes during 1999-'00 (FAI. 1999).

Nitrogenous fertilisers accounted for 64 per cent of total fertiliser consumption in 1999-2000, while phosphatic fertilisers and potassic fertilisers accounted for 26.5 per cent and 9.5 per cent of total consumption, respectively. The most important fertilisers being used in the country are urea DAP and SSP.

The fertiliser industry in India is the third largest in the World after China and the US. During 1999-2000 indigenous production was 10.87 million tonnes of N and 3.41 million tonnes of P_2O_5. This is insufficient to meet the domestic demand and hence imports have become necessary. During 1999-2000, 2.95 million tonnes of Potash, 3.27 million tonnes of DAP and 0.533 million tonnes of Urea were imported to the country (FAI, 2000).

During the year 1999 additional capacity of one million tonnes per annum of NP/DAP and 0.775 million tonnes per annum of urea were commissioned. There are seven major projects having a capacity of 0.476 million tonnes per annum of urea and 3.12 million tonnes per annum of NP/DAP under implementation. Besides the Government is also considering proposals for creation of domestic production of another 3.072 million tonnes per annum of urea.

Though certain fertiliser materials and intermediates are currently available at price levels lower than that of domestic production, we cannot take the situation for granted as international fertiliser prices are often volatile in nature and depend purely on the existing supply/demand scenario. Hence, it is essential that we have to create sufficient domestic capacities and at the same time take advantage of the prices levels prevailing in the international markets.

The industry in the country is characterized by a number of heterogeneous factors such as feedstock, vintage, location, technologies, capital costs etc. It has attained levels of capacity utilisation which compare favourably with the best in the world. The capacity utilisation during 1998-99 was 99.6% for nitrogen and 99.1% for phosphate. The capacity utilisation is estimated at 103.0% for nitrogen and 94.2% for phosphate during 1999-2000.

The capacity utilisation of the fertiliser industry is expected to improve as more and more modern plants based on proven technology and equipment go on stream. The existing plants are being encouraged to improve their capacity utilisation through revamping and modernisation and incorporation of dual fuel/feedstock facilities, energy conservation measures etc., wherever feasible.

Consumption of fertilisers grew sharply consequent to the Green Revolution, due to the integrated use of fertilisers, HYV seeds, irrigation, modern agricultural implements etc. Growth of the fertiliser industry in India is marked by the inception of the Retention Pricing Scheme (RPS) in 1977 upon the recommendation of the Marathe Committee, which enquired into almost all aspects concerned with the production operating efficiencies, feedstock, vintage, distribution and pricing of different fertiliser materials. The following years witnessed an outbreak of investment in this sector both by public and private enterprises and by the co-operatives. Availability of Natural and Associated gas from the Bombay High and Bassien and the construction of the Hazira-Bijaipur-Jagadishpur (HBJ) pipeline catalysed the above growth.

According to the RPS the Central Government guaranteed a reasonable 12% return on net worth to all investors in the fertiliser sector which was considered highly attractive at that point of time when investment opportunities have not opened up as is now. Under the RPS all manufacturers were reimbursed an amount equal to that of their actual cost of production including 12% return on net worth less the revenue realisation upon sale at the market prices fixed by the Government as fertiliser subsidy. The development of the industry continued till 1990 with a number of world class plants coming up both in the nitrogenous and phosphatic sector almost all over the country. Consequently, food production started setting trends.

A wide range of feedstock such as natural gas, naphtha, coal, coke over gas, fuel oil, Low Sulphur Heavy Stock (LSHS) and imported ammonia are used for production of nitrogenous fertilisers (Table 3.6). The choice of feedstock is dictated by factors such as availability, technology, commercial viability, alternate uses, pricing, and government policies. Natural gas is the preferred feedstock (accounting for 54 per cent of urea capacity), because it is energy efficient, economical, causing low pollution and ensures smooth plant operations. However, over the next few years, demand for natural gas is expected to far exceed supply, resulting in persistent shortages. Naphtha is the second-most important feedstock for nitrogenous fertilisers. While availability of naphtha is likely to be easy, pricing could be uncertain in the context of potential decontrol of the oil sector. The main feedstock for phosphatic fertilisers is phosphoric acid, which is made from rock phosphate processed with nitric acid or sulphuric acid made from elemental sulphur, smelter gases, or pyrites. Nearly 87 per cent of phosphoric acid is imported, mainly from China, Morocco, Tunisia, and Senegal.

The fertiliser industry has adopted several growth strategies such as expansion, retrofitting and revamping of existing units, setting up joint venture projects in countries having abundant and cheap raw material resources, seeking alternative sources like liquefied natural gas and good quality coal in order to overcome the constraints in the availability of natural gas.

Table 3.6

Installed Capacity on Feedstock Basis

(million tonnes)

Feedstock	Installed Capacity		
	Quantity	N	P
Fuel Oil	2.872	1.208	0.0328
Naphtha	8.776	3.141	0.751
Coal	0.66	0.3036	0
Natural Gas	14.415	5.8216	0.7171
External Ammonia	2.9765	0.5506	1.1452
Coke Oven Gas	0.2185	0.0459	0
Phosphate Rock & Sulphur	6.2628	0	1.0021
Total	36.1808	11.0707	3.6482

Source: *Fertiliser Statistics, 2001.*

Of the three main nutrients required for various crops—nitrogen, phosphate and potash—indigenous raw materials are available mainly for nitrogen. The Government's policy has aimed at achieving the maximum possible degree of self-sufficiency in the production of nitrogenous fertilisers based on utilisation of indigenous feedstock. As of now, the country is self-sufficient to the extent of about 92.1% in the case of nitrogen. Prior to 1980, nitrogenous fertiliser plants were based mainly on naphtha as feedstock. A number of fuel oil based ammonia-urea plants were also set up during 1978 to 1982. In 1980, two coal-based plants were set up for the first time in the country at Talcher (Orissa) and Ramagundam (Andhra Pradesh). With associated and free gas becoming available from offshore Bombay High and South Bassein basins, a number of gas based ammonia-urea plants have been set up since 1985. In view of the limitations on availability of gas, a number of expansion projects were taken up in the last few years with naphtha as feedstock with the flexibility for switching over to gas as and when it is available. Feasibility of a delivery system of Liquefied Natural Gas (LNG) to meet the demand of fertiliser units and projects is also being explored.

In the case of phosphates, the paucity of domestic raw material constrains the attainment of any degree of self-sufficiency. Recognising this, a deliberate policy-mix has been adopted which involves the modulation of three options:

i) domestic production based on indigenous/imported rock phosphate and imported sulphur;

ii) domestic production based on imported intermediates *viz.*, ammonia and phosphoric acid, and

iii) import of finished fertiliser *viz.*, Di-Ammonium Phosphate (DAP) and Mono-Ammonium Phosphate (MAP) and Nitrogen Phosphate Potash (NPK) complexes.

Roughly, 66% of the requirement of phosphatic fertilisers is met through the first two options. Since indigenous rock phosphate supplies meet only 5-10% of the total requirement of P_2O_5, phosphatic fertilisers produced in the country are essentially based on imported raw materials and intermediates.

There are no known commercially exploitable reserves of potash in the country and the entire requirement of potassium fertilisers for direct application as well as for production of complex fertilisers is met through imports.

In order to bridge the gap between demand and domestic availability, the country may have to continue to depend on imports to meet the requirement of phosphatic and potassic fertilisers, due to non-availability of indigenous raw-material. This is desirable in view of strategic considerations as the international urea market is highly volatile to demand supply scenario.

To meet the growing demand of fertilisers in the country through maximum indigenous production, self-reliance in design engineering and execution of fertiliser projects is as important as autonomy in fertiliser production. This requires a strong indigenous technological base in planning, development of process know-how, design engineering and expertise in project management and execution of the project. As a sequel to the continuing support of the Government for research and development as well as design engineering activities over the years, Indian consultancy organisations in the field of fertilisers have grown steadily in tandem with the fertiliser industry. These consultancy organisations are today in a position to undertake execution of fertiliser projects starting from the stage of conceptualising to commissioning of plants.

The fertiliser plant operators have now fully absorbed and assimilated the latest in fertiliser technology and are in a position to operate and maintain the plants at their optimum levels. The average performance of gas-based plants in the country today is amongst the best in the world. Still there is scope for further improvements in our operating plants especially with regard to energy consumption, environmental quality and optimum use of available resources.

The Government has all along followed the policy of self-sufficiency in the production of fertilisers. The policy of attaining self-sufficiency has been influenced by the availability of the three main nutrients required for the various crops apart from the need to protect the domestic industry and the logistical difficulty in importing the entire requirement. In the case of phosphates, the paucity of indigenous raw materials is a serious constraint in achieving the goal of self-sufficiency. Of late, the Government has, therefore, adopted a mixed strategy by going in for a combination of domestic production based on indigenous or imported rock phosphate and imported sulphur, domestic production based on imported intermediates like ammonia and phosphoric acid and import of the finished product *viz.*, DAP. Seventy per cent of the requirement of phosphatic fertilisers is met through the first two options (Ministry of Chemicals & Fertilisers, 2001).

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Chapter 4

FERTILISER MANUFACTURING PROCESSES AND ITS ENVIRONMENTAL PROBLEMS

Chemical fertiliser production aims at making available natural nutrients to plants as water-soluble compounds so that absorption is easy. This chapter provides a general description of the main fertiliser production processes. An understanding of these processes is essential in identifying the pollutants and the environmental issues that arise out of these plants. The products dealt with in this chapter are ammonia, urea, nitric acid, ammonium nitrate and calcium ammonium nitrate, sulphuric acid, phosphoric acid, single and triple super phosphate and complex fertilisers.

AMMONIA

Nitrogen, plentifully available in atmosphere, all around cannot be directly absorbed by plants and hence require proper fixation. It is usually converted first to ammonia and then to ammonium salts, most of which are highly water soluble. Ammonia is produced by the direct synthesis from elemental hydrogen contained in water and nitrogen present in the air. Isolation of these two gases in its elemental form from water and air necessitate the requirement of a large input of energy. Usually this energy requirement is provided by fossil fuels such as petroleum fractions, coal etc. Natural gas, coke oven gas, light hydrocarbon such as naphtha, fuel oil, vacuum residues from refining, coal etc., are the common feedstock for ammonia plants. Various technologies and processes are available for ammonia manufacture depending on feedstock. Steam reforming of natural gas and light hydrocarbons and partial oxidation of fuel oil; vacuum residue and coal are the commonly employed technologies for ammonia synthesis (Appl, Max. 1992).

Natural gas is preferred over the other feedstock for Ammonia (NH_3) synthesis from an environmental perspective. Ammonia production from natural gas includes process steps such as desulfurisation of the feedstock; primary and secondary reforming, carbon monoxide shift conversion and removal of carbon dioxide, which can be later used for urea manufacture; methanation; and ammonia synthesis (Fig.4.1).

Catalysts used in the process reaction may include cobalt, molybdenum, nickel, iron oxide/chromium oxide, copper oxide/zinc oxide, and iron. Around 77% of world ammonia production capacity is currently based on steam reforming of natural gas. A modern ammonia plant has a typical capacity of 1000-1800 MT per day (FM, 1998) and new plants are now being designed up to 3000 MT per day. The process and energy systems in these plants are integrated to maximize energy efficiency and reduce effluents and emission to the environment. More than 99% of world nitrogen fertiliser production is based on ammonia (UNEP, 1996).

Chemistry of the Process

The reactions for ammonia synthesis gas production from natural gas are mainly:

the reforming reaction: $CH_4 + H_2O \rightarrow CO + 3\ H_2$ ...... (1)

the shift conversion reaction: $CO + H_2O \rightarrow CO_2 + H_2$ ...... (2)

Reaction (1) takes place mainly in the primary and secondary reformer. Reaction (2) takes place in both reformers to a lower extent, but mostly in the downstream shift conversion reactors (Fig.4.2).

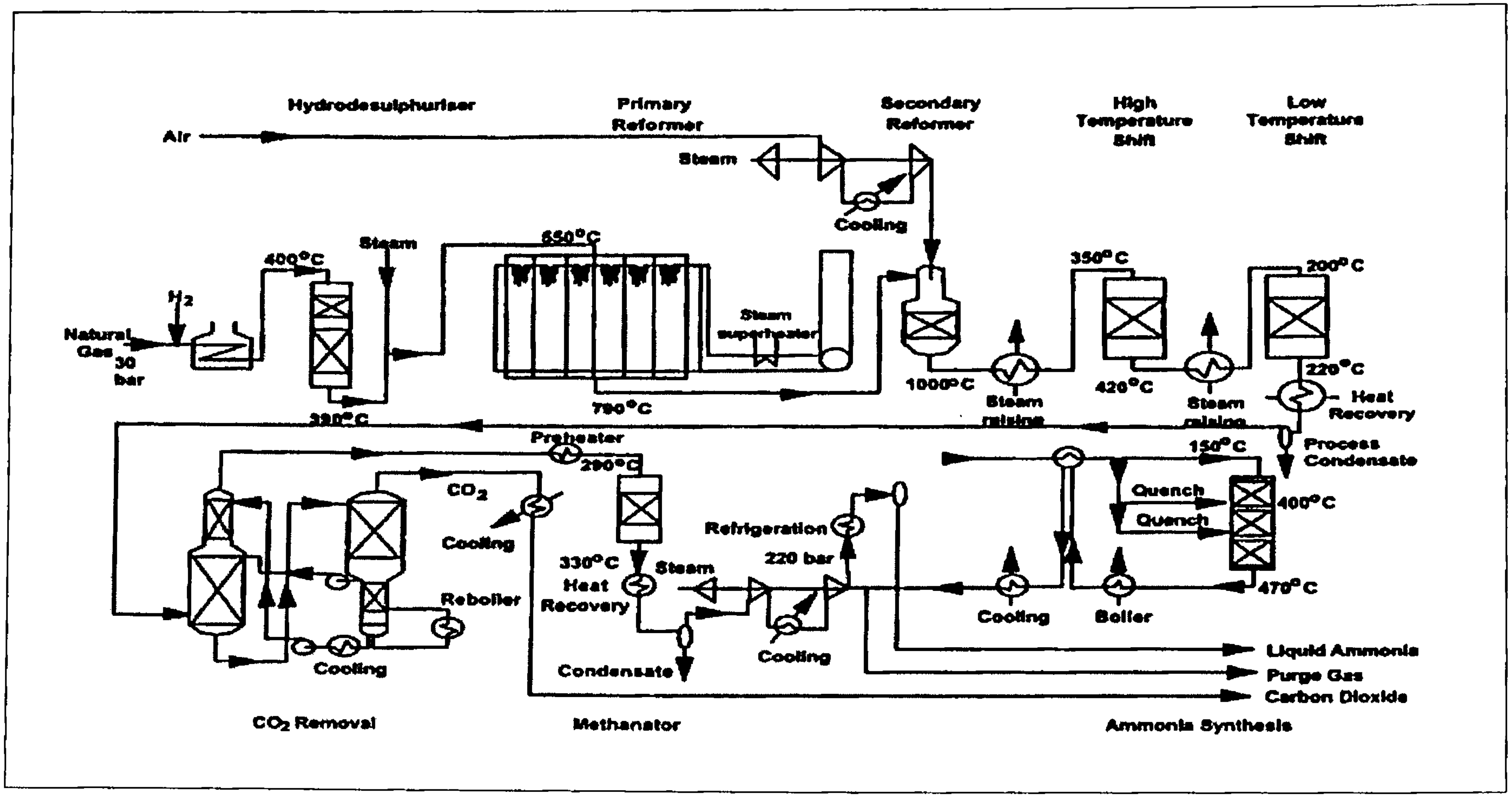

Fig.4.1: Flow Sheet of Ammonia Plant Based on Steam Reforming

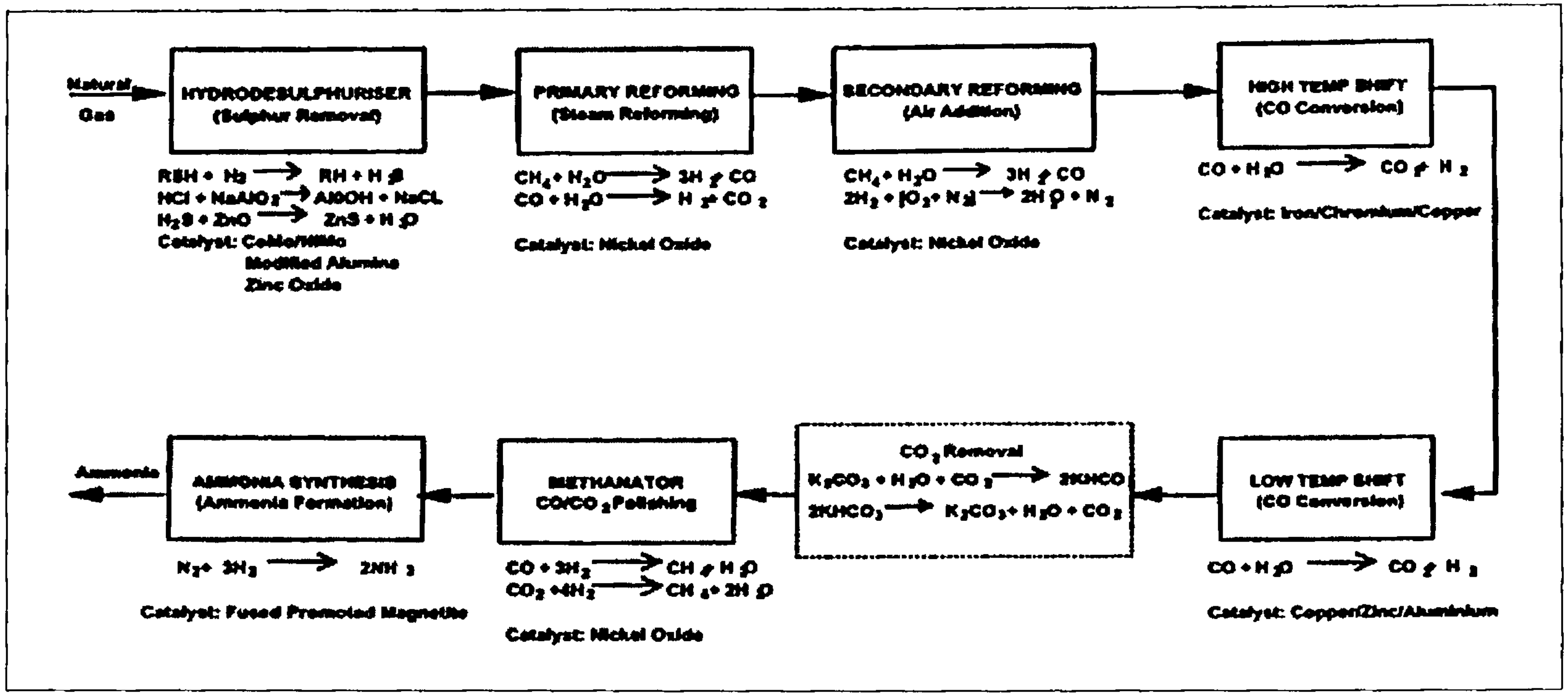

Fig.4.2: Chemistry of the Ammonia Process

Thus, the ammonia synthesis from natural gas can be represented generally as follows:

(1) $0.88\ CH_4 + 1.26\ \text{Air} + 1.24\ H_2O \rightarrow 0.88\ CO_2 + N_2 + 3H_2$

(2) $N_2 + 3H_2 \rightarrow 2\ NH_3$

The front-end reaction producing synthesis gas, normally takes place at 25-45 bar pressure, while the ammonia synthesis unit operate under pressure ranges from 100-250 bars.

Feedstock Desulphurisation.

Natural gas and light hydrocarbon invariably contains small quantities of sulphur compounds, which would poison most of the process catalysts. Consequently, these compounds are removed from the feed-gas by hydrogenating it at 350-400°C when the sulphur compounds are converted to H_2S in a desulphuriser, in presence of cobalt molybdenum (Comox) catalyst (Twigg, 1989).

The hydrogen sulphides (H_2S) from the feedstock stream is adsorbed on palletized zinc oxide, to form zinc sulphide. The hydrogen is normally provided by the synthesis section, and the zinc sulphide remains in the adsorption bed, which are deactivated over a period and then replaced.

Primary Reforming

The resulting gas feed contains less than 0.1 parts per million (ppm) sulphur and is then mixed with superheated process steam. This mixture is heated to 500-600°C and introduced to the primary reformer. The reformer is usually a rectangular tubular furnace in which the feedstock—steam mixture is heated using externally fired burners. In some cases, an adiabatic pre-reformer is also placed before the primary reformer to ease the duty of the main reformer. The primary reformer tubes contain nickel catalyst and are externally heated by fuel. The combustion of this fuel provides the heat necessary for reaction (1).

The flue gas leaving the radiant box has a temperature of about 1100°C. Only 50-60% of the heat supplied is directly used in the process. The remaining enthalpy of the flue gas is recovered in the flue gas heat recovery train to pre-heat the incoming feedstock, for steam generation, superheating steam and for other process requirements. The flue gas leaves the convection section and is sent to the atmosphere at 100-200°C and this is the main source of emissions from the plant. They contain mainly CO_2 and small amounts of Nitrogen Oxides (NOx), CO and SO_2 (James G.R. and Slack A.V., 1973).

Secondary Reforming

Secondary reforming is partial oxidation of residual methane in the process gas from primary reformer. For this, hot process air is added to the gas stream in a specially designed water-jacketed reactor, because of which internal combustion takes place. It also provides the nitrogen for the synthesis gas. The extent of primary reforming is adjusted so that the air supplied to the secondary reformer meets both the heat balance and the stoichiometric synthesis gas requirement. The gas/air mixture is then passed over a nickel containing catalyst where the reforming reaction (1) proceeds to near completion. The gases exit from the secondary reformer at a temperature of around 950-1000°C with most of the hydrocarbon in the feed converted to CO, CO_2 and H_2 together with added nitrogen (FM,1998). The process gas is then cooled to 350-400°C in a process heat recovery steam boiler or boiler feed water heater.

CO Conversion

The cooled reformed gas contains 12-15% CO, balance being hydrogen, nitrogen, CO_2 and small amounts of argon and methane (dry basis). Most of the CO is converted to CO_2 according to reaction (2) by passing the process gas through a bed of iron oxide/chromium oxide catalyst at around 370-400°C in a high temperature converter and then over a copper oxide/zinc oxide catalyst at about 200-220°C in a low temperature converter. The residual CO content of the gas is 0.2-0.4%. At this point, the gas contain mainly of H_2, N_2, CO_2 and the excess process steam, which was supplied at the primary reforming stage. Most of this steam is condensed by cooling the gas before it enters the CO_2 removal system. The condensate normally contains 1500-2000 parts per million (ppm) of ammonia and 800-1200 ppm of methanol, as well as some CO_2 and catalyst dust etc.

In older plants, the process condensate is stripped in a column into which low-pressure steam is fed in at the bottom. A mixture of steam and gases is vented to the atmosphere, whilst the stripped condensate after polishing is used as boiler feed water. (ECE/CHEM 1978, 1991).

Carbon Dioxide Removal

The converted gas usually contains about 18-22% CO_2 which is then removed by chemical or physical absorption process. The solvents used in chemical processes are mainly aqueous amine solutions or hot potassium carbonate solutions. For physical absorption solvents like glycol dimethylethers and propylene carbonate are used. The following converted processes are currently employed for absorption of CO_2.

Hot activated potassium carbonate processes

- Benfield Process (UOP)
- Catacarb Process (Eickmeyer)
- Gimmarcco Vetrocoke Process (GV)

Amine processes

- MDEA (Activated Methyl Di Ethanolamine) Process (BASF)

Physical absorption processes

- Selexol Process (UOP)
- Rectisol Process (Linde Process Technologies)
- Pressure Swing Adsorption (PSA)

In the hot potassium carbonate process CO_2 is absorbed by potassium carbonate solution to produce potassium bicarbonate, which is subsequently stripped of the absorbed gases through pressure reduction and heating up.

$K_2CO_3 + CO_2 + H_2O \rightarrow 2\,KHCO_3$ (absorption)

$2\,KHCO_3 + \text{heat} \rightarrow K_2CO_3 + CO_2 + H_2O$ (regeneration)

Vanadium pentoxide (Benfield), arsenic trioxide (GV), piperazine (BASF) and certain other compounds depending on the process are used as promoters or Catalysts. In the amine processes absorption of CO_2 takes place with the formation of amine adducts that are heat sensitive and are regenerated by heating the solution.

In the physical absorption process, CO_2 is dissolved under pressure in methanol without combining in a chemical sense and regeneration take place by simple flashing of the solution.

Pressure Swing Absorption is also employed for CO_2 removal in smaller plants. The regenerated CO_2 (1.3-1.4 tonne per tonne of NH_3) is cooled and used for the manufacture of urea.

Methanation

The gas from the absorber after CO_2 removal contain only small amounts of CO and CO_2 it must be removed, because it would poison the ammonia synthesis catalyst. This is achieved by the methanation reaction in which the CO and CO_2 are converted to methane (CH_4) and water by passing it through a reactor containing nickel catalyst at a temperature of around 350 to 400°C. The methane is an inert gas in the synthesis reaction and the water formed is removed by cooling and condensing it. The gas after methanation and cooling contain hydrogen and nitrogen in the stoichiometric ratio of 3:1 and is called the synthesis gas.

Ammonia Synthesis

The synthesis gas is compressed to 100-200 bars using centrifugal compressors, usually driven by high-pressure steam turbines. The reaction uses an iron catalyst at temperatures of 350-550°C (FM, 1998). Ammonia formation reaction is exothermic, heat thus generated is used for producing steam. Usually only 20-30% of the synthesis gas is converted with each pass through the converter, thus necessitating a loop arrangement for separating the ammonia from the converter effluent and also for admitting fresh make up gas to the system. During operation inert gases contained in the synthesis gas (argon, methane etc.) tend to build up in the synthesis loop and is maintained at about 10-15% by a continuous purge. The purge gas is first cooled to separate NH_3 contained in it as then scrubbed with water to remove remaining ammonia and is then used as fuel or sent for hydrogen recovery. (FM, 1998; Strelzoff, 1981).

The cooling and condensation of the product ammonia is achieved by a refrigeration system and the product ammonia is sent to the storage.

The liquefied product ammonia is either used directly in downstream plants or stored in tanks. These tanks are usually of the fully refrigerated type in the capacity range of 10000 to 50000 MT, pressurized spheres (3000 MT) and bullets (20 MT) (Hodge C.A. and Popovici N.N., 1994).

Future developments are expected to increase the efficiency of the process, reduce emissions by lowering the steam to carbon ratio. Improvements in the secondary reforming stage and increase in the efficiency of gas purification and the synthesis loop are intended in this direction. (Czuppon T.A. and Knez S.A.,1991; LeBlanc J.R, 1986).

Partial Oxidation of Hydrocarbon or Coal

Partial oxidation processes using heavy fuel oil, vacuum residue from petroleum refining or coal offer an alternative route for ammonia production. Economics of the process depends on the relative availability and cost and quality of these feedstock and oxygen in relation to investment costs and other factors such as the environmental need to use waste materials that are otherwise difficult to dispose off.

When the feedstock is heavy fuel oil with high sulphur content or coal, non-catalytic partial oxidation at around 50 bar pressure and 1400°C is employed for gasification. Some steam is added to the gasifier to moderate the gasification temperature. A cryogenic air separation unit is needed to supply oxygen and nitrogen for the process (Fig.4.3).

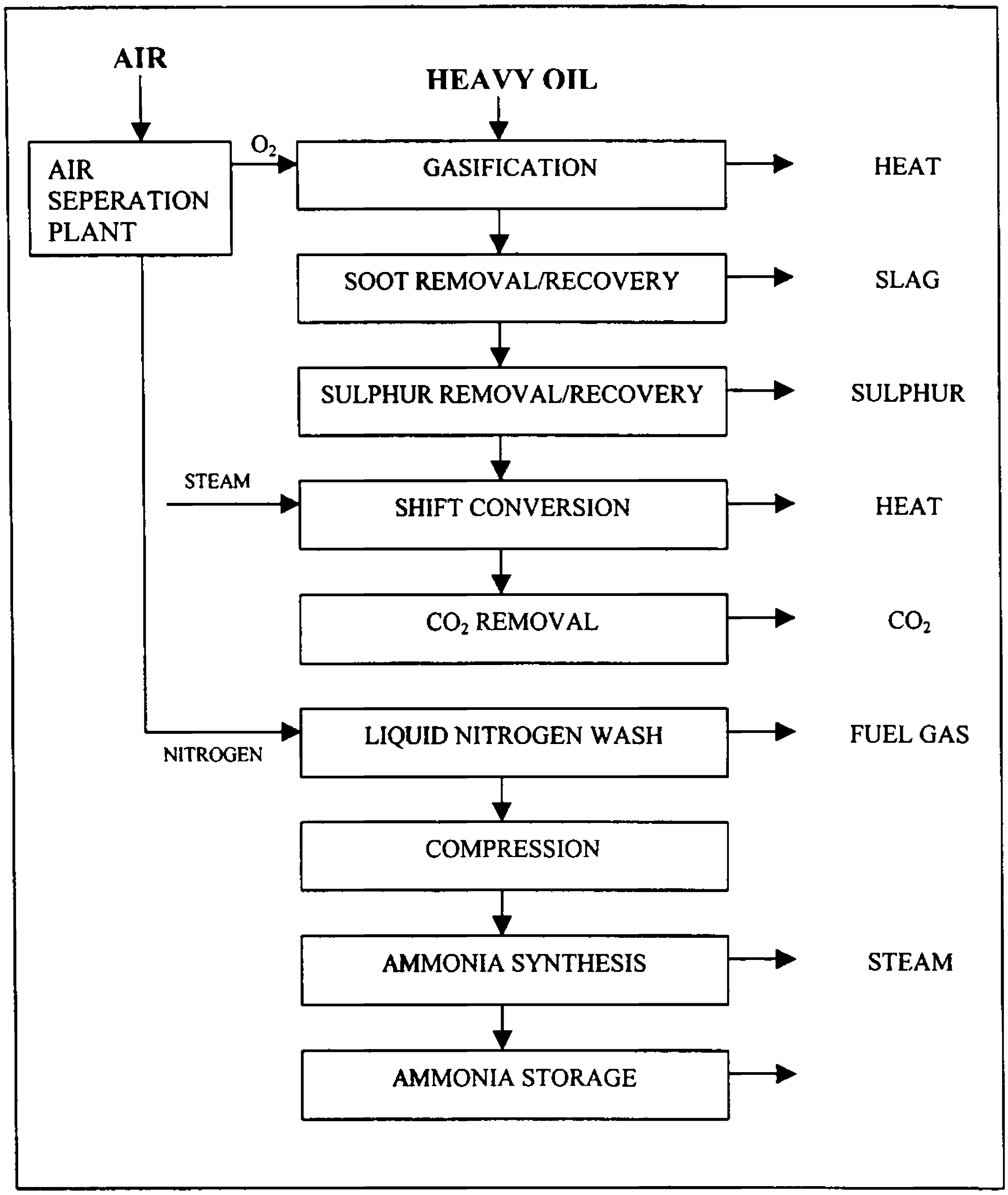

Fig.4.3: Flow Sheet of Ammonia Plant Based on Partial Oxidation

The reaction of the hydrocarbon with oxygen in the gasifier produces CO and hydrogen, as well as some CO_2, CH_4 and soot. After heat recovery from the hot and dusty gases in specially designed boiler soot is removed by scrubbing with water and separated as carbon slurry. Sulphur compounds in the feed are converted to hydrogen sulphide and it is separated from the process gas, using a selective absorption agent (which could be the same as in the CO_2 removal). The regenerated H_2S is then converted to elemental sulphur by the Claus sulphur recovery process (UNEP, 1998).

The CO is then converted to CO_2 by the water shift reaction upon passing through two beds of iron catalyst with intermediate cooling. The CO_2 is then removed by an absorption agent as in the case of the reforming route. The residual traces of CO and CO_2 are removed in the final purification of the gas by a liquid nitrogen wash. This results in a pure synthesis gas, to which more nitrogen is added to provide the stoichiometric hydrogen–nitrogen ratio for ammonia. As the synthesis gas so produced contain only H_2 and N_2, without any inerts, there is no need for a purge in the ammonia synthesis loop and hence loop efficiency is better, compared to the steam reforming process.

In coal gasification, the main stages are coal grinding and preparation of slurry for pulverization, in addition to those in the heavy fuel oil process.

UREA

Urea or Carbamide accounts for almost 50% of world nitrogenous and fertiliser production in terms of nitrogen content, and including multi-nutrient products. Urea is produced by a reaction of liquid ammonia with carbon dioxide. The process steps include synthesis, where liquid ammonia and carbon dioxide react to form ammonium carbamate, which decomposes to form urea solution, concentration by vacuum, crystallization or evaporation to produce a melt, decomposition and recycle of unconverted reactants, prilling or granulating the melt, cooling and screening of solids, coating of the solids; and bagging or bulk loading of the product. The carbon dioxide for urea manufacture is produced from the front end of the ammonia plant.

Reaction Chemistry

The reaction between ammonia and carbon dioxide takes place at high pressure (140-200 bar) and high temperature (180-190°C) to form ammonium carbamate, which is then dehydrated by heat to form urea and water, according to the following reaction:

$$2NH_3 + CO_2 \rightarrow NH_2\,COONH_4 \rightarrow CO\,(NH_2)_2 + H_2O$$

The first stage of the reaction is exothermic and proceeds to virtual completion under industrial conditions.

The second stage is endothermic, and conversion is only partial (50-80% on CO_2 basis). The conversion is increased by increasing the temperature, increasing the NH_3/CO_2 ratio and/or decreasing the H_2O/CO_2 ratio. Process design is mainly concerned with the most efficient separating of product urea from the other components recovery of excess NH_3 and decomposition of the residual carbamate to NH_3 and CO_2 for recycling.

Urea Processes

There are three main types of process depending upon the recovery of unconverted reactants (Zardy F., 1995).

Once-through process where the unconverted CO_2 and NH_3 are discharged to other plants, where the NH_3 is used for the production of ammonium sulphate and ammonium nitrate. Partial recycle process in which unconverted CO_2 and NH_3 are partially separated in the decomposition section of the first stage and are then recovered in an absorber, the remainder being delivered to other plants as in the once-through process; Total recycle process in which unconverted CO_2 and NH_3 are totally separated in multi-stage decomposers, recovered in corresponding multi-stage absorbers, and recycled back to the reactor.

If the unconverted NH_3 and CO_2 from the reactor outlet stream do not find use in downstream plants, a total recycle process is necessary. This was achieved in a series of decomposition stages with decreasing pressure, which cooled, condensed gases to form carbamate liquor, which was then recycled to the synthesis section. This increases the NH_3/CO_2 ratio, and hence the yield of urea. Modern stripping processes were developed which decompose the carbamate in the reactor effluent without reducing the system pressure using NH_3 or CO_2 as the stripping medium (FM, 1998).

Carbon Dioxide Stripping

If CO_2 is used as the stripping agent, urea conversion occurs at about 140 bar and 180-185°C, with a molar NH_3/CO_2 ratio of 2.95. This gives a conversion of about 60% CO_2 and 41% NH_3. CO_2 is added to the reactor effluent at about system pressure, and the stripped NH_3 and CO_2 are then partially condensed and recycled.

(Nitrogen, 1990). Resultant heat is used to produce steam, some of which provides heat for the downstream sections of the process, and some goes to drive the turbine of the CO_2 compressor. NH_3 and CO_2 in the stripper effluent are first vaporized and then condensed to form carbamate solution, which is recycled. The process urea solution is further concentrated in an evaporation section, producing a melt of 99.7% urea, which is then prilled or granulated (Fig.4.4).

Ammonia Stripping

If ammonia is used for carbamate stripping, the pressure and NH_3/CO_2 ratio are somewhat higher in the synthesis section, giving a CO_2 conversion rate of 65%. Excess NH_3 is introduced to the reactor effluent, decomposing a large part of the unconverted carbamate. Residual carbamate and CO_2 are then recovered in a two-stage process. Gas vapours from the top of the stripper are mixed with the recovered carbamate solution, condensed and recycled to the reactor. Resultant heat is used to produce steam. The urea solution is evaporated to a melt, and then prilled or granulated (Fig.4.5).

Advanced Cost and Energy Saving (ACES) Process

The ACES process is essentially a CO_2 stripping process which operates at somewhat higher pressure (175 bar) and NH_3/CO_2 ratio (4), as well as a slightly higher temperature, compared with the conventional process. Stripper gases are passed into two parallel carbamate condensers. Steam is generated for downstream heating, and the carbamate solution and non-condensed gaseous mixture are recycled to the reactor. The urea solution passes through a vacuum concentrator and is then further evaporated to about 99% urea melt (Uchino H and Morikawa H., 1995).

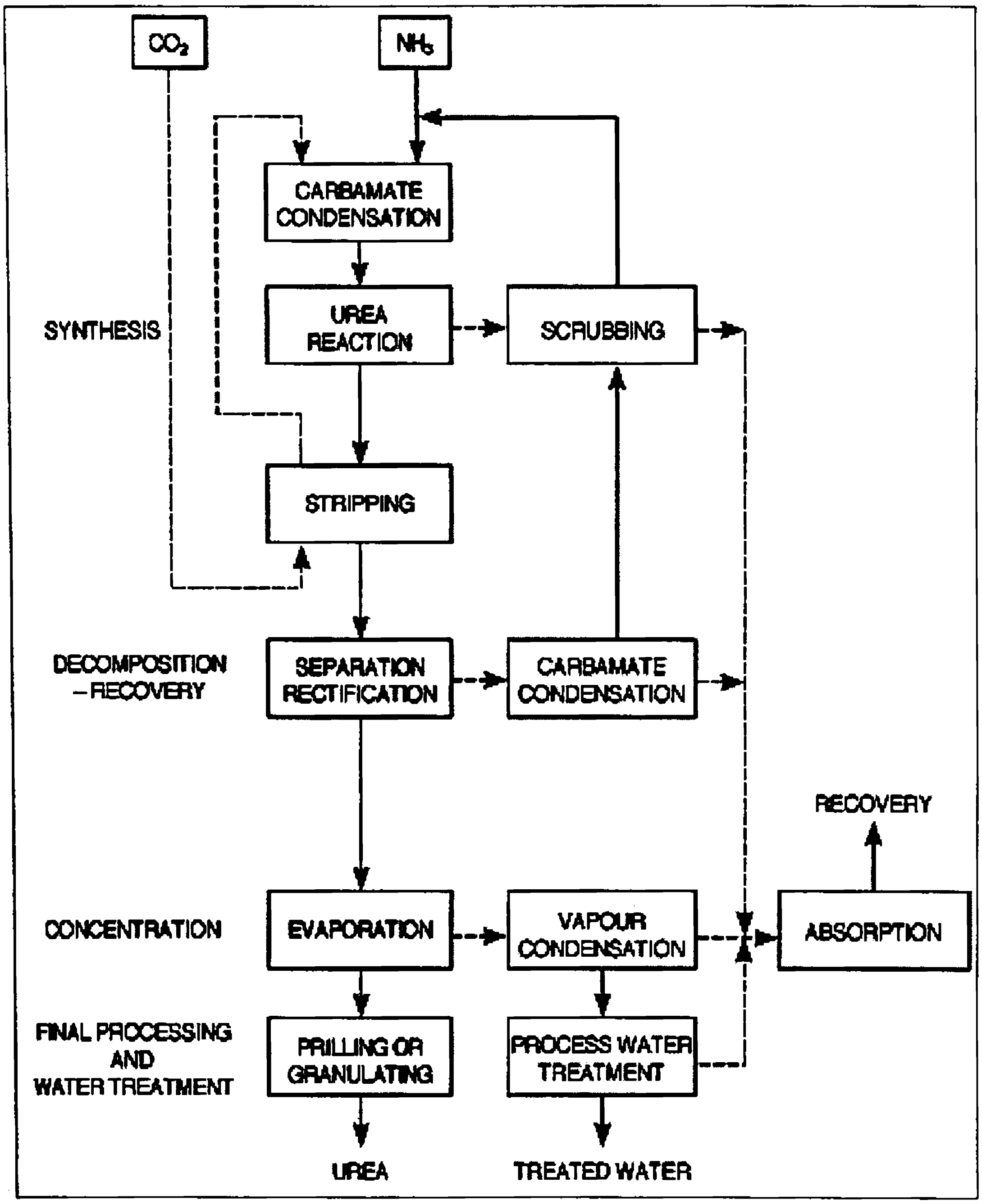

Fig.4.4: Flow Sheet of Urea Manufacturing Process by Stripping

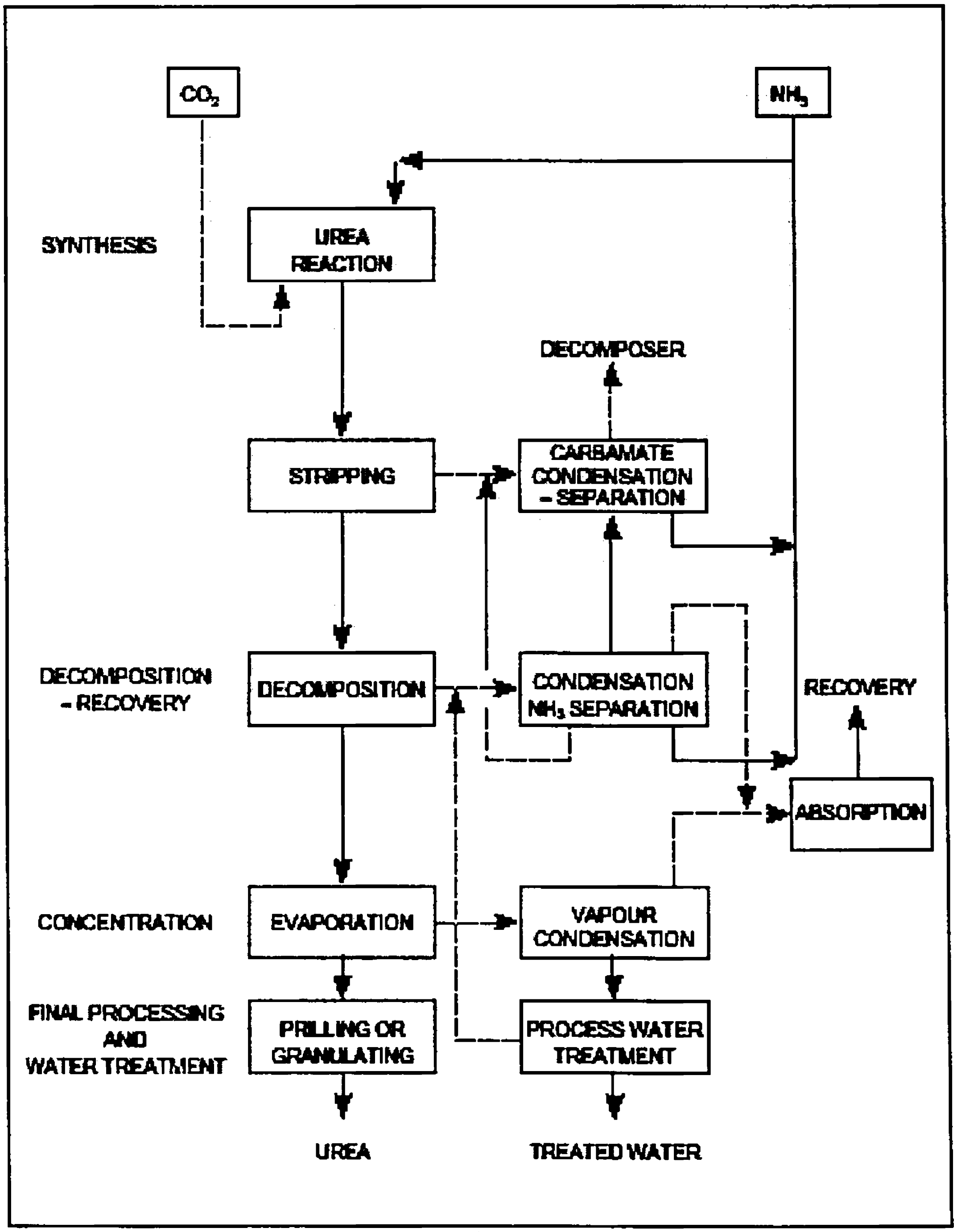

Fig.4.5: Flow Sheet of Urea Manufacturing Process by Total Recycle

Isobaric Double Recycle (IDR) Process

This process uses both CO_2 and NH_3 as stripping agents. Operating at 200 bar and 185-190°C, with an NH_3/CO_2 ratio of 4.5, a CO_2 conversion rate of 71% is obtained, with 35% for NH_3 (Pagani.G *et al.*, 1982). The reactor effluent then passes into a first stripper, which uses NH_3, and the remaining NH_3 is then separated in a second stripper, using CO_2. Gases from the first stripper go directly to the reactor, and those from the second stripper pass first through the carbamate condenser. Two vacuum evaporators concentrate the urea solution to a melt for prilling or granulation (EFMA, 1995).

Prilling is achieved by conveying the urea melt to the top of a tall tower and spraying it down the tower through an up-draft of air, which can be either natural or forced. As it falls, the liquid droplets solidify to prills with diameters of 1.6-2.0 mm.

Granulation is achieved by spraying the melt on to recycled seed particles or prills rotating in the granulator. Granules grow larger, and the product is simultaneously solidified and dried. Traditional granulation processes involve recycling, the ratio of recycled to final product varying between 0.5-1.0. However, prill granulation has a very small recycle ratio, typically 2-4% (Granelli F, 1996).

NITRIC ACID

Nitric acid is used in the manufacture of ammonium, calcium and potassium nitrates. These nitrates are used as straight or mixed into compound fertilisers. A modern nitric acid plant has a typical capacity of 1000-2000 tonnes per day. For fertiliser manufacturing purposes, the acid strength is usually maintained in the range of 50-65%.

The production stages for nitric acid manufacture include vaporizing the ammonia; oxidation (mixing the vapour with air and burning the mixture over a platinum/rhodium catalyst), cooling the resultant nitric oxide (NO) and oxidizing it to nitrogen dioxide (NO_2) with residual oxygen; and absorbing the nitrogen dioxide in water in an absorption column to produce nitric acid (HNO_3) (Twigg M.V., 1989).

Chemistry of the Process

Ammonia is vaporized, mixed with air and burned over a platinum/rhodium alloy catalyst. Nitrogen monoxide (nitric oxide) and water are formed according to the following reaction:

$$4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$$

Simultaneously, some nitrous oxides are also formed according to the following reaction:

$$4NH_3 + 4O_2 \rightarrow 2N_2O + 6H_2O$$

The nitric oxide is oxidized to nitrogen dioxide, and the latter is absorbed in water to give nitric acid:

$$2NO + O_2 \rightarrow 2NO_2$$

$$3NO_2 + H_2O \rightarrow NO + 2HNO_3$$

An yield of 97% NO can be achieved with burners at less than 1.7 bar with evolution of heat. The oxidation of nitric oxide requires high pressures but low temperatures. The heat of ammonia oxidation is used to pre-heat the waste gas and produce super-heated steam. The pre-heated waste gas drives a turbine for air compression to recover energy and is then vented to the atmosphere. After this heat exchange, the combustion gas temperature drop from over 800°C to less than 200°C and is further reduced by water cooling. The water produced is condensed in a cooler/condenser and transferred to the absorption column.

These reactions occur simultaneously. The combustion gas receives additional air to increase the oxygen content, and NO_2 is formed as the mixture cools. Since the formation of acid is exothermic, continuous cooling is required in order to promote the conversion of NO to NO_2. These reactions continue until the gases leave the absorption column. The resulting nitric acid contains dissolved nitrogen oxides and is then bleached by the secondary air (FM, 1998).

Processes

Two types of processes are currently in vogue. They are classified as single pressure and dual pressure, according to the pressures used in the oxidation and absorption stages. The second option is broken into high pressure and medium pressure designs. In mono pressure plants, the two stages occur at essentially the same pressure, between 1.7 and 6.5 bar for medium pressure plants, and between 6.5 and 13 bar for high-pressure plants. In dual pressure plants, the absorption takes place at a higher pressure than the oxidation (Slack A.V., 1968).

Mono Pressure Plants

This design is generally used in smaller plants. Ammonia oxidation and absorption of nitrogen dioxide occur at the same relative pressure (Fig.4.6). This reduces the complexity and capital cost of the dual pressure plant, but at a compromise of efficiency loss, potentially for both the front and back ends of

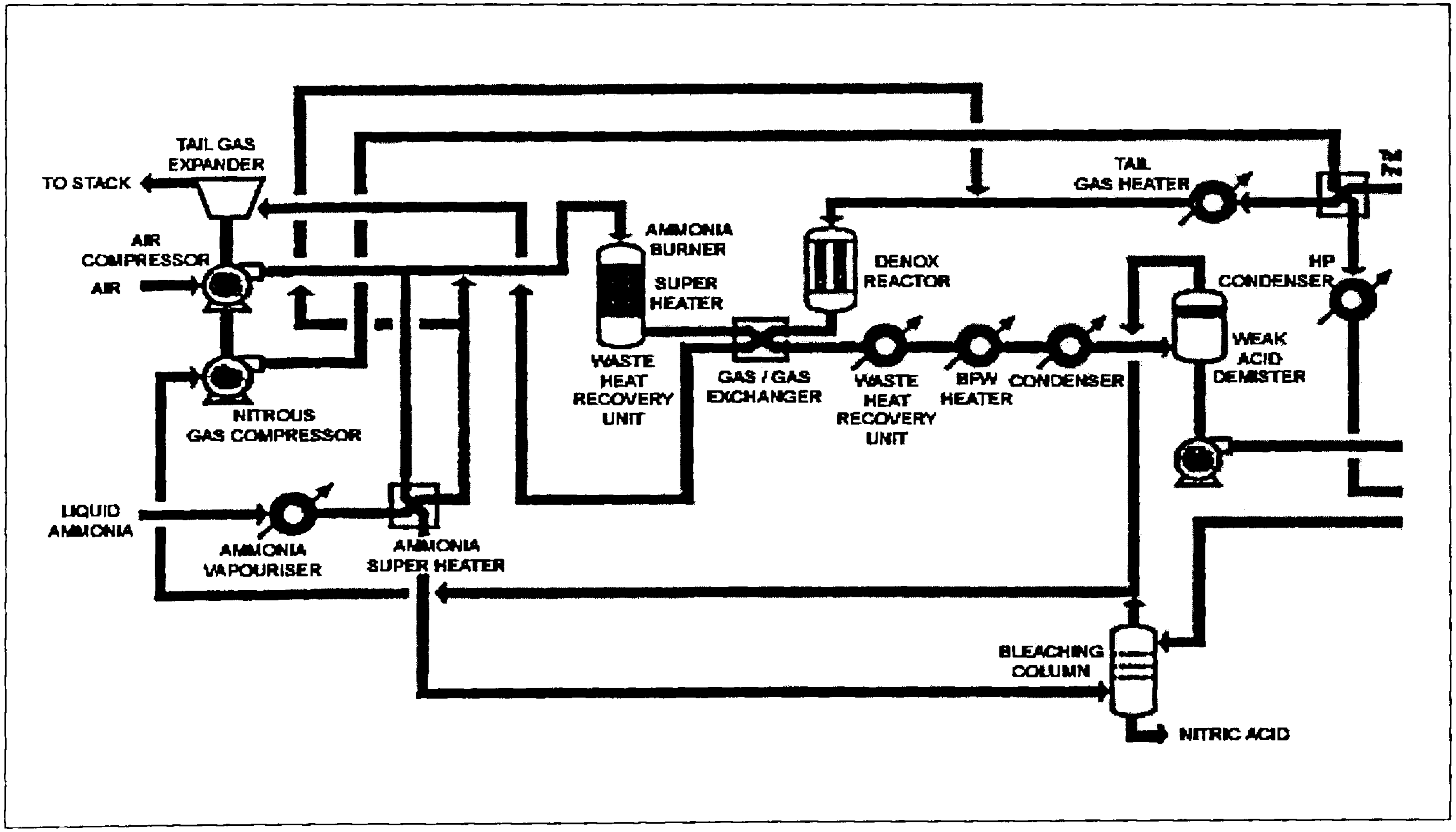

Fig.4.6: Flow Sheet for Nitric Acid Process

the plant. Single pressure plants can be designed to operate at low to medium pressure to favor the ammonia oxidation reaction; at high pressure to favour the absorption reactions; or at any operating pressure in between (FM, 1998).

Dual pressure plants are similar as far as the cooling section. Then compression of nitrogen oxides and secondary cooling/condensing intervene before the absorption section. The acid condensate is mixed with the product acid. Acid solution from the absorption section passes into an NOx stripping column, and the air and stripped NOx return to the NOx gas compressor.

Dual Pressure Plants

This design is generally used in medium and larger plants. Ammonia oxidation occurs at low pressure. This decreases the gas density and the nitrogen loading on the gauze. The result is an increase in efficiency of the ammonia oxidation reaction and minimization of platinum catalyst loss. Absorption of nitrogen dioxide occurs at high pressure to maximize the partial pressure of the gas phase reactants. The result is an increase in the rate of the nitrogen monoxide oxidation reaction and the solubility of oxygen and nitrogen dioxide in the aqueous solution. A nitrous gas compressor boosts the pressure from the front end of the process (ammonia oxidation) to the back end (absorption) (FM, 1998).

SULPHURIC ACID

Sulphuric acid is produced from elemental sulphur, pyrites as well as other scrubbing gas stream. Over 60% of world sulphuric acid production (100% H_2SO_4) is used in the fertiliser industry, the remainder being used in a very wide variety of other industrial applications.

Chemistry of the Process

The principal steps in the process consist of burning sulphur (S) in air roasting of pyrites to form sulfur dioxide (SO_2), combining the sulphur dioxide with oxygen (O_2) to form sulphur trioxide (SO_3), and combining the sulphur trioxide with water (H_2O) to form a solution containing sulphuric acid (H_2SO_4).

(1) $S + O_2 \rightarrow SO_2$ (sulphur burning)

(2) $2FeS_2 + 1\frac{1}{2}\ O_2 \rightarrow Fe_2O_3 + 4SO_2$ (pyrites roasting)

(3) $SO_2 + \frac{1}{2} O_2 \rightarrow SO_3$ (oxidation)

(4) $SO_3 + H_2O \rightarrow H_2SO_4$ (absorption)

Elemental sulphur is melted by heating to 135°C and then burned in a combustion unit at temperatures ranging from 900°C to 1800°C, followed by gas cooling. The SO_2 content of the combustion gas entering the conversion process is generally 9-12% vol. (EFMA, 1995).

Alternatively, pyrites are roasted in various types of furnaces, producing a lower SO_2 content, which is diluted to 8-10% SO_2 before conversion. Ores containing zinc, copper and lead sulphides are also similarly roasted, usually producing lower SO_2 contents. Metal sulphates are also roasted using elemental sulphur and pyrites. Here coke, tar, lignite, coal or oil are used as both fuel and reducing agents. In this case, the SO_2 content of the combustion gases vary considerably, but after cleaning and drying, the process gas usually contains around 6-7% SO_2.

The combustion of hydrogen sulphide (H_2S), carbon disulphide (CS_2) and carbonyl oxide (COS) is carried out in a muffle furnace at 800-1200°C, and combustion gases are variable, containing 0.5-12% SO_2. Iron sintering and other similar processes also give widely varying SO_2 contents.

Regeneration of spent sulphuric acid is achieved by decomposition in a hot gas stream or a moving bed of solids (coke, sand, ore) at 800-1300°C, producing gases containing 2-10% SO_2, depending on the quality of the spent acid. To compensate for varying quality, a sulphur burner can be fitted to provide supplementary SO_2.

Processes

Four types of sulphuric acid processes are currently used in the industry i.e., single contact, double contact, pressure contact, and wet contact.

In single contact plants, SO_3 is absorbed at the end of the process, whereas in double contact plants, it is absorbed at two stages in the process, allowing higher sulphur use efficiency. In new plants, single contact processes are now used only when the SO_2 content of the combustion gas is low and widely varying.

In the case of the roasting of metallic sulphides (or possibly oxides) the SO_2 containing gases are first cooled, cleaned and dried and then oxidized to SO_3 in the presence of catalysts containing alkali and vanadium oxides (Monsanto, 2000).

In the case of sulphur burning acid units, the air is dried before combustion. The SO_3 is absorbed by the water of the acid in the absorption section, the absorbing acid being kept at the desired concentration by the addition of water or dilute acid. In new plants, the conversion efficiency averages about 98.5%, with about 98% applicable to most existing plants. The lower the SO_2 content in the feed gas, the lower the conversion efficiency.

The oxidation and absorption steps in the manufacture of sulfuric acid from sulphur are all highly exothermic. The excess heat generated at each step of the process is recovered in the waste heat boiler, super heater, and economizers. The recovered heat is in the form of high-pressure superheated steam, which can be used to generate electric power in a turbo generator. The process is designed to give a conversion of sulphur dioxide to sulfuric acid of over 99.7% in the acid plant as well as a high conversion of process heat to steam. Atmospheric air is drawn through an air filter through a drying tower with 98% circulating acid and into the main compressor. Some of the sensible heat of the acid in the drying tower is transferred to the air. This sensible heat, plus the heat of compression by the main compressor, raises the temperature of the air entering the horizontal spray sulfur burner where sulfur is burned to sulfur dioxide. The SO_2 gas stream is typically 11.5% SO_2, 9.5% O_2 and 79% N_2 by volume (Duecker and West, 1959). The temperature of the SO_2 gas from the sulfur burner is cooled in a waste heat boiler, by generating as high pressure saturated steam.

Double Absorption

The basic concept of the double absorption process is to further increase the conversion reaction and reduces tail gas SO_2 emissions from the acid plant by providing secondary SO_2 to SO_3 conversion and SO_3 absorption stages following the primary conversion and absorption stages. In general, primary conversion consists of three catalyst passes and secondary conversion consists of just one catalyst pass. This final pass achieves further conversion because the SO_3 formed in the primary passes is removed in the inter-pass absorption step (Fig.4.7).

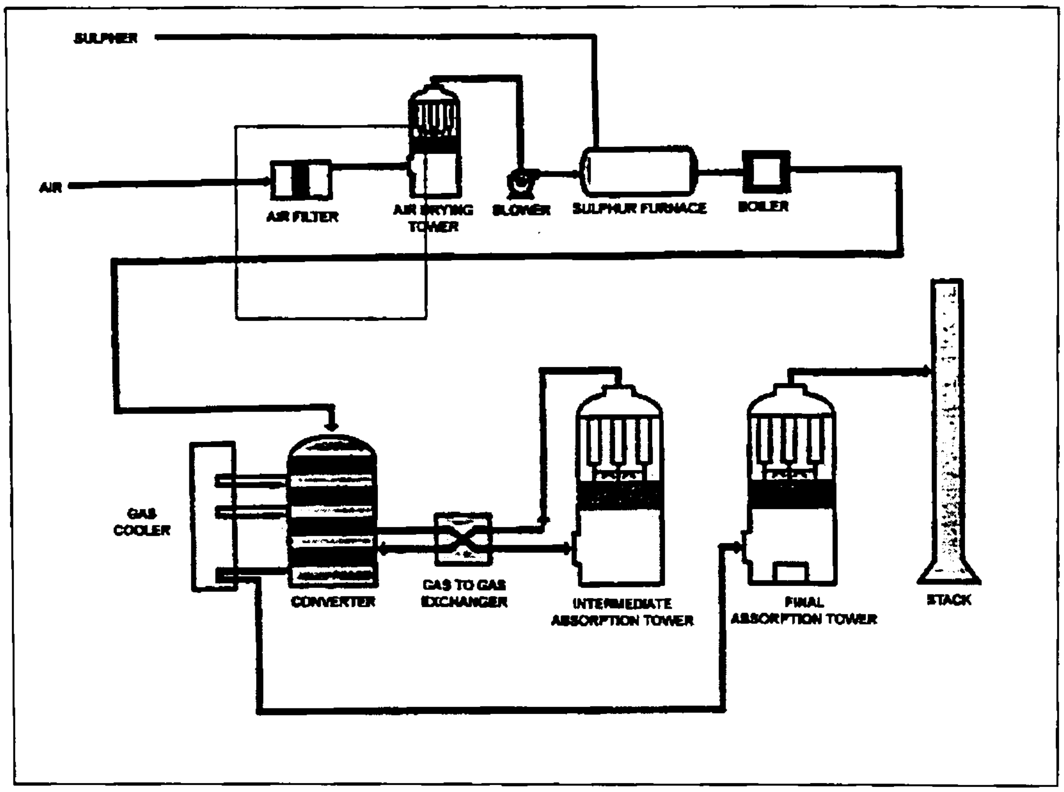

Fig.4.7: Flow Sheet of Sulphuric Acid Process

From the waste heat boiler, the gas flows to the first pass of the converter system where it is partially converted to sulfur trioxide gas in the presence of vanadium catalyst. The heat of conversion reaction is cooled by superheating steam to improve the yield of the sulfur dioxide oxidation in the next catalyst pass. The temperature of the steam and inlet gas temperature is controlled in the proper range by bypassing a portion of the steam flow around the super heater. The cooled gas stream flows from the super heater to the second converter pass where additional conversion of the sulfur dioxide to sulfur trioxide takes place accompanied by the generation of additional heat. Hot gases leaving the second converter pass are cooled by sending them through the hot interpass gas heat exchanger.

Cooled gases leaving the heat exchanger flow to the third converter pass where additional conversion of sulfur dioxide to sulfur trioxide takes place. Hot gases leaving the third converter pass are cooled by the cold interpass heat exchanger and an economizer, in route to the interpass, or intermediate, absorption tower.

In the interpass tower, the SO_3 is removed from the gas stream by absorbing it in the circulating sulfuric acid, in order to allow further conversion of the remaining SO_2 to SO_3.

The temperature of the 98-99% H_2SO_4 circulated over the interpass absorbing tower increases due to the sensible heat of the gas stream entering the tower and from the heat of formation of H_2SO_4. Acid from the bottom of the interpass absorbing tower drains to the pump tank where it is combined with acid from the other towers, and is then pumped through the coolers and circulated back to the top of the tower.

Sufficient water is added to control the strength of acid circulated over the towers between 98-99%. Cool gas leaving the interpass-absorbing tower, containing unreacted SO_2 is heated and sent to the third converter pass.

From the hot interpass heat exchanger, the gas stream flows to the fourth converter pass where final conversion of SO_2 to SO_3 is accomplished. The temperature to the fourth converter pass is controlled by bypassing a portion of gas around the cold and hot interpass heat exchangers.

The gas stream leaving the fourth pass enters the split water flow economizer where it is cooled by boiler feed water. Gas leaving the economizer enters the final absorbing tower prior to exhausting to the atmosphere through a stack.

In the final absorbing tower, SO_3 in the gas stream is absorbed by water in the 98-99% circulating acid. The temperature of the strong acid circulated over the final absorbing tower increases due to the heat of formation and the sensible heat of the gas stream entering the tower. The acid from the bottom of the final absorbing tower flows into the pump tank, where it is combined with acid from the other towers, and then it is pumped through the coolers and circulated back to the top of the towers. Some of the 98% acid from the acid circulation system is pumped to the dilution system where it is diluted to 93% for storage, use, or sales.

In double contact plants, there is a primary converter, followed by an intermediate absorber, a secondary converter and a final absorber. Primary conversion efficiencies fall in the range 80-93%, depending on the arrangement of the contact beds and the contact time. The absorption of SO_3 in the intermediate absorber shifts the reaction equilibrium towards the formation of SO_3 in the residual gas, resulting in an overall conversion efficiency averaging 99.6% (based on sulphur burning).

Pressure Contact Process

The oxidation of SO_2 is favored by pressure. Hence, pressure contact processes have been developed in which SO_2 conversion and SO_3 absorption are both achieved at high pressure. Even higher conversion efficiency is claimed for this type of process, and the tail gas SO_2 content is reported to be only 200-250 parts per million by volume (ppmv).

Wet Contact Process

In contrast with the conventional contact sulphuric acid process in which dry sulphur dioxide/air mixtures are treated, wet gas is used in the wet contact process. The hydrogen sulphide in the initial gas is first burnt to SO_2 and H_2O and the sulphur dioxide is converted to SO_3, which together with the formed steam yields sulphuric acid. The process has been used to treat waste gases containing at least 10% H_2S from coke ovens, mineral oil refineries, fuel gasification or low-temperature carbonization plants, from natural gas cleaning installations, carbon bisulphide production plants and synthetic fiber plants. Gases with a lower H_2S content have to be burnt by additional heating (eg., with fuel gas, oil or sulphur). The product is sulphuric acid of 78-93% concentration (UNEP, 1998).

PHOSPHORIC ACID

Plants require large quantities of phosphorus which is involved in its numerous functions, especially those requiring energy. Phosphorus is indeed the energizer in food production by plants.

Some 70% of world phosphate fertiliser production, conventionally measured in terms of phosphorus pentoxide (P_2O_5), uses phosphoric acid as the main intermediate. Virtually all phosphoric acid is now produced by wet processes, i.e. by acidulation of mineral phosphates. Phosphate acidulation may be achieved using nitric, hydrochloric or sulphuric acids (Slack A.V., 1968).

If nitric acid is used the product would be for the multi-nutrient fertilisers called nitro phosphates. Hydrochloric acid is used only in very special circumstances, since this acid is normally more expensive than other acids. The great bulk of phosphoric acid is produced using sulphuric acid.

Chemistry of the Process

A simplified reaction equation for the dihydrate process is as follows:

$$Ca_3\,(PO_4)2 + 3\,H_2SO_4 \rightarrow 2H_3PO_4 + 3CaSO_4$$

This reaction proceeds with the formation of calcium sulphate (gypsum) on the surface of the phosphate particles, thus blocking its continuation. This is mostly overcome by grinding the phosphate to a suitable particle size to increase the surface area of the reaction, and recirculating phosphoric acid into the reaction, according to the following reactions:

(2) $Ca_3(PO_4)_2 + 4H_3PO_4 \rightarrow 3Ca(H_2PO_4)_2$

(3) $3Ca(H_2PO_4)_2 + 3H_2SO_4 \rightarrow 3CaSO_4 + 6H_3PO_4$

The phosphoric acid is normally filtered away from the phosphogypsum (Becker P, 1989). Mineral phosphate contains small quantities of a wide variety of impurities, including fluorine, iron, aluminium, arsenic, cadmium, copper, lead, nickel, zinc, mercury and uranium. Any radium associated with the uranium passes into the gypsum, whilst the uranium itself goes into the product acid. Consequently, the commercial value of a source of phosphate is not merely a function of its phosphorus content but also of its purity. Depending on the process, between 20% and 40% of the cadmium in the phosphate rock passes into the phosphogypsum, the remainder into the phosphate fertiliser.

Processes

There are five main phosphoric acid processes viz, dihydrate; hemihydrate; di-hemihydrate (double stage); hemi-dihydrate (single stage); and hemi-dihydrate (double stage).

Dihydrate Process

The dihydrate process has three stages: reaction, filtration and acid concentration. The reaction takes place in a series of agitated reaction tanks or compartments of a single tank to which ground phosphate (particle size <150 microns) is added and gypsum is precipitated in the dihydrate form at an acid concentration of 26-32% P_2O_5 (Fig.4.8).

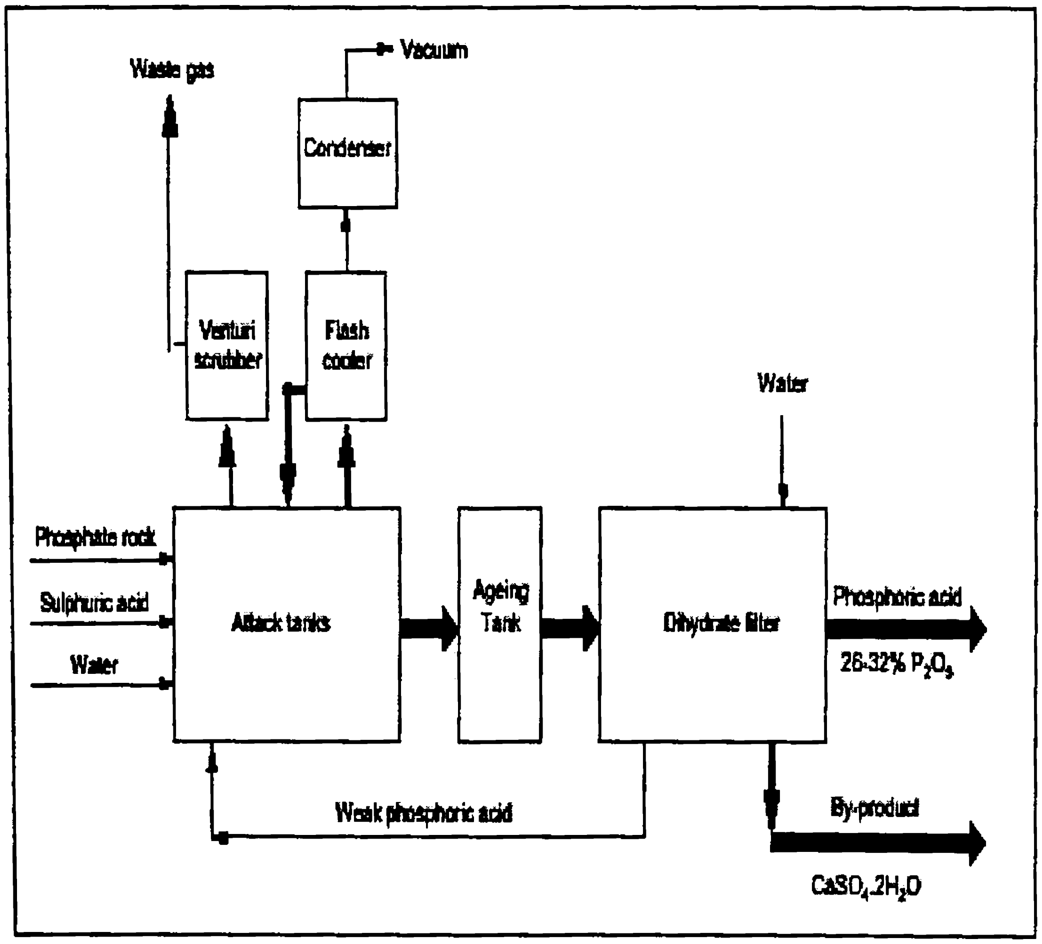

Fig.4.8: Flow Sheet of Phosphoric acid Process (Dihydrate)

and a temperature of 70-80°C. The temperature is controlled by passing the reaction slurry through a flash cooler or by using an air-circulating cooler. (A.V.Slack, 1968)

About 4.5 to 5 tonnes of calcium sulphate dihydrate ($CaSO_4$ or gypsum) are produced for each tonne of P_2O_5 in the product acid. The initial filtration is followed by at least two washings to maximize P_2O_5 recovery under vacuum conditions. At the end of the washing sequence, the remaining liquid is removed from the filter cake as far as possible, the cake is discharged, and the filter cloth is washed. The product acid is then concentrated, since fertiliser production requires an acid strength of 42-50%.

Concentration usually takes place in a forced circulation evaporator consisting of a heat exchanger vapour or flash chamber, condenser, vacuum pump, acid-circulating pump, fluro-silicic acid scrubber and piping.

Hemi Hydrate Process

In this process operating at around a temperature of 100°C and at higher acid concentration in the reaction stage (40-52% P_2O_5), the gypsum is precipitated in the hemi-hydrate form. There is substantial savings in capital investment, energy, but the smaller, poorly formed crystals are more difficult to filter, unless crystal habit modifiers are used. P_2O_5 losses are more (6-10%) compared to the dihydrate process (FM, 1998) (Fig.4.9).

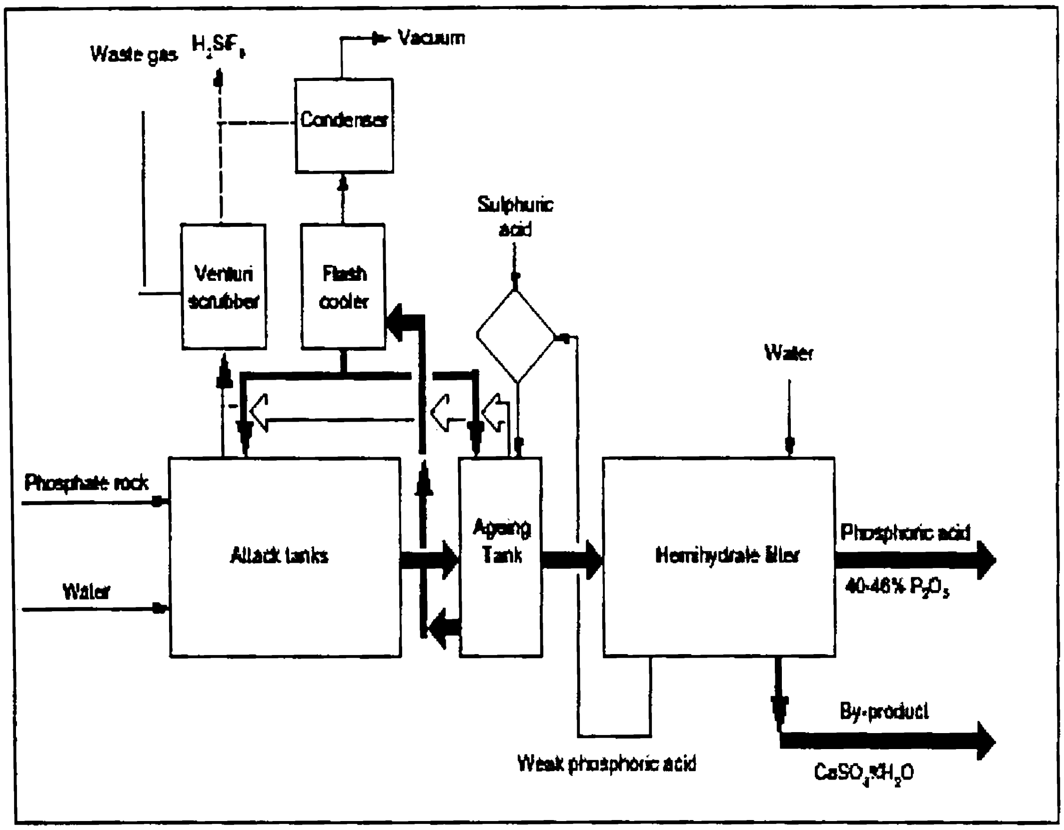

Fig.4.9: Flow Sheet of Phosphoric acid Process (Hemihydrate)

Recrystallization Processes

Losses of P_2O_5 can be partially recovered, if the gypsum is crystallized to its other hydrate, either before or after being separated from the acid. The following processes have been developed on these lines (Fig.4.10).

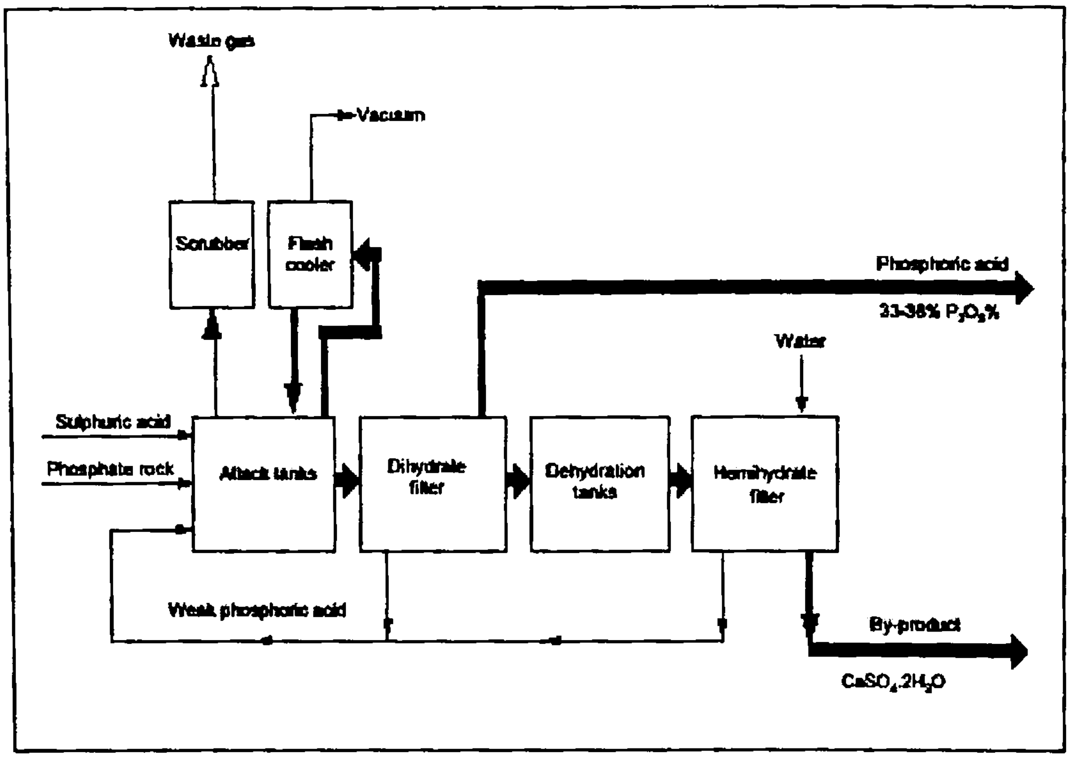

Fig.4.10: **Flow Sheet of Phosphoric Acid Process (Dihemihydrate)**

i) HRC process: Acidulation of rock under hemihydrate conditions, recrystallization to dihydrate without intermediate hemihydrate separation and product separation;

ii) HDH process: Acidulation under hemihydrate conditions, product separation, recrystallization to dihydrate and filtration and recycling of liquors;

iii) DH/HH process: Acidulation under dihydrate conditions, product separation, recrystallization to hemihydrate and filtration and recycling of liquors (Phosphorous and Potassium, 1991).

All the three processes offer substantially lower P_2O_5 losses (2-3%), lower sulphuric acid consumption and purer gypsum. The latter may possibly be used directly for plasterboard, plaster, or as a cement-retarding agent.

Ammonium Sulphate

Ammonium sulfate one of the oldest mineral fertilisers, is produced through direct neutralization of ammonia with sulfuric acid. It is also obtained as a Caprolactam by-product from the petrochemical industry.

$$2\,NH_3 + H_2SO_4 \rightarrow (NH_4)2SO_4 + H_2O$$

The reaction between ammonia and sulfuric acid produces an ammonium sulfate solution that is continuously circulated through an evaporator to thicken the solution and to produce ammonium sulfate crystals. The crystals are separated from the liquor in a centrifuge, and the liquor is returned to the evaporator. The crystals are fed either to a fluidized bed or to a rotary drum dryer and are screened before bagging or bulk loading (FM, 1998; Gopinath N.D., 1968; George K.C. and Gopinath N.D., 1963).

Ammonium Nitrate (AN) and Calcium Ammonium Nitrate (CAN)

Neutralizing nitric acid with gaseous ammonia produces ammonium nitrate.

$$NH_3 + HNO_3 \rightarrow NH_4NO_3.$$

The reaction is exothermic, producing ammonium nitrate solution and steam. In a second stage, the ammonium nitrate solution is evaporated to the desired concentration, depending on whether it will be finally prilled or granulated.

To produce calcium ammonium nitrate (CAN), the ammonium nitrate solution is mixed with a filler containing dolomite, calcium carbonate, ground limestone or, quite frequently, by-product calcium carbonate from a nitro phosphate plant. This mixture can also be either prilled or granulated.

The neutralization reaction takes place in free-boiling vessels, circulating systems, or pipe reactors. They may operate in one or two stages, at ambient or high pressure. A two-stage neutralizer reduces total ammonia emissions but costs more than a single-stage operation. High pressure will increase steam temperature and ammonium nitrate concentration, and the steam can be more easily used downstream to provide the heat for evaporation and drying. For safety and environmental reasons, temperature, pressure and pH must be strictly monitored and controlled.

Most of the water in the ammonium nitrate solution must be evaporated away before the solidification process. This may be done at about atmospheric pressure or under vacuum. During evaporation, some ammonia is boiled off in the falling film evaporators and heat exchangers (Nebel R., 1985). The product solution is maintained at a temperature, which avoids crystallization. The water content shall be maintained at less than 1% for a good quality prilled product and 3-8% for granulation processes. The prilling of ammonium nitrate is similar to that of urea .The product sprayed from the top dries up in the upward draft of air from the bottom of the tower. Some ammonia and ammonium nitrate is carried away in the air stream. Wet scrubbing of the exit air stream removes ammonia contained in it and mist eliminators remove the roduct particles.

Granulation is done with rotating drums and pans or fluidized beds. The uantity of air required is much less than for prilling, and thus emission abatement uipment is smaller, cheaper and easier to install. The calcium carbonate can be ixed with the ammonium nitrate solution either before or during granulation.

Product granules and prills are cooled in rotary or fluid bed coolers, with the air cleaned by cyclones, bag filters or wet scrubbers. This air is then recycled to the drier. The product is treated with an anti-caking agent to avoid lump formation.

Single Super Phosphate (SSP) and Triple Super Phosphate (TSP)

Super phosphates account for over one quarter of world phosphate fertiliser production. Single super phosphate (SSP) is produced by reacting mineral phosphate with sulphuric acid in proportions, which convert most of the phosphate to the water-soluble mono-calcium form. Unlike the similar reaction, which produces phosphoric acid, this process retains the calcium sulphate in the product; and it is for this reason that single super phosphate retains its importance wherever sulphur deficiency limits crop yields.

Triple super phosphate contains little sulphur, because it is produced by acidulating the mineral phosphate with phosphoric acid, instead of sulphuric acid. Double or enriched super phosphate is also produced, by using a mixture of the two acids. In all cases, the emissions to air and water are similar to those involved in phosphoric acid production, except for the problem of gypsum disposal in the latter case. There are always two stages in the manufacture of granulated single super phosphate, the first to manufacture powdered single super phosphate and the second to granulate (FM, 1998). However, in the case of triple super phosphate, there are two alternatives as in the case of single super phosphate, run-of-pile (ROP) material may be used. The run of pile material is prepared by reacting phosphate rock with phosphoric acid with a P_2O_5 concentration of 50 to 54%, but a lower concentration may be used, followed by granulation (UNEP, 1996).

Multi-Nutrient Fertilisers

Large quantities of multi-nutrient fertilisers (NP/NPK/NK/PK) are produced simply by dry mixing (or blending) single-nutrient materials without acidulation or chemical reaction (FM, 1998) (Fig.4.11).

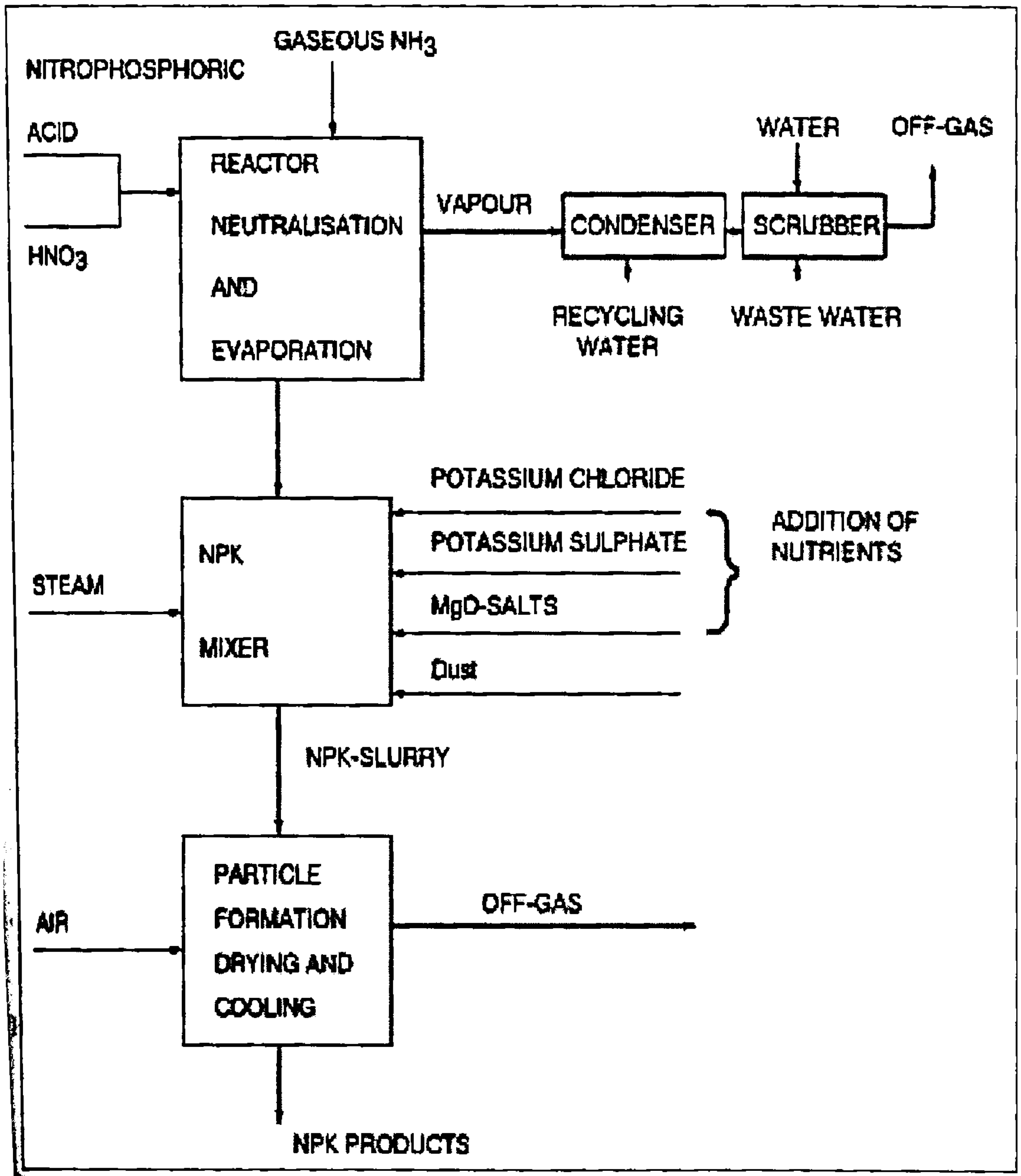

Fig. 4.11: Flow Sheet of Compound Fertilisers (NPK) Process

Mixed Acid Route Process

Phosphoric, nitric and sulphuric acids can be used together in various processes, to produce a wide variety of multi-nutrient formulations. If a reaction with mineral phosphate is involved, the first stage is the production of phosphoric or nitro phosphoric acid, as described above. Acids are then mixed, and an ammonium nitrate solution may also be added. The mixture is neutralized with gaseous ammonia and other materials may be added either during or after neutralization. These may include ammonium phosphate, ammonium sulphate, super phosphate and potassium salts.

The slurry is then fed into a buffer tank, from which it passes to granulation, drying, screening, cooling and coating. The acids may be mixed in reactor tanks or in pipe reactors, together with ammonia, ammonium nitrate solution and solid materials. Alternatively, a drum granulator may be used with a mixture of mainly solid materials, together with ammonium nitrate solution, and/or sulphuric acid and ammonia (Bhandarkar P.G. and Paudpiece, 1995).

Gases from the granulation, drying and cooling sections pass through venturi scrubbers, with recirculating ammonium phosphate or ammonium-sulphate-phosphate solution. The scrubber liquor is recycled, and dust is removed in cyclones. After dedusting, air from the cooling section is normally recycled to the dryer.

Phosphoric Acid Route Process

Monoammonium phosphate (MAP) and diammonium phosphate (DAP) are made by ammoniating phosphoric acid in a neutralizer to produce a slurry, which is granulated. Some granulators can also act as ammoniators. If a potassium salt is added during granulation, an NPK compound is produced. Alternatively, granulation may be achieved by powder blending, using small amounts of sulphuric acid (H_2SO_4) and ammonia (NH_3) to promote the reaction. Granules are dried and cooled in rotary drums. Oversize and undersize material is screened out, crushed and recycled.

The Nitric Acid Route Process

Complex grade (NP and NPK) fertilisers based on the acidulation of mineral phosphate with nitric acid, instead of sulphuric acid, lead to virtually complete use of the raw materials, since the by-product is calcium nitrate instead of calcium sulphate, and this can be either granulated and used directly as a fertiliser, made into liquid fertiliser solutions, or converted into calcium ammonium nitrate CAN.

Nitrophosphates

The basic reaction for the production of nitro phosphoric acid is:

$$Ca_5F(PO_4)_3 + 10HNO_3 \rightarrow 3H_3PO_4 + 5Ca(NO_3)_2 + HF$$

In order to improve the solubility of the product phosphate, the calcium nitrate is precipitated out of the solution by cooling in the presence of water, according to the following reaction:

$$H_3PO_4 + HNO_3 + Ca\,(NO_3)_2 + 4\,H_2O \rightarrow H_3PO_4 + HNO_3 + Ca\,(NO_3)_2.4H_2O$$

The solution of nitro phosphoric acid can then be separated from the calcium nitrate crystals by filtration or centrifugation (FM, 1998). The solution is neutralized with ammonia, mixed with potassium and magnesium salts or micronutrients, and finally granulated (Fig.4.12).

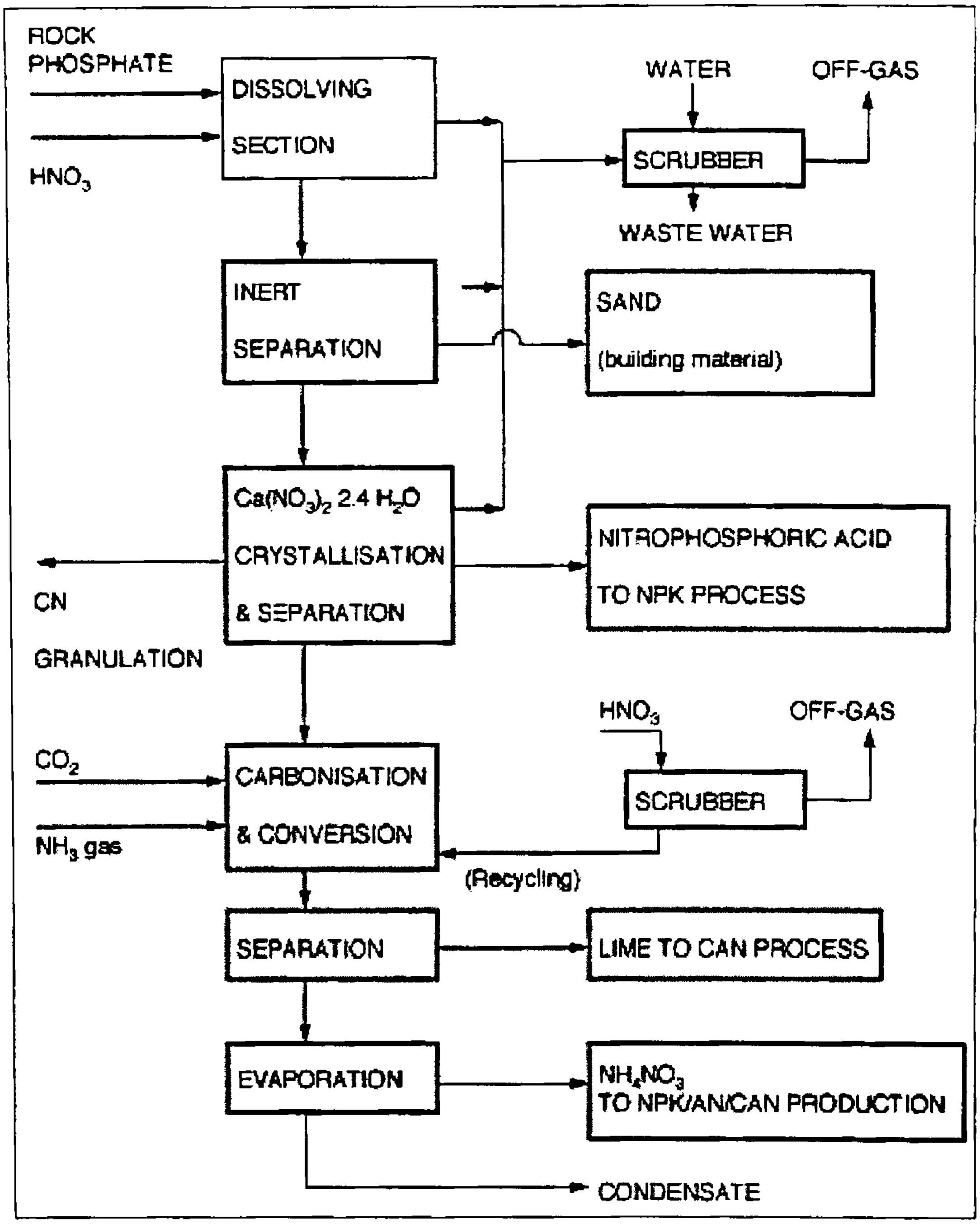

Fig.4.12: Flow Sheet of Nitro Phosphoric Acid Process

The nitro phosphoric acid solution is then neutralized with ammonia. The reaction is highly exothermic, and the evolved heat is used for evaporating the resulting slurry and the product is prilled. Neutralization under pressure produces vapour containing 2-8% NH_3. This is scrubbed with process water, and the scrubbing liquor is returned to the process. Scrubber vapours are condensed, part of the heat being used to pre-heat the NP solution before neutralization. The remaining heat is used to make low-pressure steam for use in the NPK process or in other plants. A water-cooled condenser treats any remaining vapour. and all the condensate are collected in an ammonia condenser tank (UNEP 1998) (Fig.4.13).

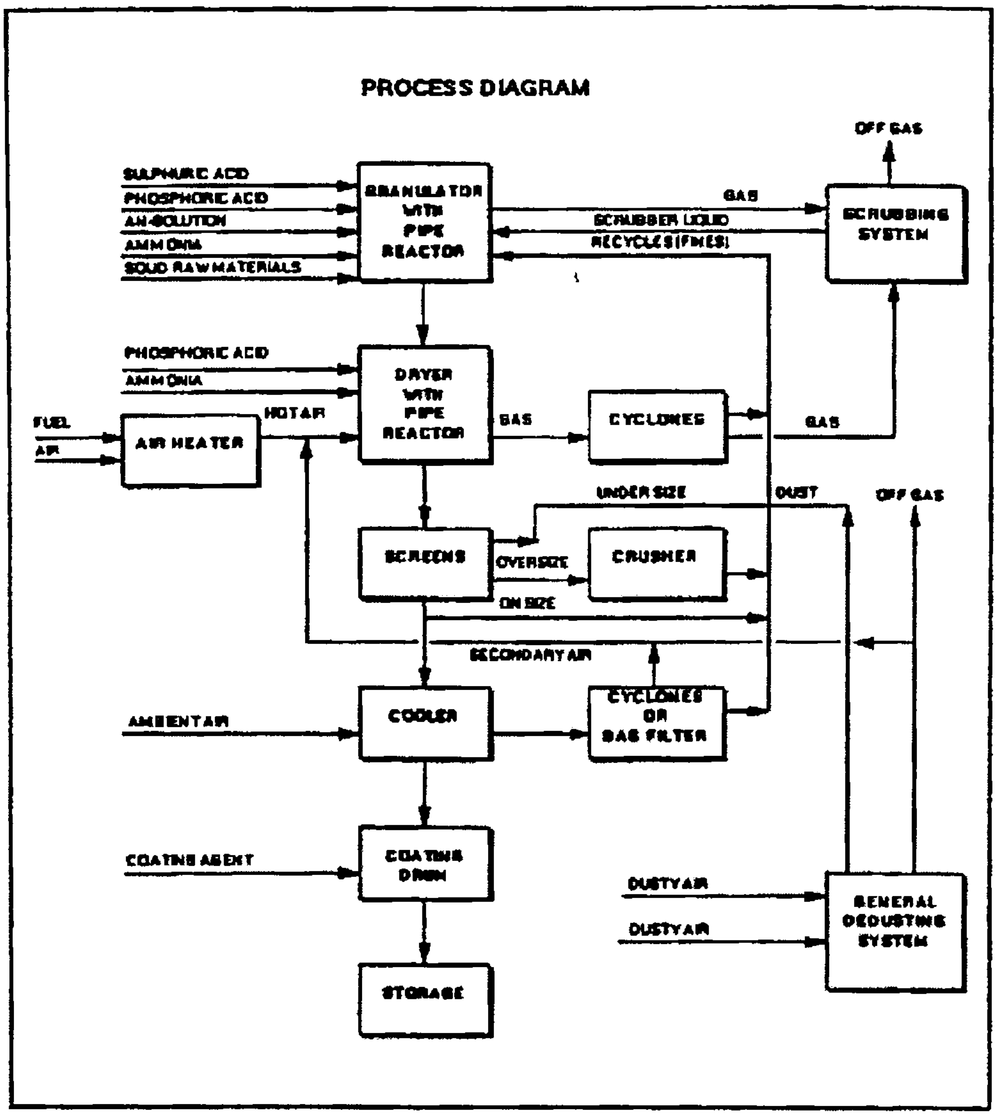

Fig.4.13: Flow Sheet of NP Granulation Process

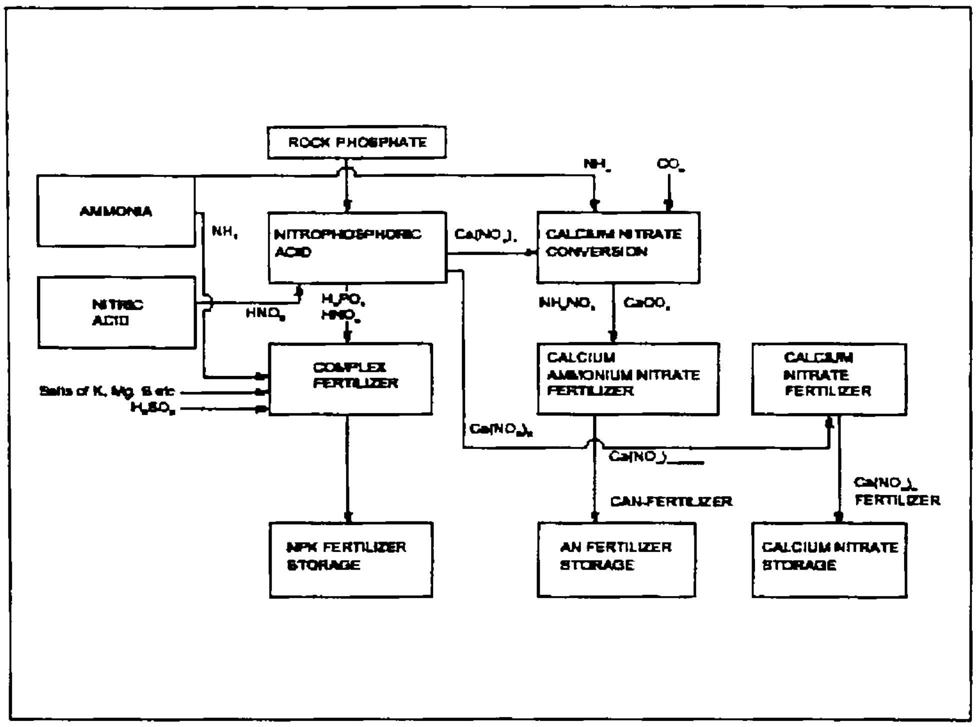

Fig.4.14: Flow Sheet of Nitro Phosphate Process

Evaporation also produces off-gases, which must be scrubbed to recover NH_3 and fluorine. The scrubbing liquor is recycled to the process. The neutralization and evaporation sections may be connected to a common NH_3 condensate stripping system, and the effluent from this contains some nitrogen in both ammonium and nitrate forms.

The evaporated NP or NPK solution may be prilled or granulated (Fig.4.14). The latter involves a rotating drum into which the product liquor is sprayed, with a co-current of hot air evaporating the remaining water and forming dry granules.

ENVIRONMENTAL PROBLEMS ASSOCIATED WITH FERTILISER MANUFACTURING

Like any other chemical processing industry, mineral fertiliser plants also contribute to atmospheric emission, effluent and solid waste generation. These environmental problems have repercussions at the local as well as global levels. Over the last 25 years considerable developments in technology has taken place in order to minimize the adverse environmental impacts. Even with the latest technology it has not been possible to fully ward off the ill effects arising out of the thermodynamic inefficiencies of the available systems and equipment. With the development of an overall awareness of the environmental degradation in the seventies of the last Century and consequent enactment of a host of national and international legislation, the issue of environmental protection has emerged as a major political issue which led to tight regulation of manufacturing industries including the fertiliser industry.

The environmental impact of a fertiliser plant depends on a wide variety of circumstances, including the nature of the plant, its design integrity, vintage, the processes and raw materials or feedstock which it uses, the location of the site, the nature of its surroundings, the regulations to which it must conform and the expertise of its operation and management network. Table 4.1 lists the potential sources of pollutants from fertiliser plants.

It includes plant wise solid, liquid and gaseous pollutants and the streams containing such pollutants. Let us discuss these issues plant wise.

Table 4.1

Fertiliser Industry Effluents and their Sources

Plant	Solid Waste	Liquid Effluent	Gaseous Emissions
Ammonia	Spent Catalysts Sludge from equipment Insulation debris Construction debris Oil Sludge	Process condensate CO_2 removal solutions Cooling tower blow down Boiler blow down	Ammonia Carbon dioxide Furnace flue gas Vent gases
Urea	Nil	Process condensate Gland leakages from pumps Floor washings	Prilling tower dust Ammonia
Sulphuric Acid	Sulphur sludge Spent Catalyst Packing etc.	Water treatment effluents Acid leaks	Acid mists SO_2/SO_3 in stack
Phosphoric Acid	Gypsum Sludges Radioactivity	Plant washings Gypsum pond water Acid leaks	Fluorine Particulate matter
Nitric Acid	Spent Catalysts	Plant washings	Nitrogen oxides Ammonia
Complex	Spillages Slurry from drainage/washing	Plant washings Plant leakages	Particulate matter Ammonia fumes
Ammonium Sulphate	Spillages Chalk slurry	Plant leakages Plant washings	Ammonia
Power Generation	Oil sludge	Water treatment effluents Oil spillage	Sulphur dioxide in flue gas
Water Treatment	Used resins Sludge from equipment	Regeneration effluents	Nil

AMMONIA PLANT

Emissions

Emissions from ammonia plants comprise of light hydrocarbons from storages, hydrogen, carbon dioxide, sulphur dioxide, ammonia, carbon monoxide and gaseous leak from flanges, stuffing boxes and dust and particulate matter from catalyst handling operations (Pachayappan V, 1980). Plant start-up may involve the flaring of synthesis gas, and in this case some oxides of nitrogen emissions may also come. Typical ammonia process based on steam reforming generate around 2.2 tonne of carbon dioxide, and less than one kilogram of nitrogen oxides and 0.2 kilogram of sulphur dioxide per tonne of ammonia produced. In the partial oxidation process 2.7-2.8 tonnes of carbon dioxide, 1.8 kilogram of nitrogen oxides and 3 kilogram of sulphur dioxide are produced per tonne of ammonia.

Carbon dioxide (CO_2) is a greenhouse gas and contributes to global warming. The production of urea requires about 1.6 tonnes of CO_2 per tonne of nitrogen. The fertiliser industry's share of the annual net addition of CO_2 to the atmosphere resulting from human activities is estimated at 2%; and human activities account for only 7% of the quantity released annually by biological processes. Consequently, the share of fertiliser production in the total annual release of CO_2 to the atmosphere is very small—in the range of 0.1-0.2%. Nevertheless, the projected growth of fertiliser use makes it all the more desirable that the industry should keep CO_2 emissions as low as possible. Since technological limits to energy efficiency have been almost attained in new generation plants whose energy consumption is less than 20% of the theoretical requirement future limitation of CO_2 emissions will have to come from the replacement of old, inefficient plants.

The fixation of by-product carbon dioxide as urea reduces the total carbon dioxide emissions considerably. Hence ammonia plants are most often associated with equivalent capacity urea plants also. Emissions also depend on the process and raw materials used as well as on the standards of operation and maintenance. Conventional combustion in the reformer furnace gives rise to nitrogen oxides (NOx) in the flue gas and it increases with increase in the combustion temperatures (Stern A.C. *et al.*, 1984). Steam injection and use of low NOx burners are control mechanisms adopted to reduce formation of nitrogen oxides. Usually the furnace is operated with excess air and hence the chances of formation of carbon monoxide (CO), usually a product of incomplete combustion, is remote.

Sulphur, an impurity invariably present in all petroleum fractions, get converted to its compounds that are major sources of pollution during the manufacturing process. Natural gas, unlike other petroleum feedstock, contains only very small quantities of sulphur (up to 5 mg/Nm^3) and is entirely removed by hydrogenation. In the case of naphtha the sulphur content in the range of 1000-1500 parts per million (ppm) and is usually removed by hydrofining or hydrodesulphurisation process prior to reforming. Thus in steam reforming of natural gas or light hydrocarbons sulphur emissions are negligible. However, larger amounts of sulphur are present in heavy oils and coal. Partial oxidation processes extract up to 95% of sulphur in the elemental form in a Claus sulphur recovery unit. Depending on recovery equipment, up to 3 kilogram sulphur dioxide per tonne of ammonia could be emitted from coal and fuel oil based plants, compared with less than 0.01 kilogram in gas-based plants. Plants employing steam-reforming technology have lower emissions compared to partial oxidation processes.

There shall be no ammonia emission (odour concentration 18-35 mg/Nm^3) from plants unless there is a leak or so. All ammonia bearing streams such as high pressure loop purge gas from the synthesis unit etc., are scrubbed with water, ammonia is recovered and the rest is used as fuel in the reformer furnace.

During plant start up and shutdown when nickel catalyst temperatures are in the range of 100-150°C, in presence of carbon monoxide, there is a chance of formation of poisonous Nickel Carbonyl ($NiCO_4$) in the reformer (Twigg M.V., 1989). Usually this situation is avoided by careful manipulation of the operating temperatures.

Modern developments in gasification and ammonia process technology such as excess air reforming and auto thermal reforming provide significant reductions in emissions. Auto thermal reforming also reduce total energy consumption by necessitating (increased) power import and decreasing net heat loss. (Czuppan T.A and Knez S.A., 1991). Specific energy consumption has decreased continuously in new plants over the last 25 years, and the optimal energy consumption of new plants are in the range of 6.5-7 Giga Calories (GCal) per tonne of ammonia as against the theoretical minimum of around 6 GCal .

Effluents

Process condensate, from excess steam put to the primary reformer, is produced upon cooling the converted gas upstream of carbon dioxide removal unit is a source of liquid effluent from the plant. Usually around one cubic metre of condensate per tonne of ammonia is generated and it contain up to 1000 ppm each of ammonia and methanol as pollutants. Most of this condensate can be recovered as steam and recycled by stripping with process steam feed to the primary reformer. The stripped condensate which contains not more than 50 ppm each of these pollutants can be further purified by ion exchange method and then used as boiler feed water. (ECE/CHEM'78, 1991). Similarly, ammonia from purge and flash gases from the synthesis loop are recovered by absorption in water followed by distillation in a closed loop. The lean gases from the stripper and purge recovery system are routed along with other off gases to the furnace.

Blow down from boilers, cooling tower and regeneration effluents from water conditioning plants also contribute to generation of wastewater.

In addition to the above in the non-catalytic partial oxidation process, water containing suspended and dissolved impurities; soot and slag are produced, which necessitates treatment using mechanical, chemical and biological means.

Solid waste

Spent catalysts and molecular sieves, used up resins, sludge from process vessels, packaging materials, insulation rejects etc., are sources of solid waste generated in modern ammonia plants. Usually eight or nine different catalysts are used in a steam-reforming based ammonia plant and most of these catalysts have an average useful life of around 2 to 6 years after which they are replaced. In the case of partial oxidation plants the number of catalysts used are only three or four. These catalysts contain heavy and toxic metals such as hexavalent chromium, nickel, zinc, iron, mineral supports etc., and hence cannot be disposed as landfills. Some of these spent catalysts are used for metal recovery.

Additives used in the potassium carbonate solution used for absorption of carbon dioxide such as vanadium pentoxide, arsenic tri oxide, amines are also hazardous.

Start up and shut downs cause majority of the process emissions from the ammonia plant. Reduction in start up time, recovery of vent gases as fuel and use of flare will reduce air pollution during start up and shut down.

The economically achievable minimum emission levels vary among old and new plants. Assuming steady-state production, oxides of nitrogen can be limited to 0.45 kilogram nitrogen oxides per tonne of ammonia (75 ppmv or 150 mg/Nm^3) in new plants, and about twice this in olden plants. Ammonia in wastewater can be reduced to 0.1 kilograms per tonne of ammonia produced. Spent catalysts can be limited to about 0.2 kilogram per tonne of ammonia. Environmental investment and operating costs vary according to emission standards or targets to be achieved, process design, integration with other facilities, raw materials, revamping requirements etc.

The modern ammonia plant is characterised by large capacities and involves the storage, transport and handling of several hazardous and toxic materials in huge quantities. These involve petroleum feedstock and fuel, carbon monoxide, hydrogen, ammonia etc., that are hazardous. Hence it is necessary that a comprehensive safety and risk analysis be carried out to operate and maintain these plants safely.

NITRIC ACID

Emissions

The main atmospheric emission from nitric acid plants are oxides of nitrogen (NOx)-nitrous oxide (N_2O), nitrogen peroxide (NO_2) and nitric oxide (NO). The concentration of these gases vary between 75 and 2000 ppmv depending on final acid concentration, pressure of the process, cooling temperatures, and degree of tail gas treatment available. Reduction in nitrogen oxides is usually achieved by absorption in cold dilute 25 to 30% nitric acid followed by stripping desorrption and recycling the gas back to the process, acid or alkaline chemical absorption, adsorption on molecular sieves, catalytic reduction with natural gas or other hydrocarbon fuel or selective catalytic reduction with ammonia (Hodge C.A. and Popovici N.N., Ed. 1994).

Effluents

Wastewaters from nitric acid plants come from water treatment unit, cooling towers and boiler blow down. The wastewater contains some dissolved salts and small amounts of ammonia, which are of little environmental significance. Wastewaters are cooled and neutralized if necessary and any significant ammonia content is vaporized and recycled to the process. The purging and sampling of ammonia and nitric acid solutions and the periodic replacement of lubricating oil in rotating equipment may also give rise to occasional generation of effluents which can be collected and recycled.

Solid waste

Spent catalysts and resins are major solid waste generated from nitric acid plants. The platinum/rhodium catalyst after use is usually returned to the manufacturer for recovery of precious metals. Spent resins are burned in kilns.

Nitrous oxide (N_2O) emissions can be minimized by various means such as extended absorption in water to achieve a concentration of 100 ppmv. Alkaline absorption by treating the tail gas with sodium hydroxide solution produces nitrite solutions which is then be treated and safely disposed or sold. In non-selective catalytic reduction hydrogen or a hydrocarbon fuel is burned along with the tail gas over a platinum, rhodium or palladium catalyst to reduce nitrous oxide to nitric oxide. Tail gases may need to be pre-heated, and the use of hydrocarbon fuel release of carbon monoxide and hydrocarbons to the atmosphere. In selective catalytic reduction ammonia is used to reduce nitrogen oxides to nitrogen over a catalyst such as vanadium pentoxide, platinum, iron/chromium oxides or zeolites. If there is some ammonia leakage, depending on catalyst efficiency, and the tail gas must be kept above 100°C after expansion. On the other hand with ammonia addition and with a high efficiency catalyst, and nitrogen oxides can be reduced to about 100 parts per million by volume (ppmv).

Extended absorption and selective catalytic reduction are appropriate treatment techniques depending on their technical and economic feasibility. A Selective Catalytic Reduction (SCR) unit costs less than a new absorption tower, but the latter would have much lower associated running costs. With the above systems it is possible to achieve a reduction of nitrogen oxides to at least 150 ppmv (1.6 kilogram per tonne of 100% nitric acid), whilst the economic target for existing plants should be 400 ppmv (4.2 kilogram per tonne), except in the case of low-pressure plants, where a realistic target would be 1000 ppmv (10.4 kilogram per tonne).

Urea Plant

Emissions

Urea plant capacities are normally commensurate with that of ammonia and carbon dioxide that are available from associated ammonia plants. Atmospheric emissions from this plant are mainly ammonia and urea dust arise out of the prilling or granulation process.

The ammonia emissions are from leaks in the plant and degradation of urea to form biuret in the prilling tower. Much of the dust from prilling towers and granulators is caused by condensation products of urea vapours.

Particulate emissions occur from seeding dust, undersize prills or granules, broken prills and also due to attrition. Prilling towers with natural draft may have less attrition and, hence, less dust than those with forced draft. Prilling tower, emissions range from 0.5 to 1 kilogram ammonia and 0.5-1.5 kilogram urea dust per tonne of product. With granulation, the granulator exit gas is scrubbed and losses can thereby limited to 0.25-0.8 kilogram of ammonia and 0.25-0.4 kilogram of urea dust per tonne. Without scrubbing, dust emission from granulators would be in the range of 5-30 kilogram per tonne or more, depending on granulation efficiency. In older plants, ammonia emitted from vents are typically be maintained within a range of 0.2-0.75 kilogram per tonne of urea, depending on the process and its operating efficiency, but in new plants this is reduced to as low as 0.06 kilogram per tonne (Hodge C.A. and Popovici N.N., Ed. 1994).

Effluents

Waste water from urea plants include the process condensate from the vacuum concentration stages (around 0.5 tonne per tonne urea) and the steam and turbine condensate (0.4 and 0.2 tonne per tonne urea respectively) and small quantities of oily water from equipment. The process condensate is normally treated and reused as boiler feed. Low-pressure steam so generated is used for process heating, in turbines, or exported to other plants. The waste water normally contains about 2% ammonia, 4% carbon dioxide, and 1% urea by weight and must therefore be treated in a thermal Hydrolyser-Stripper (Lammen W., 1994). The recovered gases are recycled to the synthesis section and the effluents now contain only around 0.0025 kilogram ammonia and 0.0005 kilogram urea per tonne of product. Alternatively the ammonia bearing effluents are also biologically treated , initially oxidizing to nitrate and then by de-nitrifying to nitrogen gas (Dave J.M., 1992).

Solid waste

There are no solid wastes from urea plants except spillages of product and mechanical refuse which can be fully retrieved.

Ammonium Nitrate (AN) and Calcium Ammonium Nitrate (CAN) Plants

Atmospheric emissions from these plants are particulates and ammonia which on an average comes to around 2 kilogram per tonne of product. In new generation plants using the best available technology (BAT) the above content is reduced to as low as 0.5 kilogram per tonne for particulates and 0.2 kilogram per tonne for ammonia. Emissions of ammonium nitrate and ammonia to water are of the order of 6 kilogram per tonne and 3 kilogram per tonne respectively (5000 and 2500 mg/litre) and it is reduced to 0.2 kilogram of nitrogen per tonne for ammonium nitrate and essentially nothing for ammonia by resorting to best available techniques of pollution control in these plants.

Liquid effluent from these plants comprise of condensates from neutralization, evaporation, blow down from air scrubbing and contain some amounts of ammonium nitrate and nitric acid. A thermal hydrolyser system will be able to strip out the ammonia content and after polishing through a demineraliser unit, the condensate can be recycled (Hodge C.A. and Popovici N.N., Ed., 1994).

Solid wastes problems are not encountered in AN plants. In addition to the emissions from an ammonium nitrate plant, a calcium ammonium nitrate plant produce solid wastes such as calcium carbonate or other filler used. These could be used elsewhere or safely disposed as landfill.

SULPHURIC ACID

Emissions

Atmospheric emissions from sulphuric acid plants consist of sulphur dioxide, sulphur trioxide, particulate matter and acid mist. Both are released with the waste gas from the final absorber tower. Acid mist can be effectively eliminated by equipment such as Brink filters or irrigated candle filters, Sulphur trioxide emission being as low as 0.15 kilogram per tonne of sulphuric acid in new double conversion and double absorption (DCDA) plants where as it is usually around 0.6 kilogram per tonne in single contact plants. Sulphur dioxide emission is about 10-12 kilogram per tonne of sulphuric acid in single contact plants. and only 2-3 kilogram per tonne in double contact plants (UNEP, 1998). In plants where sulphur is burnt to produce SO_2 the only liquid effluent is generated from boiler blow-down and water treatment. In plants where SO_2 is received from pyrites roasting, effluent from gas cleaning operations also arise.

Solid wastes

Solid wastes from these plants are spent catalyst and sulphur muck. Spent catalyst is returned to the catalyst supplier for recycling. Otherwise, solid wastes are usually disposed of by land-filling, subject to screening for heavy metals.

PHOSPHORIC ACID

Emissions

The main atmospheric emissions from these plants are gaseous fluorides from the reaction and filtration stages and dust from rock phosphate grinding and handling operations. After scrubbing, the fluorine content of these emissions is reduced to less than 10 mg/Nm^3, and in an efficient plant using BAT a level is 5 mg/Nm^3 is easily achieved. However, fluorine recovery from the hemihydrate process presents special difficulty, owing to the relatively high hydrogen fluoride (HF) content of the gas released from the reactors. Dust arising from the unloading, handling and grinding of mineral phosphate can also present an environmental problem, as it contains 3-4% water insoluble fluoride. New plants using BAT can keep dust and particulate emissions to 50 mg/Nm^3, though for existing plants a limit of three times this amount is more realistic. Liquid effluent from the condenser also contains some fluorine, as well as small amounts of phosphoric acid. This can be recycled to the process or, where feasible, discharged into a river or sea (UNEP, 1998).

A major solid waste from phosphoric acid plant is phosphogypsum. For every tonne of acid produced 4.5 tonnes of gypsum is generated, part of which is sold as chemical or soil conditioner. Earlier it was used to make ammonium sulphate by the Merceberg process which is not in extensive application now-a days (Gopinath N.D., 1968; George K.C. and Gopinath N.D., 1963 and Vyas V.M., 1992).

Bulk remains to be disposed and there is no cost effective value added products that could be made from this waste product. Usually gypsum is disposed in open sites as a stack over an impervious layer of polythene so that leaching will not occur and cause pollution for ground water. The lechetes from the stack are collected and safely discharged after necessary treatment (Isherwood K.F., 1992).

Complex Fertilisers (NP, NPK) Plant

Atmospheric emissions from complex fertiliser plants include ammonia, oxides of nitrogen, fluorine, dust, and aerosols composed of ammonium nitrate, fluoride and chloride. The amounts vary with the kind of process employed and its efficiency of operations and management (EFMA, 1995). Normally it ranges from 0.04 to 0.2 kilogram of ammoniacal nitrogen, 0.04 to 0.3 kilogram of nitrogen oxides, up to 0.02 kilogram fluoride and 0.1 to 0.2 kilogram of particulate matter per tonne of product. In principle, all solid and liquid wastes can be recycled, although some nitrogen (0.2 kilogram per tonne) may be lost in effluent with high concentrations of ammonium nitrate. The processes involving the acidulation of mineral phosphate with nitric acid has the highest emission of nitrogen oxides. Ammoniation in a drum granulator will lead to higher ammonia emissions and the more nitrogen or phosphorous in the formulation, the more nitrogen or fluorine respectively will be emitted (UNEP. 1998).

The fluoride and phosphate bearing effluents are treated with lime and they are precipitated as their insoluble calcium salts and are filtered. The calcium fluoride cake is either sold or disposed with out any chance for leaching and consequent contamination of ground water. The precipitated calcium phosphate is fed to the process.

COMPLEX FERTILISERS (MAP, DAP)

Atmospheric emissions from the manufacture of complex fertilisers such as mono ammonium phosphate (MAP) and diammonium phosphate (DAP), include ammonia, ammonium chloride (NH_4Cl), fluorine as silicon tetra fluoride (SiF_4), hydrogen fluoride (HF), and particulate matter. Dust and fines are separated from these emissions by water scrubbing. The liquid effluent is subjected to further treatment.

Emissions to water include compounds of nitrogen, phosphorous and fluorine, as well as solids in suspension. They are mainly derived from waste gas scrubbing and can be recovered by recycling the scrubber liquor. Lime is generally used to precipitate fluorine (and any phosphates or sulphates) in waste water. Ammonia and fluorine compounds are contained in the waste gas leaving an ammoniator granulator or acid neutralizer. They are recovered by scrubbing with phosphoric or sulphuric acid, or water, and returned to the granulator. With powder blending, no ammonia is released unless it is used with acid to promote the granulation.

When potassium chloride is added to the process to introduce the potassium content, ammonium chloride forms in both the granulator and the drier, it tends to vaporise above 130°C due to sublimation, and the vapours are removed in a mist eliminator. Wet scrubbers and bag filters are ineffective in this case. However, ammonium chloride fumes can be greatly reduced by formulating with a mixture of diammonium phosphate and urea, and/or by using potassium sulphate instead of potassium chloride.

Bag filters, wet scrubbers or dry cyclonic collectors are suitable for dust removal. The air velocity through the dryers and coolers affects the amount of dust, the higher the velocity, the more dust is emitted. Cyclones collect only the larger particles and final cleaning of exit fumes is to be done by water scrubbing. Bag filters are highly efficient and have smaller exit plumes than wet scrubbers. They recover a dry product that can be recycled without adversely affecting the water balance. They do not capture gases such as chlorides and fluorides and are operated under slight vacuum and lower temperatures. Wet scrubbers usually use weak phosphoric acid which flows counter-current to the gas flow, the resulting liquor being recycled to the neutralizer or granulator. The most commonly used scrubber in the ammonium phosphate industry is the venturi type of scrubber. With this system the fluorine and ammonia recovery is very efficient and emissions are further reduced by installing a tail-gas scrubber in series often using phosphogypsum pond water as the medium for scrubbing.

SINGLE SUPER PHOSPHATE (SSP) AND TRIPLE SUPER PHOSPHATE (TSP)

Emissions

The emissions from these plants are gases from the reaction section and particulate matter. The gaseous fluorine compounds are absorbed in a recirculating stream of a solution of fluorosilicic acid (Hodge C.A. and Popovici N.N., 1994). For TSP plants multistage venturi type cyclonic scrubbers are used. Dust control is usually by effective dust recovery systems either wet or dry, by changing the grain size or by adding chemical agents that lower dust formation.

Atmospheric emissions from a new nitrophosphate plants consist of ammonia, fluorine, nitrogen oxides and dust. The exhaust gaseous streams after treatment, including complex (NPK) formulation, shall be about 0.3 kilogram ammonia, 0.2 kilogram of oxides of nitrogen, 0.02 kilogram fluoride and 0.3 kilogram dust per tonne of fertiliser produced.

Waste water effluents from washing and scrubbing operations in new plants shall typically contain about 0.06 kilogram P_2O_5, 0.15 kilogram nitrogen (mostly as NH_3), and 0.05 kilogram of fluorine per tonne of fertiliser produced. In existing plants, achievable levels shall be 0.11 kilogram P_2O_5, 0.8 kilogram nitrogen and 0.05 kilogram fluoride. There are no solid wastes emanating from this plant.

NOISE LEVEL IN PLANT ATMOSPHERE

Noise sources in fertiliser plants are furnaces and fired heaters, burners, blowers and fans, air coolers, pumps, compressors, cooling tower fans, steam venting and let down, grinders, crushers, centrifuges, compressed air, vibration of equipment and pipelines, moving machinery, conveyors and so on. Insulating the source from the operators console is usually adopted as the basic strategy to combat sound pollution. Special refractory linings for furnaces, insulation, low noise burners, installation of silencers for fans, blowers, vent stacks etc., special noise attenuation for ducting and pipe work, control valves with special trims to reduce noise, low air velocity and low fin tip air coolers, special protective enclosures for machinery such as pumps, turbines, compressors etc., are the available techniques by which the impact of sound pollution in plants are reduced to an acceptable level (Johansen T. *et al.*, 1992).

The major plant nutrients that are supplemented through mineral fertiliser industry, as described above, are nitrogen, phosphorus and potassium. These nutrients are made into the form of water-soluble compounds that are mostly ammonium salts. The various chemicals and intermediates used in the manufacture of mineral fertilisers are ammonia, nitric acid, sulphuric acid, phosphoric acid, urea, ammonium nitrate, muriate of potash and to a lesser extent certain other chemicals.

The process of manufacture involve, chemical reactions at high pressure, temperature and concentration, consumption of large quantum of energy, most severe corrosive environments, and handling and storage of inflammable, toxic and hazardous chemicals and intermediates in large quantities. The raw materials and reactants used in the chemical processes pose concerns to human health, safety and the environment.

Pollution to air, water and land caused by emissions and effluents containing oxides of nitrogen, sulphur and carbon, ammonia, hydrogen sulphide, fluorine, other greenhouse gases, acid mist, dust and particulates, radiation, phosphogypsum, heavy metals, toxic chemical, used catalysts. resins, chemical residues and spillages, waste oil and lubricants. chlorofluorocarbons, laboratory wastes, redundant equipment, mechanical refuse, plastics etc., are the major environmental issues and concerns from the fertiliser industry.

These concerns are addressed in fertiliser production in such a way to keep the environmental impact of emissions and waste to a minimum by increasing the efficiency of production processes and adopting techniques of reducing pollution and through effective abatement. The extent of pollution, risk to human beings and damage to the environment, arising out of the production processes vary with the different fertiliser materials and thus call for specific control strategies and abatement facilities suitable to each of them. With the currently available technologies, it is possible to control the impact of these concerns within an acceptable level. To achieve the lowest levels of environmental consequences, the operation and maintenance of these plants are to be held in good order with a high standard of adherence to established and innovative control measures.

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Chapter 5

ENVIRONMENTAL MANAGEMENT AND CONTROL STRATEGIES

The production of chemical fertilisers entails certain safety, environmental and health concerns that are addressed by the industry through a strategy of proactive policy and programmes. It involves chemical reactions under varying conditions of temperatures, pressure, flammability, toxicity and such thermodynamic and physical parameters and is achieved through the application of a wide variety of chemical engineering techniques in systems usually called process plants. Thermodynamics impose certain limitations in achieving an overall efficiency of unity in operating systems and it applies to all our activities from cooking everyday food to the large-scale manufacture of numerous industrial chemicals. Pollution arises out of the lower level of thermodynamic efficiency of our activities. Technology plays a key role in improving the efficiency of operations and thus it has a vital role in reducing pollution. But, today even with the best-developed technology we are not able to fully ward off pollution.

Control of Pollution

With the increased use of chemical fertilisers and the increased concerns of controlling pollution from all sources in our environment, more emphasis is being placed on controlling the major sources of these chemicals getting into the environment (World Commission, 1987). Over the past fifty years there has been a step-by-step development in the approach to environmental issues from ignoring to diluting and discharging to proper treatment and now towards prevention and elimination of pollution. In developing countries like India, even today, treatment and prevention of pollution are considered important. As environmental regulations getting more and more stringent every year, industries are under heavy pressure to improve their environmental performance.

It is essential that we may have to continue the path of the developmental process, which we are in, at least for some more time with the prime focus on industrial development. Hence it becomes necessary that we have to address the problems of pollution caused by the industries with a view to reduce and control its harmful effects. Fertiliser industry must continue to supply products at affordable price to the farmers and at the same time it must also reduce waste and pollution to protect the environment. In some cases efforts to protect the environment will complement the profitability goals of the company whereas in other cases innovative measures are to be introduced to reduce pollution.

Most of the pollution control measures till the nineties of the last century are intended to treat the effluents from fertiliser units to attain the specific stipulations set by the statutory authorities with regard to the pollutant constituents and dispose them to the nearby environment with their consent. Considerable degradation has taken place as a consequence of this approach and it necessitated an altogether different kind of approach other than the above end-of-pipe treatment method.

Modern thinking in this line is to have a holistic approach for industrial pollution control and can be summarised as follows:

Source Reduction

The traditional approach to process design has been to first engineer the process to manufacture a product and then incorporate systems for treatment and disposal of waste streams arising out of the process. The modern approach is to analyse the system in its totality *ie*., different sections of the plant including effluent treatment facilities, to arrive at an economic option. Waste generation at source considerably reduce operating costs and capital investment requirements (Dyer James A. and Mullholland Kenneth L, 1998).

Harold A. Wagner, Chairman, Air Products and Chemicals Inc. observed: "future leadership in chemical industry will be defined by companies who not only practise safety and environmental responsibility at their own facilities, but who also create a safer environment through the product they sell" (Wagner H.A., 1999).

Reduction of pollution is achieved through improvements in process chemistry, reaction kinetics, stoichiometry, conversion and yields. Engineering design modifications is another method for reduction of pollutants at source. Extremes of temperature, pressure and concentration in the process adopted are reduced so as to render reactions to proceed in milder environments.

Management approaches with regard to inventories, quality, and house keeping and optimized operation are also important. Substantial technology modifications involving considerable investment have been successful in reducing pollution levels in fertiliser plants to as much as 70% below the existing levels .In the case of Urea plants a hydrolyser-stripper system reduce pollution loads almost completely and the whole investment to build and operate such a plant is paid back in four years through recovery of costly inputs to the process that are otherwise wasted and causing pollution.

Clean Technology

The concept of cleaner production applies to production processes, in conserving raw materials and energy, in eliminating toxic raw materials and reducing the quantity and toxicity of all emissions and wastes, in reducing negative impacts along the life cycle of the product *ie.*, from raw materials extraction to its ultimate disposal and services and incorporating environmental concerns into the design and delivery of such services.

Cleaner technologies are coming up in the modern development phase of the chemical processing all over the world especially in fertiliser manufacture. Changes in industrial raw materials to less toxic ones (from coal and oil to natural gas), improvement in the material efficiency (lower specific consumption) of the manufacturing process, guarding the environment from adverse impacts throughout the life cycle of the product (balanced application) etc., result in clean production processes. Techniques available for achieving clean production include using aqueous rather than solution based reactions, carrying out reactions at ambient temperature and lower pressures, just in time generation and consumption of toxic materials, use of specific chemical catalysts to avoid side reactions to form hazardous substances, use of artificial enzymes etc.

The UNIDO/UNEP joint initiative of National Cleaner Production Centres (NCPC) is an important step in building national capabilities in cleaner production in developing countries by acquiring international experience, expertise and technology and adjusting it to the national context (Table 5.1). These centers undertake in-plant demonstrations, training and information dissemination and policy assessments that can be incorporated into the national environmental legislation of developing countries. India joined the programme in the initial phase itself and is benefited by way of the national industries getting exposed to a wide scale and sustainable application of cleaner production.

Experience with cleaner production shows that many improvements can be made in the existing production process at minimal cost and achieve increased profitability. The programme focus on the potential for direct savings in the process through resource recovery and indirect savings in expenditure on pollution control (Volodin N.I., 1997).

Cleaner Production Assessment

A Cleaner Production assessment is a procedure, which companies, consultants etc. can identify sources of environmental concern and catalyse corporate efforts to achieve continuous environmental improvement through an on-going programme. It resembles a waste audit in concept but also includes a broader set of steps to search for prevention options. A central element of the assessment is analysis of the material and energy flows entering and leaving a process.

Table 5.1

UNEP's International Declaration on Cleaner Production.

We recognize that achieving sustainable development is a collective responsibility. Action to protect the global environment must include the adoption of improved sustainable production and consumption practices.

We believe that Cleaner Production and other preventive strategies such as Ecoefficiency, Green Productivity and Pollution Prevention are preferred options. They require the development, support and implementation of appropriate measures.

We understand Cleaner Production to be the continuous application of an integrated, preventive strategy applied to processes, products and services in pursuit of economic, social, health, safety and environmental benefits.

To this end we are committed to:

LEADERSHIP

> using our influence to encourage the adoption of sustainable production and consumption practices through our relationships with stakeholders.

AWARENESS, EDUCATION AND TRAINING

> building capacity by developing and conducting awareness, education and training programmes within our organization by encouraging the inclusion of the concepts and principles into educational curricula at all levels.

INTEGRATION

encouraging the integration of preventive strategies into all levels of our organization; within environmental management systems; by using tools such as environmental performance evaluation, environmental accounting, and environmental impact, life cycle, and cleaner production assessments

RESEARCH AND DEVELOPMENT

creating innovative solutions by promoting a shift of priority from end-of-pipe to preventive strategies in our research and development policies and activities; by supporting the development of products and services which are environmentally efficient and meet consumer needs.

COMMUNICATION

sharing our experience by fostering dialogue on the implementation of preventive strategies and informing external stakeholders about their benefits.

IMPLEMENTATION

taking action to adopt Cleaner Production by setting challenging goals and regularly reporting progress through established management systems; by encouraging new and additional finance and investment in preventive technology options, and promoting environmentally-sound technology co-operation and transfer between countries; through cooperation with UNEP and other partners and stakeholders in supporting this declaration and reviewing the success of its implementation.

Source: *UNEP Technical Report No.26, 1998.*

Cleaner production options such as substitution of raw materials or use of more energy efficient equipment are identified using such an analysis. Cost of inputs and outputs are also an important element of such analysis *eg.*, costs of raw materials, disposal charges, maintenance charges etc. The assessment is only a starting point for a clean production programme in companies. By assessing its energy and raw material use, a company should be able to identify key environmental, health and quality issues. Following the assessment, companies can use a variety of tools such as monitoring and auditing (waste, energy, health and safety) to address these issues and perhaps provide benchmarks for improvement.

The industry has developed several techniques on the lines of the above thinking.

Ecoefficiency

There exist close inter-linkages between eco-efficiency and cleaner production. Like cleaner production, ecoefficiency links corporate performance with sustainable development, integration of economic growth and environmental improvement. Eco-efficiency goes beyond resource use and pollution reduction by emphasizing value creation for business and society at large, while providing for competitive needs. By increasing value for the goods and services it creates, business will maximize resource productivity, gain bottom-line benefits, and reward shareholders, rather than simply minimize wastes or pollution. Ecoefficiency embraces cleaner production concepts such as efficient use of raw materials, pollution prevention, source reduction, waste minimization, and internal recycling and reuse. It promotes the idea of pollution reduction through process change as opposed to the earlier end-of-pipe approaches. It shares characteristics with many environmental management tools such as environmental assessment or design for environment by including them among the technological options for reducing material and energy intensity in production, as well as facilitating reuse through recovery and recycle. Eco-efficiency also features a life cycle perspective that follows products from the raw material through to final disposal stages, an extension of the total quality management process. Ecoefficiency is an evolving concept, which helps companies to adapt to the changing dynamics of the economic environment. It is observed (Senge Peter M., 1999) that all industrial products are created from resources extracted from nature—minerals, energy, wood, water, and so on. But only a tiny fraction of resources extracted becomes final goods sold, *i.e.*, less than 6% by weight. The rest becomes waste by-products. Therefore, there are huge potential gains in 'ecoefficiency'.

Environmental Burden Approach

ICI, England, has developed a new method as a art of their '*SHE Challenge 2000*', a voluntary programme developed to promote continuous improvement in Safety, Health and Environmental performance, to assess the potential harm to people and the environment from chemical emission which is described as the Environmental Burden (EB) approach (ICI, 1997).

It provides a meaningful picture of the emissions from operations, help to identify most harmful emissions, reduce them first, and give the public a better understanding of the problems and steps taken to reduce them.

First a set of recognized global environment impact categories are identified such as acidity, global warming, human health effects, ozone depletion, photochemical smog, aquatic oxygen demand, ecotoxicity to aquatic life etc on which the emissions and effluents exert an effect. Secondly, a factor is assigned to each individual emission which reflects the potential of its possible impact. The next step is to calculate the Environmental Burden by multiplying the weight of each substance emitted by its potency factor.

$$EB = (W_a \times PF_a) + (W_b \times PF_b) + (W_c \times PF_c) + \ldots\ldots\ldots\ldots$$

Where, W is the weight in tonnes for each substance of emission (a,b,c,.....) and PF is the specific potency factor based on the known or estimated environmental risk posed by an individual substance to the specific category under consideration.

Environmental burden can be used to compare performance with that of the previous years, compare emissions with other similar technologies and processes and set targets for improvement.

Natural Capitalism (NC)

Natural Capitalism proposes a new approach for environmental management of our production systems (Lovins A.B., Lovins H.L. and Hawken P., 1999) by which natural resources could be made more productive and at the same time environmental concerns are minimized yielding benefits both for today's shareholders as well as future generations. This has a particular relevance in the fertiliser industry because of the high energy intensity of the manufacturing processes employed and the large scale dependence on natural raw materials. The approach is to dramatically increase the productivity of natural resources through fundamental changes in design, and technology, eliminate waste generation by shifting to biologically inspired production models, moving to solution based business models rather than selling products and reinvesting in natural capital based on the principle of expanding returns.

Total Cost Assessment Methodology (TCA)

The Total Cost Assessment method developed by the American Institute of Chemical Engineers' (AIChE) Centre for Waste Reduction Technologies (CWRT) provides a disciplined and standardized approach for identifying all life-cycle costs and benefits associated with decisions related to environmental, safety and health (ES&H) issues for industrial products and processes. Prior to the development of this tool, a standardized, industrially accepted approach to conducting a Total Cost Assessment was not publicly available. It takes in to account all the costs associated with manufacturing operations for users and manufacturers of chemicals from raw material extraction to ultimate ecological fate *ie.*, the entire life cycle of a process or product), and helps decision-makers to assess the total costs incurred, cost savings accrued and the costs avoided for materials, products, processes or services that explicitly include the costs of environment, health and safety issues. It helps users to increase the awareness within the organization by providing a way to make greener and more sustainable process development decisions (Rogers Jo Dr., 2001).

The International Chamber of Commerce has brought out a business charter for sustainable development incorporating the above principles and management practices for organizations to achieve a better environmental performance (Table 5.2).

Table 5.2

The Business Charter for Sustainable Development 1991, International Chamber of Commerce.

The objective is that the widest ranges of enterprises commit themselves to improving their environmental performance in accordance with the following Principles, to having in place management practices to effect such improvement, to measuring their progress, and to reporting this progress as appropriate internally and externally.

The principles are as follows:

1. Corporate Priority

   To recognize environmental management as among the highest corporate priorities and as a key determinant to sustainable development; to establish policies, programmes and practices for conducting operations in an environmentally sound manner.

2. Integrated Management

   To integrate these policies, programmes and practices fully into each business as an essential element of management in all its functions.

3. Process of Improvement

   To continue to improve corporate policies, programmes and environmental performance, taking into account technical developments, scientific understanding, consumer needs and community expectations, with legal regulations as a starting point; and to apply the same environmental criteria internationally.

4. Employee Education

   To educate, train and motivate employees to conduct their activities in an environmentally responsible manner.

5. Prior Assessment

   To assess environmental impacts before starting a new activity or project and before decommissioning a facility or leaving a site.

6. Products and Services

   To develop and provide products or services that have no undue environmental impact and are safe in their intended use, that are efficient in their consumption of energy and natural resources, and that can be recycled, reused, or disposed of safely.

7. Customer Advice

   To advise, and where relevant educate, customers, distributors and the public in the safe use, transportation, storage and disposal of products provided; and to apply similar considerations to the provision of services.

8. Facilities and Operations

   To develop, design and operate facilities and conduct activities taking into consideration the efficient use of energy and materials, the sustainable use of renewable resources, the minimization of adverse environmental impact and waste generation, and the safe and responsible disposal of residual wastes.

9. Research

   To conduct or support research on the environmental impacts of raw materials, products, processes, emissions and wastes associated with the enterprise and on the means of minimizing such adverse impacts.

10. Precautionary Approach

    To modify the manufacture, marketing or use of products or services or the conduct of activities, consistent with scientific and technical understanding, to prevent serious or irreversible environmental degradation.

11. Contractors and Suppliers

    To promote the adoption of these principles by contractors acting on behalf of the enterprise, encouraging and, where appropriate, requiring improvements in their practices to make them consistent with those of the enterprise; and to encourage the wider adoption of these principles by suppliers.

12. Emergency Preparedness

    To develop and maintain, where significant hazards exist, emergency preparedness plans in conjunction with the emergency services, relevant authorities and the local community, recognizing potential transboundary impacts.

13. Transfer of Technology

    To contribute to the transfer of environmentally sound technology and management methods throughout the industrial and public sectors.

14. Contributing to the Common Effort

    To contribute to the development of public policy and to business, governmental and intergovernmental programmes and educational initiatives that will enhance nvironmental awareness and protection.

15. Openness to Concerns

    To foster openness and dialogue with employees and the public, anticipating and responding to their concerns about the potential hazards and impacts of operations, products, wastes or services, including those of transboundary or global significance.

16. Compliance and Reporting

    To measure environmental performance; to conduct regular environmental audits and assessments of compliance with company requirements, legal requirements and these principles; and periodically to provide appropriate information to the Board of Directors, shareholders, employees, the authorities and the public.

Source: *UNEP Technical Report No.26, 1998*

The realm of chemical processing in general and the production and use of mineral fertilisers in particular is fast changing with the widespread and growing concern on the quality of the environment. Extensive research and experimentation are to be undertaken to improve existing technologies and developing new ones for better environmental performance having least pressure on nature and its resources. Even now in India, research and development efforts are geared more to agronomic and engineering aspects of fertiliser production rather than addressing environmental concern. The industry must become increasingly proactive in developing mechanisms and supporting policy initiatives aimed at environmental care and pollution prevention as an integral part of their social responsibility. As noted by Robert S.Macnamara, former President of the World Bank, "Business leaders have a duty to serve society as well as their shareholders ...A company can drive for profits and at the same time meet the social responsibilities. ... There is no contradiction between a soft heart and a hard head" (Bump. B.L, 1997).

RISK MANAGEMENT AND CONTROL STRATEGIES

In the fertiliser manufacturing industries, it is necessary to handle, store and process large quantities of hazardous chemicals and intermediates posing risk to the employees and the neighboring community. Due to growing public concern of safety, now a days governmental authorities, industries, and civic bodies are very much aware of the requirement of minimizing the potential for injury to people and damage to the environment and property from industrial activities. The traditional approach (Bowonder, 1986) in chemical plants was that following an accident, investigations are made and necessary changes are incorporated in the system and its operation to avoid recurrence of such incidents. Today this approach is not at all acceptable because of the fact that a single incident itself besides causing loss of life and injury to many may even challenge the existence of the company itself. Thus process hazard management is gaining importance in the chemical industry in general and fertiliser sector in particular because of the fact that expensive fires, explosions and toxic gas release that have occurred in the past in the industry have invited worldwide attention to focus on preplanning disasters and on taking remedial actions well in advance.

The objectives of process hazard management are to render the fertiliser plant installation utmost safe by identifying hazardous situations that can crop up, assessing the potential damage it can cause and taking remedial actions so as to minimize their adverse impacts, and to be prepared to combat any possible disaster in the unlikely event of its happening with the help of an appropriate Disaster Management Plan. In recent years, a number of legislation and enactment have come to effect making the above requirement more stringent.

Inherent Safety

If the hazards that are likely to arise out of a plant can be eliminated by careful process selection and engineering design it becomes inherently safe and hence no additional safety systems are required. Attempts towards this approach are done by reducing the presence of hazardous inventories (intensification), replacing the hazardous materials with less hazardous ones (attenuation) or by resorting to a simpler design, easy to build and operate and therefore least prone to failures (simplification) (David M, 1996).

Inherently safe designs though have a high degree of reliability, avoid costly protection systems and their maintenance and have the least hazard and risk potential, lack of awareness and the more conservative attitude of the designers still remain as hurdles in adopting this approach as the basis of process design. This is mostly because of the insufficient knowledge and training, statutory obligations, concerns of project time and cost and also design constraints. Thus most plants are designed with the available information on know-how and technology and the desired standards of safety are built into it (Roberts R.H., 1989). Later the risk arising out of the facility is assessed and suitably tackled to sustain a safe and productive environment. In chemical process safety design, risk is understood in terms of likelihood and consequences of incidents that could expose people, property or environment to the harmful effects of a hazard.

Hazard Identification

This is the first step and a number of tools are available for identifying the potential hazards from a plant. These are based on previous experience, discussions involving people with more specialised knowledge and other creative and analytical methods (Ozog Henry and Bendixen M, 1987).

Experience based methods use a variety of design codes, which incorporate the collective experience in the industry, which is documented by bodies such as the American Iron and Steel Institute (AISI), American Society for Testing Materials (ASTM), National Fire Protection Agency (NFPA), Bureau of Indian Standards (BIS) etc.

'What if' Check List

Another method is to discuss the whole issue of process safety, personal safety, electrical safety, fire protection etc. among a set of specialists using the "What If" check list. Limitations of the process, changes in process streams, changes in equipment design, suitability and adequacy of protective devices, operating procedures, material of construction etc are carefully reviewed during this evaluation. Analytical methods include the fault tree, event tree and cause consequence diagram.

Fault Tree Analysis

In the fault tree approach, a logic diagram is constructed from an undesirable event and all the causes that can lead to the event. This is a top down approach in analyzing the potential that a hazardous situation may arise in a system.

Event Tree Analysis

An event tree is similar to a fault tree but explores the consequences of an undesirable event. This is a bottom up approach method suggesting how a wrong initiating event can lead to a potential danger.

Cause Consequence Diagram

The cause consequence diagram is a combination of fault and event tree analysis. It presents the sequence of events in the form of a logic diagram and presents a quantification of the risks from a system. It is easier to identify by this method, the sequence of events that finally culminate in a disaster. The above methods display logical relationships, identify combination of failures that can lead to the undesired event and can be used as the basis for hazard assessment.

Creative methods of hazard identification are adapted from approaches being used for seeking innovations and improvements to existing systems. Brainstorming and the Hazard and Operability Study (HAZOP) are the two important methods.

Brainstorming

Brainstorming is a creative group activity giving out a number of ideas on a specific issue, which are later sorted and evaluated. However it does not ensure comprehensive coverage and hence it is used in support of other systems being employed in hazard identification.

Hazard and Operability Studies

Hazard and Operability Studies (HAZOPS) are intended to systematically analyse the process and identify the hazards arising from like deviations from normal safe operations and their consequences and to devise measures to prevent or minimize such deviations from occurring as far as possible. A structured guideword approach is used to analyse each piece of equipment, operating parameters and critically examine all possible situations that are likely to be encountered in the operating environment (ILO, 1988; Lawley H.G., 1973). A comprehensive check list covering all sections of the plant is used for the study (AIChE, 1992).

A list of major hazards that are likely to arise from the various fertiliser plants are shown in Table 5.3.

Table 5.3

Major Hazards from Fertiliser Plants

Ammonia

Fire or explosion hazard due to leaks from the hydrocarbon storages and feed system.

Leaks of synthesis gas in the conversion, carbon dioxide removal and synthesis gas compression areas.

Furnace/ fired heaters explosions,

Pump/ compressor explosions,

Release of Carbon Monoxide,

Toxic hazards from liquid ammonia during storage and handling.

Urea

Equipment or piping failure due to corrosion,

Explosion hazard due to the formation of an explosive gas mixture,

Toxic hazard due to ammonia release.

Nitric Acid

Ammonia leaks, Equipment piping failure because of corrosion,

Explosion hazard due to the air ammonia mixture,

Explosion of nitrite and nitrate salts, Release of nitrogen oxides

Ammonium Nitrate and Calcium Ammonium Nitrate

Ammonium nitrate explosions in pumps, Dust explosions

Sulphuric Acid

SO_2/ SO_3 release, Sulphur dust explosions,

Acid leaks, spillage

Phosphoric Acid

Acid leaks, Release of Hydrogen Flouride

Compound Fertilisers

Slurry pump explosions, Slurry decomposition,

Product decomposition.

Hazard Assessment

Hazard assessment estimates the consequences arising out of an identified hazardous situation. It depends on two factors–the probability of occurrence of such an incident and the potential damage it can cause if it occurs.

Commonly available tools for estimating the probability of occurrence or hazard rate are Dow Fire and Explosion Index, Mond Fire, Explosion and Toxicity index, Failure Mode Effect Analysis, Fault Tree Analysis and Event Tree analysis.

Dow Fire and Explosion Index

The Dow Fire and Explosion Index is a systematic objective evaluation of the realistic fire, explosion and reactivity potential of process equipment and its contents. The qualitative analysis is based on historical data, quantities stored, chemical energy potential of the material handled, and the extent of safety practices being currently applied. For a particular unit it is calculated from weighting factors termed as general process hazards (GPH), special process hazards (SPH), and the material factor (MF). General process hazards include exothermic and endothermic reactions, material handling and transfer, and plant layout. Special process hazards relate to incidents that relate to increase in the probability of fire or explosion such as operating in or near the flammable range, quantity etc. Material factor is a measure of the intensity of energy release. The index provide a comparative measure of the overall risk of fire and explosion of a process. It is also used as a practical tool for assessing the inherent safety of a design and see whether modifications can improve things to a better level of safety. Units with a high index can be taken up for further studies leading to quantitative risk assessment (Dow, 1998; Lees F.P., 1996).

Table 5.4

Dow Fire and Explosion Index

Dow Index	Degree of Hazard
1-60	Light
61-96	Moderate
97-127	Intermediate
128-158	Heavy
159 and up	Severe

Source: *Fire and Explosion Index Hazard Classification Guide, 1998.*

Mond Fire, Explosion and Toxicity index

The Mond Index is a rapid hazard assessment used in process plant design, developed from the Dow index taking into account additional hazard considerations. It produces a numerical ranking for each section of the plant based on the nature of the process properties of materials present, quantity, transfer operations, plant layout and reactivity (Table 5.5). The plant is divided into units based on the feasibility of locating a separating barrier such as an open space, wall or floor between them.

Additional considerations, which go into the working of the Mond index, are coverage for a wide range of processes and storages, processing of chemicals having explosion potentials, differentiating heat of combustion and heat of reaction of the same material, Inclusion of additional process hazards affecting the existing level of hazards significantly, aspects of toxicity and factors affecting relative hazard levels under varying degree of inherent safety.

Table 5.5

Mond Fire, Explosion and Toxicity Index

Mond Index	Degree of Hazard
0—20	Mild
21—100	Low
101—500	Moderate
501—2500	High
2501—12500	Very High
12501—65000	Extreme
>65001	Very Extreme

Source: *The Mond Index, ICI 1985.*

By a similar calculation as that of the Dow, separate indices are worked out for internal explosion, combustion load and toxicity. These indices are combined to work out overall ranks relating to the qualitative descriptions of the hazard potential of each unit (ICI, 1985).

Failure Mode Effect Analysis (FMEA)

Failure Mode Effect Analysis identifies single equipment or system failure modes and their potential effects. The causes or modes of failures are considered and the possible outcomes or effects are noted down. The exercise is repeated for all known failure models of all components of the system. The outcome is an assessment ranking the probability and severity of the identified failure modes. It is quite useful for the analysis of very critical systems but is extremely time consuming.

Fault Tree Analysis (FTA)

Fault tree is a graphical display of how the faulty situations in a system can lead to a predefined failure. This is an analytical technique to identify a particular (unusual) effect from the system and to trace it backward to the caused resulting in this effect. It gives a quantitative evaluation of the probability of the occurrence of the "top event". Fault Tree is widely used for quantitative risk analysis especially where extremely tight process controls are needed to attain the required standards of safety. It worked from a chosen top event and then considers the combination of failures and conditions, which cause the event to occur (CMA, 1985).

Event Tree Analysis (ETA)

Event Tree Analysis is a forward reasoning technique, which identifies the ultimate consequences arising out of a basic cause or initiating event. It gives the probability of occurrence of the ultimate consequence. Event Tree analysis records the accident sequences and defines the relationship between the initiating events and the subsequent events that combine to result in an accidental situation. The procedure involves identifying the initiating event, listing of all undesired events that can arise out of it, construction of the event tree and evaluation of the frequency of failure. If the failure frequency level is intolerable special efforts shall be taken to contain the same.

Disaster Management

Knowledge of the consequences of events will be helpful for planning control of hazards during the design and operation of the facility by taking proper action to reduce hazard rate or minimise the consequence as the case may be. Or else the assessed risk may be ignored for not having any serious consequences.

The other important function of hazard analysis thus, is to develop a comprehensive disaster preparedness plan by providing a clear understanding as to what hazard exist and what risk it pose to those inside and the neighboring community.

Planning for disaster management require estimation of hazard potential, vulnerability of incidents and risk arising out of incidents. Hazard potential of chemical processing unit depend on chemical identities, locations of facilities that use, produce, process or store hazardous materials, the type and design of chemical container or storage, quantity of material that could be involved in an air born release and nature of the hazard (*eg*., air borne toxic vapours or mists, fire, explosion, large quantities stored or processed, handling conditions etc.) most likely to accompany hazardous material spills or release.

The characteristics of the chemical handled, its physical and chemical properties, health hazard data, fire and explosion related data, reactivity data, precautions for safe handling and usage, protective equipment to be used, and emergency first aid treatment information are available from the chemical profiles or Material Safety Data Sheets (MSDS). Information relating to the type and design of the storage (such as single walled, double walled, pressurised, refrigerated or cryogenic type of storage) will be available from the engineering documentation pertaining to the installation. Regarding the quantities involved it will be necessary to know the quantity that is stored on any given day, the maximum quantity that could be present in each storage or processing location and the total number of storage at that location. Conditions, under which the chemicals are processed, handled or stored including the temperature, pressure and other unique features in manufacturing, storage or handling if any, are also to be understood. Information may also be obtained on transportation routes used for movement of chemicals, quantities involved in transportation, frequency of such movements and form of transportation such as tank truck, tank car, drums, wagons, pipelines, barges etc.

Vulnerability of Incidents

Vulnerability analysis identifies areas in the locality that may be affected or exposed, individuals who may sustain injuries or death from hazardous materials and facilities and property or environment that may be damaged by the accidental release. A comprehensive vulnerability analysis provides the following information:

1) Extent of the vulnerable zones: This is an estimation of the area likely to be affected significantly, because of a chemical spill or gas release. This may be in terms of numbers, density or types of individuals such as employees, local residents, people in community centers such as hospitals, schools, worship places, day care centres etc.

2) Property that may be damaged including essential support systems: Details of property such as critical facilities, dwelling homes, schools, hospitals, business, office etc. and essential support systems like water, power, food, communications, medical transport are to be gathered.

3) Environment that may be affected and the impact of release on sensitive natural areas and endangered species.

4) Estimation of Vulnerable Zone: The vulnerable zone is the area coming under the maximum dispersion distance for which resulting airborne chemical concentrations would be in excess of the specified exposure levels. The extent of the vulnerable zone depends on the quantity of the hazardous material released, the rate of release, air borne dispersion and the air borne concentration that could cause irreversible health effect or death. Different methods are available for dispersion calculations and they vary in their assumptions and therefore the results obtained also may differ.

With a wind flow in a particular direction, at the time of release, the affected zone fall under the direction of down wind only. As the wind direction at the time of an accident release cannot be predicted, it is necessary to consider all possible wind direction and subsequent plume paths. Thus, the estimated vulnerable zones are circles with the potential release site located at the Centre, the size of which depends on the distance the air borne chemical travels before it is diluted in the air to a concentration below the level of concern (LOC) for acute health effects.

Factors affecting the size of the vulnerable zone are quantity and rate of release, meteorological conditions, surrounding topography and the level of concern (LOC) of the chemical (IChemE, 1990; EPA, 1987).

Risk Assessment

Risk analysis has to address two components—hazard and risk. Hazard is anything that has a potential to cause damage to life, property and the environment *eg.*, toxic chemicals such as chlorine or ammonia and inflammable materials like gasoline, LPG etc. This inherent property of the material remains the same whenever they are present.

Risk is a variable function indicating the probability that a hazard will manifest itself and the severity of the damage it can cause (Kolluru R.V., 1991). The risk factor depends on the nature of chemicals, quantity stored, design safety aspects, weather conditions etc. It provides an assessment of the likelihood of an accidental release and the actual consequences that might occur based on the estimated vulnerable zones and is a judgment of probability and severity depending on past knowledge and information.

Risk out of an Activity = Probability of Occurrence x Consequence

Risk analysis tend to estimate the probability that the hazard (accidental release) will occur under existing conditions as well as unusual or abnormal situations and the consequence (severity of damage) to human beings, critical facilities, property (reversible and irreversible) and environment (recoverable or permanent). Comparing both, with a target or specification a decision is taken whether or not action to reduce the probability of occurrence or minimize the consequence is desirable, or whether the risk should be left, at least for the time being (Kletz T, 1977).

Risk assessment can be subjective or quantitative. For subjective assessment relevant information is collected to develop a relative measure of the likelihood and severity of possible hazardous events and arranged in the form of a matrix. A relative ranking of the probability of occurrence and severity of consequences is given below:

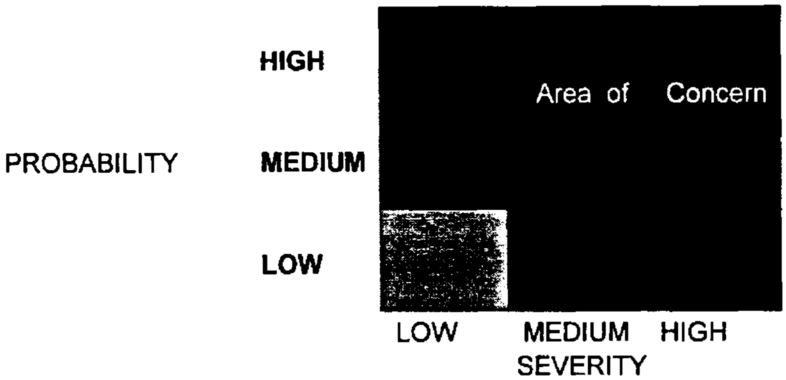
Probability of Occurrence

LOW	UNLIKELY during the expected lifetime of the facility under normal operation and maintenance
MEDIUM	IBLE during the expected lifetime of the facility
HIGH	Sufficiently HIGH to assume event will occur at least once during the expected lifetime of the facility

Severity of Consequences

LOW	Chemical is expected to move into the surrounding environment in negligible concentrations. Injuries expected only for exposure over extended periods or when individual personal health conditions create complications.
MEDIUM	Chemical is expected to move into the surrounding environment in concentrations sufficient to cause serious injuries and/or deaths unless prompt and effective corrective action is taken. Death and/or injuries expected only for exposure over extended periods or when individual personal health conditions create complications.
HIGH	Chemical is expected to move into the surrounding environment in concentrations sufficient to cause serious injuries and/or deaths upon exposure. Large numbers of people expected to be affected.

From the above data a risk analysis matrix is developed as follows:



Source: *Technical Guidance for Hazard Analysis, USEPA, 1987.*

Fig.5.1: Risk Analysis Matrix

The area of concern lies in events with probability-severity ranking of high-high, high-medium, medium-high and medium-medium which requires additional attention and possible mitigating measures (Fig.5.1).

Quantitative Risk Assessment (QRA)

Quantitative risk assessment involves estimation of disaster potential and the probability of their occurrence using mathematical models.

Disaster Potential

In order to estimate the disaster potential, calculations are done based on effect models. These mathematical models are those relating to idealised situations that are likely to occur in actual operating conditions of the plant or installation. They include:

1) Discharge of liquid, gases and vapours: The release of liquid, gas or a mixture of gas and liquid from containment through a hole or pipeline rupture and the spreading characteristic immediately after the release.

2) Evaporation of liquids on land: Nature of the evaporation process depending on the surface characteristics and heat draw from ground for boil off.
3) Evaporation of liquids on water: Extent of release into air once the liquid spills over water.
4) Gaussian dispersion models: For dispersion of neutrally buoyant plumes and for heavy gases at sufficiently high wind velocities and at sufficient distance from downwind.
5) Heavy gas dispersion models: These incorporate terrain effects, complex geometries and wind effects.
6) Heat radiation due to pool fire, flash fire, and BLEVE (Boiling Liquid Expanding Vapour Explosion): Poolfire can be from a pool of fuel spread over ground, water or a tank fire. Flash fire involves delayed ignition of a dispersed vapour cloud, which does not cause blast damage. BLEVE result from the overheating of a pressurised vessel by primary fire.
7) Unconfined Vapour Cloud Explosions (UVCE) or explosive deflagration of a dispersed flammable vapour;
8) Lethality due to toxic gas release: These include acute toxic effects arising out of short-term exposure at high concentrations and chronic effects from long term exposure at low concentrations.

These models will quantify the effect of the disastrous situation in terms of damage criteria. In most cases the damages occur mainly due to thermal radiation effects, pressure wave effects and toxic gas release (World Bank, 1988).

Thermal Radiation Effects

Thermal radiation effects from fires are calculated from the thermo physical properties of materials involved, heat liberated during the combustion and transmissivity of air path to people and property away from the site. A fire situation can be a pool fire, jet fire, fireball, BLEVE (boiling liquid expanding vapour explosion) or flash fire. Fire damage estimates of incident radiation flux are given in Table 5.6.

Table 5.6

Damage Caused at Different Incident Levels of Thermal Radiation

Incident Flux (KW/m2)	Type of Damage Caused	
	Damage to Equipment	Damage to people
62	Spontaneous ignition of wood; are sufficient to cause damage to process equipment.	
37.5	Damage to process equipment	100% lethality in 1 min. 1% lethality in 10 sec.
25.0	Minimum energy to ignite wood at indefinitely long exposure without a flame.	100% lethality in 1 min. Significant injury in 10 sec.
12.5	Minimum energy to ignite wood with a flame; melts plastic tubing.	1% lethality in 1 min. 1st degree burns in 10 sec.
8	Maximum heat flux for uninsulated tanks	
4.5		Causes pain if duration is longer than 20 sec. But blistering is unlikely.
1.6		Causes no discomfort for long exposure.
0.7		Equivalent to Solar radiation.

Source: *World Bank Technical Paper*, 1988.

Pressure Wave Effects

Pressure wave effects are due to explosion in which a sudden release of energy to the surrounding atmosphere takes place. It can be due to:

1. Explosive deflagration of a dispersed flammable vapour (unconfined vapour cloud explosion).
2. Detonation of an unconfined vapour cloud.
3. Explosion of a flammable mixture in a confined space.
4. Explosion of a pressure vessel due to process abnormalities.
5. Explosion of an unstable chemical.
6. Bursting of a pressurised container or

Damage characteristics of blast waves are given in Table 5.7.

Table 5.7

Explosion Damage Criteria: Pressure Wave Damages

Over pressure (bar)	Type of Damage
0.7	Complete demolition of houses
0.33	Houses severely damaged
0.25	Houses inhabitable due to damage
0.04	90 % Windows smashed.
0.02	50 % Windows smashed
0.005	5 % Windows smashed.

Source: *Major Chemical Hazards*, 1987.

Toxic Gas Release

The effects of toxic gas release are categorised as acute or chronic based on the duration and concentration of exposure. Carbon monoxide poisoning is an example of acute toxic effect. These arise from short-term exposure of high concentrations. Asbestosis and lead poisoning are examples of chronic toxic effects arising out of long term exposure of low concentrations. The effect of exposure is irritation, narcosis, asphyxiation and systematic damage. Severity of the effect depends on the concentration, duration of exposure and the toxic properties of the material. Dispersion of gases are influenced by stability of atmospheric conditions, mechanical turbulence caused by wind, terrain, forests, hills, temperature gradient existing at lower atmospheres and inversion height of mixing layer.

The probability of experiencing a lethal dose of toxic material at a given distance from a source taking into consideration of the prevailing atmospheric conditions and dispersion characteristics can be calculated and marked on the plot plan of the installation. These calculations are based on LC-50, the lethal concentration that would be expected to kill 50% of the exposed population over the exposure period (Bosch W.W., 1992).

Event Probabilities

Two approaches are often used for estimation of event probabilities. The first one is the historical approach using statistical data on failure from plants or systems. The second method involves analytical techniques, which break down the event into its contributory factors and causes.

Though the former encompasses all aspects including reliability of equipment, human errors, operational methods, quality of design, construction, maintenance, environment etc., the estimation based on this approach is considered as conservative, mostly due to the presence of not so relevant data typical of such situations and as well as those pertaining to older generation plants. The event frequencies for different types of fire damages for a floating roof oil storage tanks based on past operating data of such tanks is given in (Table 5.8).

The results of the various analytical techniques discussed earlier will predict the event probability in terms of number of occurrence per year. The probability of a disaster depend on the probabilities of the initiating event, likelihood of the counter measures functioning as intended and that a particular consequence may occur. Other dependent factors of the consequences are atmospheric conditions, weather, time of occurrence of the day etc.

Table 5.8

Event Frequencies for Open Top Floating Roof Oil Storage Tanks

Type of fire damage	Event frequencies (x 10^{-5} Tank Year)
Rim seal fire	100
Spill on roof fire	3
Small bund fire	9
Large bund fire	6
Full surface fire (sunken roof)	28

Risk Specification

In general two levels of risk that are usually encountered are the individual risk and societal risk. Maximum permissible level of individual risk that is accepted worldwide is one in one million per person per year ($1x10^{-6}$/man/year) (Andrews and Moss, 2002). Most of the studies have shown that the risk to life for members of the public from fertiliser plants is less than one in ten million per person per year and this level is considered acceptable for the community. The accuracy of quantitative risk assessment heavily depends on the authenticity of the data, reliability of the model used and human error (Lees F.P., 1996). Such studies will be able to remove the apprehensions of the local community around hazardous installations and facilitate promoting the social cause of the industry (EPA, 1995).

Exercise of this kind done in numerous installations when compared with similar situations occurring in real life operating environment in the industry suggest that in these kind of probabilistic assessments, there is a tendency usually to err on the side of caution, thereby overestimating the risk. Experiences of such studies suggest that process hazard analysis of fertiliser installations is to be redone every five years at least to maintain an effective safety management programme (Smith K.E., and Whittle D.K., 2001). An assessment of the safety performance of the Indian Fertiliser Industry (Nand. S. and Jain, B.K., 1991) reveal that strengthening of systems, procedures and training are necessary to minimize the incidents and their undesirable consequences.

The above pollution control methods for each kind of processes and risk reduction methodologies for potential hazards are successful in ensuring environmental protection and safety in the plants to an acceptable level to sustain production of mineral fertilisers.

They are also sufficient, to fully comply with the stipulations of the regulatory authorities in respect of pollutants discharged from the process. However, meticulous care and management commitment is essential to ensure diligent operation and maintenance of such facilities. Moreover, as technologies keep on changing, it shall be the endeavor of all concerned that new and proven technologies are adopted to achieve better performance in environmental management and safety in the plants.

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Chapter 6

LEGAL FRAMEWORK OF ENVIRONMENTAL PROTECTION

The awareness of risk posed to the society and environment from operation of major industries such as the fertiliser manufacturing, have resulted in a number of initiatives aimed at maintaining and continually improving safety and environment culture in the industry. Pollution prevention through enforcement of the stipulations of the various control legislations and related rules and regulations is an important part of Environmental Management. The basic premises of such legislation are prevention of major accident hazards and limiting the consequences of such accidents not only for mankind but also for the environment. It place more emphasis on the socio-technical aspects of control policy and attempt to bring more transparency and openness into the process by allowing for public consultation and by strengthening the role of statutory authorities through information exchange (Duffield. J.S, 2001). In this chapter, the various enactments of the Government of India on the environmental front that have a direct bearing on the operation of fertiliser plants are examined.

Constitutional Provisions

The Directive Principles of State Policy in the Constitution of India provide for the Protection and improvement of environment and safeguarding of forests and wild life. The State shall endeavor to protect and improve the environment and to safeguard the forests and wild life of the country. The Constitution also declare that it shall be the duty of every citizen in the country to protect and improve the natural environment including forests, lakes, rivers and wild life, and to have compassion for living creatures. The language of the Directive Principles of State Policy (Article 47) requires not only a protectionist stance by the state but also compels the state to seek the improvement of polluted environments. This allows the government to impose restrictions on potentially harmful entities such as polluting industries.

India was among the first group of countries to insert an amendment into its Constitution allowing the State to protect and improve the environment for safeguarding public health, forests and wild life. The 42nd Amendment of the Constitution of India, enshrining the importance of environmental protection was adopted in 1976 and came to effect January 3, 1977. The Indian Penal Code, passed in 1860, penalises person(s) responsible for causing defilement of water of a public spring or reservoir with imprisonment or fines (Shamad D, 1996).

The Indian Forest Act was a product of British rule in 1927. It reflected the British policy of exploitation of natural resources rather than the desire to preserve and protect the forest environment. It conferred vast rights on Governments to exploit the forest resources. The British looked upon the forest as a source of supply of timber for manufacturing railway sleepers. Even at this early stage, awareness of man's destructive tendencies was emerging.

The Factory Act also addressed public safety and health issues. Section 12 of the Act empowered each state government to legislate its own rules and throughout the 1950's and 1960's individual states framed their own rules under the Act. The legislation has indeed addressed the question concerning the discharge of water and effluents by factories and called for effective arrangements for disposal at the plant-level. Non-compliance of these provisions is liable to invite punishments. Though we have a number of legislation fostering environmental protection the basic issue still remain as indiscriminate exploitation of nature and thoughtless introduction of high technology ignoring the need for environmental protection. (Diwan P. and Diwan P, 1998).

The Water (Prevention and Control of Pollution) Act, 1974

The Water (Prevention and Control of Pollution) Act was passed in 1974. Creation of a regulatory agency for controlling water pollution marked the beginning of a number of environmental legislations by the Indian Parliament. The Water Act also established the Central Pollution Control Board (CPCB) at central government level and State Pollution Control Board (SPCB) at the state government levels.

Some of the main responsibilities of the Central Board in promoting pollution abatement included coordinating activities of state boards and resolving disputes among them; providing technical assistance; conducting investigations; opening laboratories for analysis of samples; establishing fees for different types of sample testing; researching issues and problems; training personnel; conducting media and public awareness campaigns; collecting and disseminating data on water pollution; and working with state boards to set standards.

The state boards undertake plant-level inspections and monitoring, and advising the Central Board of problems and trends at the local level. Plants can be required to provide the state with information on their pollution control technologies.

The Central Pollution Control Board (CPCB) has instituted the Minimal National Standards (MINAS) for major industry sectors including fertilisers. An instrument of ‘Consent’ is used by the PCBs for control of pollution through legal provisions. Fertiliser units are required to obtain a consent, which is granted after verifying that the conditions stipulated are fully complied with. The consent regulates the quality and quantity of effluents that can be discharged over a period of time.

Subsequent amendments to the Act were made to overcome difficulties in implementations of rules, siting of industries, empower the Board to order regulation or closure of excessively polluting units and give right to citizens to initiate legal action against polluting industry.

The Water (Prevention and Control of Pollution) Cess Act promulgated in 1977 provided the Central and state boards with the authority to levy and collect a tax on industries using water (FAI, 2000).

Air (Prevention and Control of Pollution) Act, 1981

The Air (Prevention and Control of Pollution) Act was passed in 1981 for the prevention, and control of air pollution and preservation of air quality. Under the provisions of this Act, the CPCB is authorized to develop national standards for quality of air and devise means to prevent, control and abate pollution. The State Pollution Control Board will advise the State Government with regard to the suitability of location for establishing any industry that is likely to cause pollution. Noise is also included in the list of air pollutants and provisions of the Act are made applicable for its control.

Environment (Protection) Act, 1986

In 1986, the Parliament passed the Environment (Protection) Act, designed to act as umbrella legislation on the environment. The responsibility entrusted to administer the new legislation also fell to the central and state pollution control boards.

In 1993, the Ministry of Environment and Forests (MoEF) of the Government of India completed its Environmental Action Plan to integrate environmental considerations into developmental strategies, which, among other priorities, included industrial pollution reduction.

The Ministry also decided to shift from concentration to load-based standards. This would add to a polluter's costs and remove incentives to dilute effluents by adding water, and strengthen incentives for adoption of cleaner technologies. It also issued water consumption standards for different industries and proposed additional penalty for excessive water use.

Targeting small-scale industries has been an important task as well since these facilities greatly add to the pollution load. The Ministry provides technical assistance and limited grants to promote central effluent treatment plants. It has also created industrial zones to encourage clusters of similar industries in order to help reduce the cost of providing utilities and environmental services.

Under this measure, the Central Government has responsibility for deciding standards, restricting industrial sites, laying down procedures and safeguards for accident prevention and handling of hazardous waste, overseeing of investigations and research on pollution issues, on-site inspections, establishment of laboratories, and collection and dissemination of information. The bill also sets standards on specific pollutants in specific industrial sectors including fertiliser industries.

The measure provides guidelines for location of industries and mining areas, for permitting and restricting industries in environmentally sensitive areas, coastal zone regulations and environmental impact assessments of development projects. Committees convened to conduct Environment Impact Assessments must have disciplines in eco-system and water resource management, air and water pollution control, flora and fauna conservation, land use planning, social sciences, ecology and environmental health. Public hearings are also pre-requisite for project clearance.

The law also promulgates rules on hazardous waste management and handling. The act defines the responsibilities of handlers, circumstances for granting authorization, conditions of disposal sites, rules for importing hazardous wastes, reporting of accidents, packaging and labeling requirements and an appeal process for potential handlers who have been denied authorization.

Rules were also promulgated on the manufacture, storage and import of hazardous or toxic chemicals, micro-organisms, genetically engineered organisms, or cells. For the first time, private citizens were given the right to file cases against non-complying factories

Hazardous Wastes (Management and Handling) Rules, 1989

The purpose of these rules is to regulate the handling of hazardous substances and establish a control mechanism for the management of hazardous wastes. Under the rules it shall be the responsibility of the facility operator to properly collect receive, treat, store and dispose these materials safely at locations intended for the same under the authority granted to them by the State Pollution Control Boards. Some of the hazardous wastes associated with fertiliser industry as regulated above are materials containing chromium, arsenic, sludge from water treatment plants, acid, alkali and slurry wastes, spent catalysts etc.

Manufacture, Storage and Import of Hazardous Chemical Rules, 1989

These rules prescribe procedures and safeguards for the prevention of accidents arising out of the use of hazardous and toxic chemicals in industries. The list of such chemicals include ammonia, arsenic trioxide, hydrogen, oxides of nitrogen, sulphur, vanadium and its compounds, chromium and its compounds etc., that are extensively used in the fertiliser industry. It has been made the responsibility of the occupier of the facility to identify major hazards and take adequate preventive steps, provide information, training and equipment to the personnel at work to ensure their safety, provide information to all who are likely to be affected by a major accident, develop material safety data sheets for such chemicals and prepare safety reports and on-site emergency plans.

Consequent to the amendments in 1994, it has become obligatory for plants to carry out safety audits every year and submit the report to the authorities. Mock drills were also made mandatory.

Noise Pollution (Regulation and Control) Rules, 2000

Whereas the increasing ambient noise levels in public places from various sources, including industrial activity have deleterious effects on human health and the psychological well being of the people, it is considered necessary to regulate and control noise producing and generating sources with the objective of maintaining the ambient air quality standards in respect of noise.

The State Government may categorise the areas into industrial, commercial, residential or silence areas/zones and specify ambient air quality standards in respect of noise for different areas/zones for the purpose of implementation of noise standards for different areas.

The State Government shall take measures for abatement of noise and ensure that the existing noise levels do not exceed the ambient air quality standards specified under these rules. All development authorities, local bodies and other concerned authorities shall take into consideration all aspects of noise pollution as a parameter of quality of life to avoid noise menace and to achieve the objective of maintaining the ambient air quality standards in respect of noise.

The Public Liability Insurance Act, 1991

The Act is intended to provide immediate relief to persons affected by accidents while handling hazardous materials. The owner is made liable to give relief for injury or death of any person or damage to any property resulting from an accident. It is also mandatory for the owner to have insurance cover for such potential liability. An Environmental Relief Fund was established and is maintained by industry operators.

The Government enacted the National Environmental Tribunal Act, 1995 to provide for strict liability for damages arising out of accidents from handling of hazardous substances. The tribunal ensures speedy relief and compensation to the affected.

Conclusions

The complexity of the process technologies being adopted in fertiliser plants makes it difficult, if not impossible, for anybody other than the owner and operator to carry out detailed inspection on the systems, practices and control methodologies so often responsible for the prevention of environmental damages. Therefore, adequate regulations, which could be enforced on facility owners and operators through the authority of the Government and local administration, are necessary to take care of public safety and environmental protection. The requirements of such regulations also need to be updated in unison with the developments in technology of the process employed for production.

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Chapter 7

ENVIRONMENT MANAGEMENT SYSTEMS

An Environmental Management System (EMS) is a method organisations use to establish, implement and keep track of its environmental objectives and policies. This is very much relevant to fertiliser industries in minimizing the adverse environmental impacts and ensures clean production. The concept of Cleaner Production necessitates the continuous application of an integrated preventative environmental strategy to processes, products and service to increase ecoefficiency, reduce risks to humans and the environment so as to achieve a development strategy that is sustainable (Bose S. and De Alak, 2000).

Environment Management Systems, in general, in chemical processing and particularly in fertiliser manufacturing, aim at conservation of raw materials and energy, elimination of toxic materials and reducing the quantity and toxicity of emissions, effluents and wastes, reducing negative impacts all along the life cycle of the product till its ultimate use and final disposal. It also incorporate all known environmental concerns into the design and delivery of services and a strong commitment of which will systematically reduce pollution and improve efficiency in resource use.

The United Nations Conference on Environment and Development, or Earth Summit, Rio de Janeiro, Brazil, 1992, was convened to address global environmental issues and recommend solutions. Two important results of this conference were Agenda 21 and ISO 14000. Agenda 21 is a comprehensive set of guidelines for achieving sustainability in all areas of human intervention in nature. It was adopted by 172 nations at the conference.

ISO 14000 is a group of standards, which addresses environmental management and pollution prevention. Prior to the conference, representatives approached the International Organisation for Standardization (ISO), asking them to participate and create international environmental standards. ISO announced at the conference that they would undertake this effort. Thus, ISO 14001 was conceived to help achieve sustainable development (McIntosh D.L., 1997).

After the Earth Summit, the concept of sustainable development has been widely accepted and manufacturers worldwide have recognized that there should be a convergence between economic development and environmental protection, both now and for future generations. Ecoefficiency emphasizes value creation for business and society at large by maximizing resource productivity, achieving better bottom line benefits and reward to shareholders, rather than simply minimize wastes or pollution. Existing design philosophies for loss prevention, which concern safe and environmentally acceptable chemical plant design is extended to include environmental sustainability also as an important criterion (Lemkowitz *et al.,* 2001).

Ecoefficiency in fertiliser production embraces all cleaner production concepts such as efficient use of raw materials, pollution prevention, source reduction, waste minimization, and internal recycling and reuse. It captures the idea of pollution reduction through process change and recycles as opposed to the earlier end-of-pipe approaches. It is thus an extension of the total quality management process and an evolving concept, which allows companies to adapt to the changing dynamics of the marketplace, remain competitive and at same time protect the environment, employee health and safety. The EMS provides a set of practical tools to implement strategies supporting this concept.

In 1993, the International Organisation for Standardization (ISO) set up a Technical Committee on Environmental Management (TC 207), and a number of sub-committees, to develop standards on a broad range of topics related to environmental management. The International Organisation for Standardization (ISO), a non-governmental organisation established in 1947, comprises a worldwide federation of national standards bodies from each of 100 countries. The organisation aims to facilitate the international exchange of goods and services by establishing international standards and reconciling regulatory differences between countries.

In 1996, the ISO issued the first standard for environmental management systems (EMS) called ISO 14001. This standard provides for elements of an effective environmental management system that can be integrated with the other management systems of an organisation. The standard is based on the following five basic principles (Schiffman R, *et al.*, 2001).

1. Defining an environmental policy that is relevant to the nature, scale , and environmental impacts of its activities, products and services and commitment to it through a formal environmental management system;
2. Devising an objective plan and setting targets to work for the fulfillment of the environmental policy;
3. Developing the human, financial, technical, and other capabilities including emergency preparedness and response plans to deal with even unexpected situations to achieve the policy initiatives;
4. Measuring, monitoring, and evaluating environmental performance through periodic audits and

5. Reviewing and continually improving its environmental management system to better the overall environmental performance of the organisation.

Thus the benefits of implementing an EMS include better environmental performance, reduced operating costs and better financial performance, increased access to markets, regulatory relief, increased safety, better customer and community relations and employee involvement. The goal is to establish a common approach to environmental management systems that is internationally recognized, leading to improved environmental protection.

The 14001 standard can be used as a valuable set of practical, certifiable tools to implement an environmental strategy for any fertiliser manufacturing company. As with any good overall business strategy, the fundamental focus of the environmental strategy needs to be the position of the firm and its products and services *vis-a-vis* its stakeholders such as customers, suppliers, employees, public community etc. Moreover, environmental strategies require some special considerations deviating from the traditional strategic planning processes. Effective environmental strategy implementation requires a proactive stakeholder management interaction, which support sustainable development and provide for reconciliation of differing and sometimes conflicting stakeholder interests.

The International Institute of Sustainable Development stipulates that, for the business enterprise, sustainable development means adopting business strategies and activities that meet the needs of the enterprise and its stakeholders while protecting, sustaining, and enhancing the human and natural resources that will be needed in the future.

An ISO 14000 Environment Management System, thus, provide the tools to monitor and improve organisation's impact on the environment and help assure customers, manufactures' commitment to environmental management; improve cost control; reduce incidents that result in liability; reduce consumption of materials and energy; obtain permits and authorizations; reduce the cost of complying with environmental regulations; maintain good public relations; enhance social image and market share and improve industry-government relations (UNEP,1998).

Stakeholders

Different groups of people are involved in the environmental management of an organisation involved in fertiliser production are agriculturists, employees, shareholders, banks and financial institutions, government and the public. Hence it is necessary to integrate the interests of all stakeholders and management with the corporate strategy and vision and environmental management systems (Camarota A.G., 2000).

Let us analyse as to how this can be achieved.

The parties who have a primary interest in the financial performance of any organisation are shareholders, lenders, and insurers. The three basic principles organisation should focus are growing sales and increasing profitability, reducing costs and improving productivity and keeping asset utilization as high as possible.

Agriculturists

The farmers are important in ensuring the ultimate success of any fertiliser product. Customer perceptions of a product or service are shaped not only by its specific environmental attributes, but also by the reputation of the company as an environmental leader. Market research has shown that the environmental properties of products and services, while important in the minds of consumers, mean much less than price, quality, convenience, style, and ease of use. In managing customers points to be borne in mind include developing products that are environmentally benign while maintaining competitive cost, function, style, ease of use, and performance, minimizing the environmental impacts of product use and disposal and educating the customer about the environmental benefits of the products.

Employees

The primary internal stakeholders for any organisation who are concerned with the degree of internal environmental excellence are the management and the employees. The environmental focus of employees is on the production processes that create value for customers, produce acceptable financial results, and integrate the organisation with the communities, public policy-making bodies, and ecosystems with which it interacts.

Pollution prevention and process reengineering are the two primary methods used to refine production processes and minimize environmental impacts at the point of generation. The organisation and employees need to know how much of the different types of resources it consumes in order to produce a given unit of product. Resources include energy, capital equipment, information, people, money, raw materials, water, and supplies. Conversely, the organisation needs to know how much waste (hazardous, solid, liquid, and gaseous) it emits per unit of production. Only with this complete picture can the organisation establish a meaningful baseline of performance.

The organisation should reduce the specific consumption of resources in making a given unit of product; reduce the amount of wastes generated from making a given unit of product; encourage product and process innovation; and measure and communicate the results of these efforts.

Public

The stakeholders in this area are local, national and sometimes even international communities. They are external to the organisation, and hence pose a special challenge to management. The key question management must answer with regard to these stakeholders is whether the organisation is environmentally responsible member of the communities in which it operates. The fundamental effort with the public is to manage the ongoing relationships in an open and transparent manner. With the community of competing firms, the organisation can look for opportunities to form joint ventures, share technology, or develop integrated partnerships.

The basic principles in managing community and public policy stakeholders are establishing an open communications policy through efficient public relations using a variety of communication methods, such as fruitful interaction with different segments, mediation, arbitration, participatory planning, focus groups, and strategic alliances, establishing a proactive and participatory role in the lives of communities, establishing a process for self-audit and disclosure of environmental aspects and impacts; and ensuring accurate perceptions of environmental risks posed by its activities.

The organisation should use land in a sustainable manner that preserves naturally occurring ecosystems; engender ecosystem integrity, including maintaining biodiversity, preserving habitats, and optimizing flora and fauna health; maintain water quality for drinking, recreational, and wildlife use; and maintain air quality.

In order to align the existing environmental management systems of fertiliser production units with the international standards EMS the following methodology may be adopted.

Establishing a Strategic Position

The current position of the organisation with regard to the environmental interests of stakeholders should be established by performing an initial review. The initial review is essentially a data-gathering exercise that includes identification of applicable legislative and regulatory requirements; financial requirements; environmental aspects and impacts of the organisation's current products, services, and activities; customer perceptions of the environmental characteristics of the organisation's products, activities, and services; current performance with regard to internal criteria, external standards, codes of practice, and sets of principles and guidelines; existing environmental management processes, including procurement and contracting; feedback from investigations of previous incidents of non-compliance; opportunities for technology sharing, joint ventures, and strategic alliances; current community perceptions of the organisation's environmental aspects and activities; and other existing management systems that could either enable or impede environmental performance.

Once this information is gathered and organized, it can be used as inputs to a positional analysis, which will indicate areas of management priority based on stakeholder concerns.

Defining a Vision and a Policy

The key to defining a comprehensive vision of the organisation's environmental commitment is to include the views, perceptions, and requirements of the stakeholders. This can be easily accomplished by using the results of the initial review to determine the guiding principles and values to which the organisation should ascribe. Active communication with stakeholders can help to clarify their interests and perceptions. Top management should then codify their environmental commitment and values in a documented policy. The policy should be relevant to its activities, products, and services, while taking into account the data from stakeholders. Management should then make this documented policy available to all interested stakeholders, thus ensuring an accurate perception of the organisation's commitment to environmental excellence.

A typical Environmental Policy of a Company may be stated as follows:

> "Achieve excellence in the protection of the environment, health and safety of our employees, contractors, users of our products and the communities in which we operate;
>
> Anticipate and incorporate future Health, Safety and Environment requirements into business objectives;
>
> Assure compliance with laws and company policies; and
>
> Make a step –change in employee awareness and ownership of Health, Safety and Environment processes and performance." (UOP, 1999).

Developing a Plan to Implement the Policy

Once the policy commitments have been established, management then draw up plans necessary to fulfill the policy commitments. This analysis is by using the stakeholder information from the initial review. It is based on the environmental aspects of its activities that the organisation can control and over which it has an influence. These aspects and their associated environmental impacts are prioritized according to the stakeholder criteria obtained from the initial review. Management develops a set of objectives, targets, and programs, which serve as milestones against which the performance of the environmental management systems can be measured.

Developing the Capabilities and Support Mechanisms

The focus of this set of activities is on how the objectives, targets, and programs become translated into literal reality. Management defines the accountability for specific actions within the environmental management system, and provides the resources to perform these actions.

The actions required by the EMS include reporting on its performance to top management, as well as ensuring the interests of specific stakeholder groups are adequately addressed. Management also creates an awareness of the environmental commitments it has made to all personnel in the organisation, thus ensuring motivation to achieve stakeholder interests. This awareness is usually coupled with a training program that is related to the prioritized environmental impacts defined in the planning activities. Each person in the organisation is required to know their roles and responsibilities in achieving the environmental policy and satisfying stakeholder interests.

Communication

An important EMS activity is establishing communication procedures with stakeholders, both internal and external. The communication program ensures that stakeholder requirements and perceptions are actively monitored, and that management is given the opportunity to positively influence perceptions.

When communicating with lenders, insurers, local communities, and activist groups, it can be especially important to ensure that they understand clearly the environmental risks posed by the organisation's activities and products. A central component of this risk communication can be the description of what emergency preparedness and response procedures are in place to identify the potential for and respond to accidents and emergencies.

An important discipline in improving resource productivity and reducing waste intensity is the management of operations using documented procedures and defined process controls. These two elements ensure that a documented performance baseline is defined, clearly described, and revised when processes change. They give management a disciplined, engineering-based approach to controlling its operations and knowing exactly what happens when the organisation moves from its defined baseline. Procedures and process controls ensure that internal stakeholders obtain accurate knowledge related to operational performance.

Measuring and Monitoring Performance

Once the environmental management system is in place, it is necessary to continually monitor its progress. This can be done through various means, but in general there will be daily measurement of the measurable impacts and an annual audit of the system in general. This process of monitoring will alert the concerned to conditions that require corrective actions. It will also point out where real improvements have been made. Top management should review all of this information so that they can update and revise the strategic environmental plan. The idea is to promote the continuous improvement of the system and the environmental friendliness of the company.

Fact-based decision-making enables management to avoid the trap of making decisions based on inaccurate perceptions of what is going on, which can often worsen the problems the organisation it is seeking to solve. The data gathered and reported internally can also often be used directly for regulatory compliance and financial reporting, as the basis for customer education, and for developing environmental labeling background information.

Documentation

A key activity supporting performance measurement is the establishment of a records management system. If an environmental incident should occur, this system allows management to recreate the data and perform a root cause analysis, again supporting fact-based decision-making and accurate communications to stakeholders. Summary reports can be generated from verified records, ensuring the integrity of reporting and communication activities. Effective records management processes can greatly assist management when they define stakeholder strategies by providing a documented historical record of communications with the stakeholders as well as other relevant information.

Another measurement tool is the performance of EMS audits. The audit reports give management an accurate picture of how well the EMS is fulfilling its function and managing stakeholder interests, and provide an "early warning" system before significant issues arise that could negatively impact the perceptions of stakeholders.

Reviewing and Improving the Systems

In order to close the EMS loop, management reviews the EMS performance at predefined intervals. These reviews look at the internal strengths and weaknesses of the EMS, as well as the opportunities and threats resulting from the changing perceptions and requirements of its external stakeholders. This review can result in a complete revision of the original set of stakeholder data based on what information the EMS has generated. The fundamental concept underlying this exercise is that it re-establishes the strategic position of the firm, and sets the stage for possible revision of the policy, development of new plans, and movement around the circle of continual improvement. The review is the essence of proactive stakeholder management, as it requires a redefinition of stakeholder requirements and perceptions at regular intervals.

ISO 14001 promises to foster innovative solutions to pollution problems at the facility level. The standard requires that all employees be made aware of their environmental responsibilities and trained to exercise care when performing duties with environmental consequences. By instilling environmental awareness in all employees, firms can harness the technical know-how of employees on the production floor to help find creative strategies to minimize or reduce their environmental impacts. Often, it is these employees, the ones most familiar with a given firm's production processes, who are in the best position to identify creative strategies for improving environmental performance.

Merits and Demerits

ISO 14001 as an important policy tool for encouraging proactive environmental management and fostering cooperation between industry and the regulatory authority. It provides a systematic framework for incorporating environmental protection into overall management strategy. It encourages a holistic approach to improving environmental performance, and establishes a framework for continual improvement. ISO 14001 calls for a high level of involvement of top-level management. Given that ISO 14001 is a system built for business by business, it's crafted in a language that management understands and is therefore more likely to capture and retain upper management's attention. ISO certification could be used as a public relations tool to boost a firm's image in the eyes of consumers. Using life cycle analysis and assessment and other tools for comparing environmental impacts, an organisation can examine the cradle to grave impacts of its products. It can question suppliers about contents of materials and even methods of delivery. This holistic approach can help foster preventative solutions by encouraging an organisation to identify opportunities for doing things in new ways, for finding new products from "waste", and for going beyond the traditional view of environmental problems as being the sole domain of the environmental health and safety manager. Many companies that have instituted a thorough EMS have benefited by becoming aware of inefficiencies that were not apparent beforehand; generating cost savings and reduced environmental liabilities. Another important feature of ISO 14001 is its provisions for continual improvement in a firm's environmental management system. The standard requires firms to create specific time lines for designating responsibilities and implementing strategies to reduce environmental impacts. Also, periodic compliance and EMS audits are required to assess procedural improvements and identify needed system improvements. Such a mechanism for improvement is completely absent in command and control regulations such as BAT (Best Available Technology) standards and emission standards. Standards such as these give firms no incentive to go beyond what is necessary for compliance. It should be noted, however, that the requirement for continual improvement applies to the management system, not environmental performance.

In its present form, ISO 14001 has several potential shortcomings that may reduce its effectiveness in encouraging pollution prevention and limit its ability to spur improvements in environmental performance. To begin with, the standard is a management system standard, not a performance standard. A firm, therefore, is not actually required to improve its environmental performance, and may be able to point to ISO certification as "proof" of its commitment to protecting the environment. The standard do not promote inefficient "end-of-pipe" strategies as pollution prevention. The standards have been developed without sufficient input from the environmental community and public interest organisations, and the standard does not require sufficient public disclosure of a firm's environmental impacts.

ISO 14001 defines "prevention of pollution" as the "use of processes, practices, materials or products that avoid, reduce or control pollution, which may include recycling, treatment, process changes, control mechanisms, efficient use of resources and materials substitution." The definition recognized by the National Pollution Prevention Roundtable and US. Environment Protection Act (under the

Pollution Prevention Act of 1990) is source reduction, or any process that reduces the amount of any hazardous substance, pollutant, or contaminant entering any waste stream or otherwise released into the environment (including fugitive emissions) prior to recycling, treatment or disposal. ISO 14000 is a management standard, and does not mandate any specific requirements for improved environmental performance. Instead, the requirement is more obliquely stated, requiring firms to identify their environmental impacts; prioritise those impacts; set targets and objectives for reducing those impacts; select activities to achieve the identified targets and then to use a continuous improvement cycle to evaluate and re-approach the system. ISO certification in no way absolves an organisation from compliance with existing environmental regulations. However, since regulators are looking at the possibility of granting regulatory flexibility to ISO certified firms, this issue is critical.

Increasingly, business leaders around the world are recognizing the importance of developing an environmental strategy that supports sustainable development and integrates stakeholder issues, concerns, and requirements. The ISO 14001 standard for environmental management systems offers a set of practical and certifiable tools to implement stakeholder management processes, and to ensure stakeholder satisfaction. As business moves into the information age, this set of tools will emerge as the dominant management technology supporting a sustainable global economy. The best way to look at an environmental policy is to think in terms of conservation of resources. In other words, if we reduce waste as little as possible, it automatically results in lesser environmental impacts and better profits.

ENVIRONMENTAL IMPACT ASSESSMENT OF FERTILISER PLANTS

Environmental Protection and Sustainable Development have been the cornerstones of the policies and procedures governing the industrial and other developmental activities in India. This is very much relevant to the fertiliser sector as it involve massive consumption of a wide variety of raw materials, energy, handling of large quantities of toxic and hazardous cargo, involve thermodynamic operations at high temperature, pressure, all having a great potential for environmental impacts and risk and also require huge investments.

Ministry of Environment and Forests (MoEF) has taken several policy initiatives and enacted environmental and pollution control legislations to prevent indiscriminate exploitation of natural resources and to promote integration of environmental concerns in developmental projects. One such initiative is the Notification on Environmental Impact Assessment (EIA) of developmental projects issued under the provisions of Environment (Protection) Act, 1986 making EIA mandatory for 30 categories of developmental projects including fertiliser plants (MoEF, 2000).

EIA is a valuable, inter-disciplinary and objective planning tool that is now generally accepted as an integral component of sound decision making with respect to alternate routes for development, process technologies and project sites. The objective of EIA is to foresee and address potential environmental problems and concerns at an early stage of project planning and design. EIA is expected to assist planners and policy makers in the decision making process by identifying the key impacts and formulating mitigation measures. The role of Environmental Impact Assessment

(EIA) is to contribute to the planning of a new operation or major alterations of an existing one. The systematic consideration of environmental impacts, which is the main feature of EIA, often leads to the identification of alternative engineering or siting options and or mitigating measures. As a result, EIA can have a major positive influence on the project design.

EIA is a legal requirement for a company before it can receive planning permission or a permit to operate a major installation. A major benefit of a formal EIA is that it provides environmental baseline information and prediction of impacts against which future operations can be periodically audited.

The final planning permit or site license for the plant will usually reflect the results of an EIA. Such a license will specify a number of conditions concerning site preparation, layout, and equipment. Day to day management requirements are more likely to be specified in an operating permit. Carrying out an EIA requires some environmental expertise and insight in addition to technical knowledge concerning the project itself. For major projects a multi-disciplinary team is usually assembled to research further information, evaluate impacts, and propose practical alternative options. Local public authorities are often good sources of information and should be involved in the EIA.

The objectives of EIA are to assess the level of environmental protection achieved so far, identify shortfalls in statutory requirements, identify emergency situations that may arise and check implementation of mitigatory actions. It will review the progress of implementation of environment related policies and decisions recognize good practices and forcing changes wherever necessary to improve performance. EIA aim at demonstrating management's commitment to environmental protection and motivating all for improvement. It provide information on achievements in environmental protection to public authorities and neighboring communities and use them as input into the company's education and training activities.

The steps involved in conducting EIA of a fertiliser project are screening, scoping and consideration of alternatives, base line data collection, impact prediction, public hearing, environmental management plan, decision making and monitoring the clearance conditions

As all fertiliser projects require environmental clearance as per statutory notifications, screening has little relevance. Scoping is to specify the terms of reference to the EIA study. It identifies major environmental issues to be addressed, range of alternatives to the project to be examined and set the geographical boundaries of the study. The next step is to establish a baseline data, which is an environmental profile of the site proposed for the project. Then project activities including the raw materials, products, process employed, discharges, wastes and emissions are described.

The likely environmental impacts of project activities on climate and air quality, water, including groundwater, geology and soils, ecologically sensitive areas and habitats, land-use and surrounding activities, noise, vibration and radiation, visual quality are noted down.

The impacts on socio-economic factors such as population and demographic impacts, land-use and settlement, cultural and historical features, local economic structure, transport aspects are also studied. The environmental services proposed in the project such as wastewater treatment facilities, safe landfill, competent disposal teams etc., are also reviewed. Data used for environmental assessments should be concise, limited to significant environmental issues, and aimed at informing project designers and decision-makers.

A public hearing is to be held involving local residents, local associations, active environment groups in the area and the community that is likely to be affected by the project in which all the reasonable queries from the people will be explained with all facts and figures.

A well-defined and workable Environmental Management Plan (EMP) is to be developed addressing all the likely scenarios and containing mitigartory measures.

Based on the EIA and EMP and involving the project proponent and impact assessing authority a decision is taken on the project proposal.

Upon completion of fertiliser projects and commissioning the same all these installations are subjected to a periodical environmental impact review to see that the commitments made are complied with and to see whether the prediction made in the EIA report were correct or not. The frequency of the evaluation is established either by law or by internal company regulations.

The EIA process may be taken up in-house by the safety or environmental department of the company, by a task force composed of the operational staff, safety staff, and maintenance staff under the responsibility of a technical manager or may be contracted to a specialized auditing company.

In all cases the group should be given access to all technical documentation, environmental reports, and regular water and air analysis results, reports of technical deviations, accident reports, and all legislative background related to factory operations. Group members during the period of EIA preparation should be freed from their everyday functions and responsibilities.

The EIA report shall contain the following sections:

1) A brief description of the proposed development containing:

    Details of the plant and processes
    Key siting criteria
    Alternate sites and project designs
    Infrastructure requirements
    Employment generation
    Environmental changes—effluents, emissions and disposals and
    Emergency service requirements

2) A brief description of the local area

3) Review of the legislation and internal company rules.

4) Potential impacts and benefits

5) Irreversible and irretrievable commitment of resources

6) Mitigating actions

7) Projections of the likely situation without the development

8) Recommendations for monitoring.

EIA as conceived in the country is only as a project level planning tool and does not address to developmental programmes at the policy and planning level. Major issues resulting in deficiencies in EIA are lack of land use planning, information on socio-economic aspects of the projects, alternate technologies, public participation, integrated approach to environmental management and rural development, sufficient and reliable environment data, historical information on environmental components and monitoring facilities. Certain policy initiatives sometimes fall outside the environmental review and overshadow the importance of EIA. It should have been ideally undertaken at the policy and planning levels as the environmental consequences of projects arise due to high-level decisions. EIA shall also incorporate elements of strategies for preventive environmental intervention such as resource conservation, by-product recovery, optimized plant operation etc., as its explicit goals.

ENVIRONMENTAL AUDIT OF FERTILISER PLANTS

An Environmental Audit (EA) is a systematic, documented, periodic and objective evaluation of how well the environmental organisation, management and systems are performing. It is a formalized procedure to provide the management the vital knowledge of its compliance to environmental laws and procedures towards environmental protection and their social acceptability. Audits are one of the key elements of an environmental management system in fertiliser plants and they can be considered as management tools to collect and analyze information on operating plants, which could be compared over several years and measure environmental performance (Krishnan K.S., 1995).

The environmental audit (EA), like any other audit, is not an attempt to find fault with or lay blame for failures but is an examination of the system to determine why failures occur, and then encourage participation to improve the system. Most companies keep the results confidential and for internal use. Audit procedures have been developed by several companies, consultants and national authorities to meet varying requirements and specific needs. At the international level, the ISO 14000 series provides guidelines on environmental auditing. ISO 14010 provides the general principles of environmental auditing, applicable to all types of environmental audit. ISO 14011 establishes audit procedures. ISO 14012 provides guidance on qualification criteria for environmental audits. It is applicable to both internal and external auditors. Audits are helpful in facilitating management control of environmental practices, assessing compliance with company policies, including meeting regulatory requirements.

Benefits of an Audit

The benefits of environmental audits are many. It include, enhanced employees awareness of environmental policies and responsibilities of the organisation, identification of avenues for potential cost savings and waste reduction, evaluation of environmental training programmes, effective emergency preparedness, achievements for good environmental performance, good compliance to statutory obligations and better insurance coverage for environmental impairment liability.

One of the important aspects of an audit is to monitor regulatory compliance. Compliance audits include a comparison of the current operation with applicable laws and regulations (standards) that is sometimes required for amendment of permits and licensing etc. In addition to regulatory compliance and management system auditing, specific technical audits of energy consumption, waste and pollution sources, and site contamination are possible. Each technique has its own application and method, which is described in appropriate operations manuals and procedures.

Audit Procedures

Audits may be carried out in-house by a company audit team, or by external auditors familiar with environmental issues of fertiliser plants. External auditors are practically unable to effectively recommend solutions to operating problems since they do not have sufficient exposure to the plant as well as employees. On the other hand, they are often able to bring a fresh approach and additional technical experience to the problem. A large number of companies already carry out internal audits, and the requisite training is provided by several agencies specialised in this work.

Preparing the Audit

The audit is conducted by a competent team under the responsibility of an environmental manager who assigns the tasks to be performed by each audit team member. The managers establish an audit plan for every plant to be checked and which concentrates on the environmental risk areas in the plant. The plan shall contain, environmental risk areas and high priority items, audit scope, objectives and criteria, details of units and individuals to be visited and interviewed, important reference documents, time, duration, places of the audit and meetings, language and confidentiality requirements, reporting issues and document retention requirements.

Executing the Audit

A formal opening meeting between the audit team and the plant managers offers an occasion to discuss the audit plan and the audit procedures. The plant managers shall provide essential information on improving working conditions and preventing accidents (Cascio, 1996). Then the audit team collects and compiles data from the company internal documents. The information obtained should be completed and verified by a site visit and inspection. The audit findings are then submitted again to the plant managers to obtain acknowledgment about the factual basis.

Audit Reporting

The report may include the following details such as the audit team, audit period, the scope, objectives, criteria, reference documents, the audit plan, summary of audit process, the period covered, confidentiality, distribution list and the audit findings. According to the conclusions, existing plans and targets may be revised and adapted. It is up to the management to decide on the follow-up of the audit. The frequency of the audit will depend on the size and complexity of the operations. For example for a high-risk operation, one where the management system is new, it would be appropriate to audit the system annually. For a low risk operation, a full audit may be undertaken every three years.

Systems approach to environmental protection, in addressing day-to-day operation of facilities, assessing impact on the environment right at the planning stage and systematically and regularly auditing the associated environmental aspects, are important in the fertiliser industry. The net effect of such an effort is that manufacturers are under increasing pressure to develop and implement environmentally sensitive fertiliser production technologies and more efficient pollution abatement processes and installations. Environment management systems, therefore, enhance the human potential to maximize the effective utilization of resources while minimizing environmental impacts of operations and thus contribute to sustainability in fertiliser production.

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Chapter 8

ENVIRONMENTAL MANAGEMENT IN INDIAN FERTILISER PLANTS

The study covered a representative group of six major fertiliser producers in the country. The methods of pollution control and environmental management adopted in respect of each of the causative factors for pollution are thoroughly reviewed. An assessment was also done as to how far existing technologies are effective in mitigating pollution from plants to the required level of standard being practiced in India as well as abroad. Areas where strengthening is required, both in the technology at the plant level and management perspective at the corporate level, are highlighted.

All the units studied have specific environmental policies and are maintaining the characteristics of the emissions to atmosphere and effluents discharged to the local streams within the limits of the stipulations of the regulatory authorities. This is achieved by treating pollutants in effluent streams in suitably designed pollution control plants following the end-of-pipe treatment approach. New plants such as those belonging to Tata Chemicals and Indo Gulf Fertiliser Corporation, have modern process technologies where considerable integration have taken place at the inception stage itself to see that pollution prevention is a part of the process design itself. In the case of units that came to existence long back, pollution control facilities were built and attached later as and when legislation in this area became effective. In fact, the study revealed that the pollution and environment control departments of these units exhibit meticulous care to see that the above objective is achieved. Thus now-a-days states of art control facilities exist in these units and they are operated effectively. The stipulations of the Pollution Control Boards are with in the achievable limits of the available technology at hand. Sometimes excursions occur in the analysis of certain parameters on account of start up, shut down of plants or may be due to accidental situations. Existing facilities are ensured capable of handling such situations also.

Table 8.1.1 and 8.1.2 provides a comparison of pollution control and environment management techniques being adopted by the various units studied vis-a-vis the best available technology in the field. It indicates the methods of pollution control adopted in the various plants in respect of each of the pollutants. In comparison with the currently available best practices for efficient pollution control in the industry, projections for further improvement of existing control measures in these plants are identified.

Table 8.2 show the average effluent and emission characteristics of the discharged streams from the units studied. In the fertiliser industry key parameters being monitored universally are pH, ammoniacal nitrogen, nitrates, fluorides, phosphates, total suspended and dissolved solids and chemical and biological oxygen demand, toxic metals such as hexavalent chromium, vanadium etc., in the effluent streams, particulate matter, nitrogen oxides, sulphur oxides and carbon monoxide in exhaust streams, and temperature at which the effluents are discharged.

Fig.8.1 which is a graphical presentation of the key effluent characteristics from the plants vis-à-vis the mandatory standards, show that all the units have been successful in maintaining the respective effluent parameters below the prescribed standards with regard to discharge of effluents.

Table 8.1.1

Status of Environment Management in Selected Fertiliser Plants

Unit	Best Availble Practice for Control	FACT, Cochin	Tata, Babrala	MFL, Chennai
(1)	(2)	(3)	(4)	(5)
Capacity MT/annum				
a) Nitrogenous		330000	742500	242000
b) Phosphatic		485000		840000
Year of operation		1972	1994	1971
Feedstock		Naphtha	Natural Gas	Naphtha
Technology		Steam Reforming	Steam Reforming	Steam Reforming
Environmental Policy statement		Yes	Yes	Yes
EMS ISO 14000		Yes	Yes	Yes
Green Belt Development		Yes	Yes	Yes
Ambient Air Quality Monitoring		Yes	Yes	Yes
ENVIRONMENTAL CONTROL PARAMETERS				
Liquid Effluents				
1. Ammonia process condensate	Saturating steam feed to reformer	Stripped and water recovered	Recycled to DM plant	Stripped NH_3 and water recovered
2. Turbine condensate	Recycle and use as boiler feed water	Recycled along with boiler feed water	Recycled along with boiler feed water	Recycled along with boiler feed water
3. Urea process condensate	NH_3 and CO_2 recovered and water recycled	NH_3 and CO_2 recovered and water recycled	Recycled to DM plant	NH_3 and CO_2 recovered and water recycled
4. Water Treatment Plant Effluents	Neutralised and sent to guard ponds	Neutralised and sent to guard ponds	Neutralised and sent to guard ponds	Neutralised and sent to ETP
5. Cooling Tower Effluents	Treat in ETP, dispose to guard ponds	Disposed to guard ponds	Disposed to guard ponds	Treated in ETP
6. Oily water	Water separated and oil disposed off	Water separated and oil disposed off	Oil separated and water disposed	Water separated and oil disposed off

(1)	(2)	(3)	(4)	(5)
7. Boiler blow down	**Neutralised and sent to treated effluent pond**	Sent to guard ponds	**Neutralised and sent to treated effluent pond**	**Treated in ETP**
8. Gypsum pond effluents	Discharged as per PCB stipulations	Discharged as per PCB stipulations		Discharged as per PCB stipulations
9. Sulphuric acid plant effluents	Neutralised and sent to ETP	Neutralised and sent to ETP		Neutralised and sent to ETP
10. Phosphoric acid plant effluents	Disposed after removal of F, PO_4, NH_3 and suspended solids	Disposed after removal of F, PO_4, NH_3 and suspended solids		Disposed after removal of F, PO_4, NH_3 and suspended solids
11. Sewerage	Treated at the STP and disposed	Biological treatment	Treated at the STP and disposed	Biological treatment
Emissions				
1. Petroleum storage emissions	**Floating roof tanks, reduce** inventory	**Floating roof tanks to reduce** emissions	**No storages**	Floating roof tanks to reduce **emissions**
2. Boiler stack emissions	Better combustion control and stack monitoring	Better combustion control and stack monitoring	Gaseous fuel has little emissions	Better combustion control and stack monitoring
3. Prilling tower dust	Minimum dust design,recover dust and recycle	Dust recovered by scrubbing and urea recycled	Minimum dust design	Dust recovered by scrubbing and urea recycled
4. SO_2 emissions	High efficiency mist eliminators, increased stack height and start up scrubber	High efficiency mist eliminators, increased stack height and start up scrubber	NA	High efficiency mist eliminators, increased stack height and start up scrubber
5. Sulphuric acid mist	High efficiency mist eliminators	High efficiency mist eliminators	NA	High efficiency mist eliminators
6. Dust from bagging operations	Monitor and control		Monitoring and control	
7. Flourine emissions	Cyclone scrubbers and treatment of flourides in ETP	Cyclone scrubbers and treatment of flourides in ETP	NA	Cyclone scrubbers and treatment in ETP
8. Dust from rock grinding	Cyclones, multiple scrubbers and recycle	Cyclones, multiple scrubbers and recycle	NA	Cyclones, multiple scrubbers and recycle
9. SO_3 emissions	Mist eliminators	Mist eliminators	NA	Mist eliminators

(1)	(2)	(3)	(4)	(5)
10. Catalyst dusts	Use dust protection equipment			
11. Vent gases	Burnt off in flare stack	Vented at elevated point	Burnt off in flare stack	Burnt off in flare stack
12. Ammonia emissions	Recovered by scrubbing	Recovered by scrubbing	Recovered by scrubbing	Recovered by scrubbing
13. CO leaks	Immediate leak sealing	Immediate leak sealing	Immediate leak sealing	Immediate leak sealing
14. Noise level	Maintain within limits			
Solid Wastes				
1. Sludge from plants	Store in hazardous waste pits	Stored as hazardous waste	Stored as hazardous waste	Stored as hazardous waste
2. Gypsum	Sell or dispose as per regulations	Partly sold to cement/gypsum board manufacturers and balance disposed as per regulations	NA	Partly sold to cement/ gypsum board manufacturers and balance disposed as per regulations
3. Spent catalysts	Dispose for metal recovery	Sold	Sold	Sold
4. Insulation debris	Land filling	Used as land filling	Used as land filling	Used as land filling
5. Construction debris	Land filling	Used as land filling	Used as land filling	Used as land filling
6. Oily sludge	Recover oil and use in furnace		Oil recovered and used	
7. Redundant equipment	Dispose	Sold and disposed	Sold and disposed	Sold and disposed
8. Hazardous solid waste	Safe storage	Safe storage	Safe storage	Safe storage
9. Precipitated flourides	Safe storage without leaching and ground water contamination	Safe storage without leaching and ground water contamination	NA	Safe storage without leaching and ground water contamination
10. Precipitated phosphates	Recycle to plant	Recycled to plant	NA	Recycled to plant

Note: The table provides a comparison of the pollution control and envrionmental management strategies being adopted by the different units vis-à-vis the best available practice for effective control of pollution in respect of each of the pollutants.

Table 8.1.2

Status of Environment Management in Selected Fertiliser Plants

Unit	Best Availble Practice for Control	RCF, Trombay	Indo Gulf, Jagadishpur	KRIBHCO, Hazira
(1)	(2)	(3)	(4)	(5)
Capacity MT/annum				
a) Nitrogenous		430000	726000	1452000
b) Phosphatic		660000		
Year of operation		1978	1988	1986
Feedstock		Natural Gas	Natural Gas	Natural Gas
Technology		Steam Reforming	Steam Reforming	Steam Reforming
Environmental Policy statement		Yes	Yes	Yes
EMS ISO 14000		Yes	Yes	Yes
Green Belt Development		Yes	Yes	Yes
Ambient Air Quality Monitoring		Yes	Yes	Yes
ENVIRONMENTAL CONTROL PARAMETERS				
Liquid Effluents				
1. Ammonia process condensate	Saturating steam feed to reformer	Stripped and water recovered	Stripped and water recycled	Stripped and water recycled
2. Turbine condensate	Recycle and use as boiler feed water	Recycled along with boiler feed water	Recycled along with boiler feed water	Recycled along with boiler feed water
3. Urea process condensate	NH_3 and CO_2 recovered and water recycled	NH_3 and CO_2 recovered and water recycled	NH_3 and CO_2 recovered and water recycled	NH_3 and CO_2 recovered and water recycled
4. Water Treatment Plant Effluents	Neutralised and sent to guard ponds	Neutralised and sent to guard ETP	Neutralised and sent to effluent conditioning sump	Neutralised and sent to effluent conditioning sump
5. Cooling Tower Effluents	Treat in ETP, dispose to guard ponds	Treated in ETP	Sent to guard ponds through conditioning sump	Sent to guard ponds through conditioning sump
6. Oily water	Water separated and oil disposed off		Oil separated and water sent to effluent conditioning sump	Oil separated and water sent to effluent conditioning sump

(1)	(2)	(3)	(4)	(5)
7. Boiler blow down	Neutralised and sent to treated effluent pond	Treated in ETP	Used as cooling tower make up	Used as cooling tower make up
8. Gypsum pond effluents	Discharged as per PCB stipulations	Discharged as per PCB stipulations, used in horticulture	NA	NA
9. Sulphuric acid plant effluents	Neutralised and sent to ETP	Neutralised and sent to ETP	NA	NA
10. Phosphoric acid plant effluents	Disposed after removal of F, PO_4, NH_3 and suspended solids	Disposed after removal of Fluorides, PO_4, NH_3 and suspended solids	NA	NA
11. Sewerage	Treated at the STP and disposed	Disposed after biological treatment in STP	Disposed after biological treatment in STP	Disposed after biological treatment in STP
Emissions				
1. Petroleum storage emissions	Floating roof tanks,reduce inventory	No storages	No storages	No storages
2. Boiler stack emissions	Better combustion control and stack monitoring	Gaseous fuel has little emissions	Gaseous fuel has little emissions	Gaseous fuel has little emissions
3. Prilling tower dust	Minimum dust design,recover dust and recycle	Dust recovered by scrubbing and urea recycled	Minimum dust design	Minimum dust design
4. SO_2 emissions	High efficiency mist eliminators, increased stack height and start up scrubber	High efficiency mist eliminators, increased stack height and start up scrubber	NA	NA
5. Sulphuric acid mist	High efficiency mist eliminators	High efficiency mist eliminators	NA	NA
6. Dust from bagging operations	Monitor and control		Wet dedusting system installed	Dust recovered by water scrubbing
7. Flourine emissions	Cyclone scrubbers and treatment of flourides in ETP	Water scrubbing and treatment in ETP	NA	NA
8. Dust from rock grinding	Cyclones,multiple scrubbers and recycle	Cyclones,multiple scrubbers and recycle, Mist eliminators	NA	NA

(1)	(2)	(3)	(4)	(5)
9. SO_3 emissions	Mist eliminators	Mist eliminators	NA	NA
10. Catalyst dusts	Use dust protection equipment			
11. Vent gases	Burnt off in flare stack	Burnt off in flare stack	Burnt off in flare stack	Burnt off in flare stack
12. Ammonia emissions	Recovered by scrubbing	Recovered by scrubbing	Recovered by scrubbing	Recovered by scrubbing
13. CO leaks	Immediate leak sealing	Immediate leak sealing	Immediate leak sealing	Immediate leak sealing
14. Noise level	Maintain within limits			
Solid Wastes				
1. Sludge from plants	Store in hazardous waste pits	ETP sludge is used as poultry feed and in blending fertilisers other slud disposed as hazardous waste	NA	NA
2. Gypsum	Sell or dispose as per regulations	Partly sold to cement/gypsum board manufacturers and balance disposed as per regulations	NA	NA
3. Spent catalysts	Dispose for metal recovery	Sold	Sold	Sold
4. Insulation debris	Land filling	Used as land filling	Used as land filling	Used as land filling
5. Construction debris	Land filling	Used as land filling	Used as land filling	Used as land filling
6. Oily sludge	Recover oil and use in furnace	Used for anticaking/ coating	Oil recovered and used	Oil recovered and used
7. Redundant equipment	Dispose	Sold and disposed	Sold and disposed	Sold and disposed
8. Hazardous solid waste	Safe storage	Safe storage	Safe storage	Safe storage
9. Precipitated flourides	Safe storage without leaching and ground water contamination	Safe storage without leaching and ground water contamination	NA	NA
10. Precipitated phosphates	Recycle to plant	Recycled to plant	NA	NA

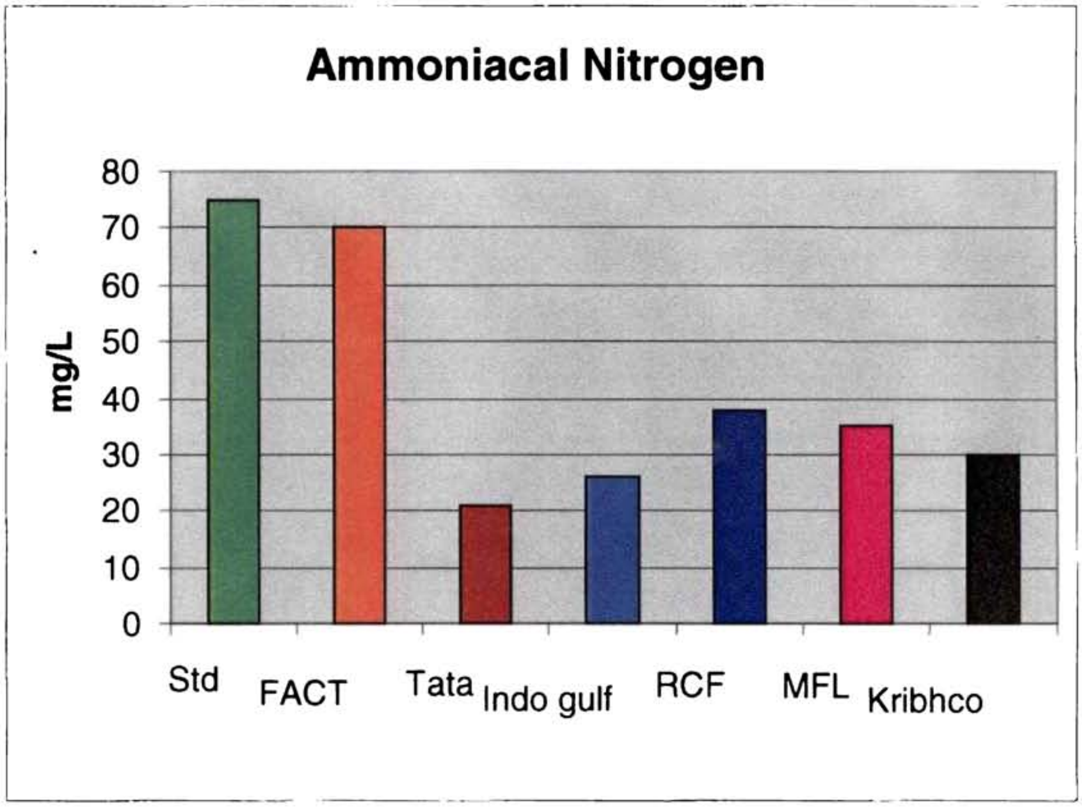
Note: The table provides a comparison of the pollution control and envrionmental management strategies being adopted by the different units vis-à-vis the best available practices for effective control of pollution in respect of each of the pollutants.

Table 8.2

Effluent and Emission Characteristics (Average Values)

Parameters	Unit	Tolerance limit	FACT	TATA	Indo Gulf	RCF	MFL	KRIBHCO
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Total Suspended solids	mg/l max	100	25	17	33	35	38	26
Total Dissolved Solids	mg/l max	2100	1000	1748	649	964	800	469
Temperature	°C	40	35	36	35	38	35	35
pH		6.5-8.0	6.6—8.0	7.7-8.1	7.16	6.5-8.5	6.9-7.5	7.8
Biological Oxygen Demand	mg/l max	30	14	14.5	5.2	25	22	5
Chemical Oxygen Demand	mg/l max	250	75	55	11	62	85	9
Dissolved Oxygen	mg/l min							
Oil & Grease	mg/l max	10	2.6	2	ND	2	2	2
Ammoniacal Nitrogen as N	mg/l max	75	70	21	26	38	35	30
Free Ammonia	mg/l max	4	0.67	0.8	0.15	0.8	0.5	0.16
Total Kjadahl Nitrogen as N	mg/l max	150	136	54	29	30	45	29
Nitrate as N	mg/l max	20	1.8	1.25	0.61	2	3	0.56
Sulphate as SO_4	mg/l max	1000		460			540	
Phosphate as P	mg/l max	5	3.2	1.3	0.75	1	1.2	0.6
Sulphide as S	mg/l max							
Fluoride as F	mg/l max	10	2.9		1.5	1.8	1.1	1.2

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Chloride as Cl	mg/l max							
Cyanide as CN	mg/l max	0.2						
Lead as Pb	mg/l max							
Selenium as Se	mg/l max							
Zinc as Zn	mg/l max	5		0.3	0.4	0.5	1.2	0.35
Copper as Cu	mg/l max							
Nickel as Ni	mg/l max							
Cadmium as Cd	mg/l max							
Hexavalent Chromium as Cr	mg/l max	0.1	ND	ND	ND	ND	ND	ND
Total Chromium as Cr	mg/l max	2						
Mercury as Hg	mg/l max							
Arsenic as As	mg/l max	0.2						
Sodium as Na	% max							
Iron as Fe	mg/l max	3	1	0.23	0.8	1	0.5	1
Free Carbon di oxide CO_2	mg/l max							
Phenol as C_6H_5 OH	mg/l max							
Residuel Chlorine as Cl	mg/l max							
Barium as Ba	mg/l max							
Vanadium as V	mg/l max	0.2	ND	ND	ND	ND	ND	ND
Urea dust	mg/NM^3	50	50	25	25	35	40	25
Particular matter	mg/NM^3	150	140	100	110	120	120	92
Flouride	mg/NM^3	25	15			20	24	
Acid mist	mg/NM^3	50	20			20	25	



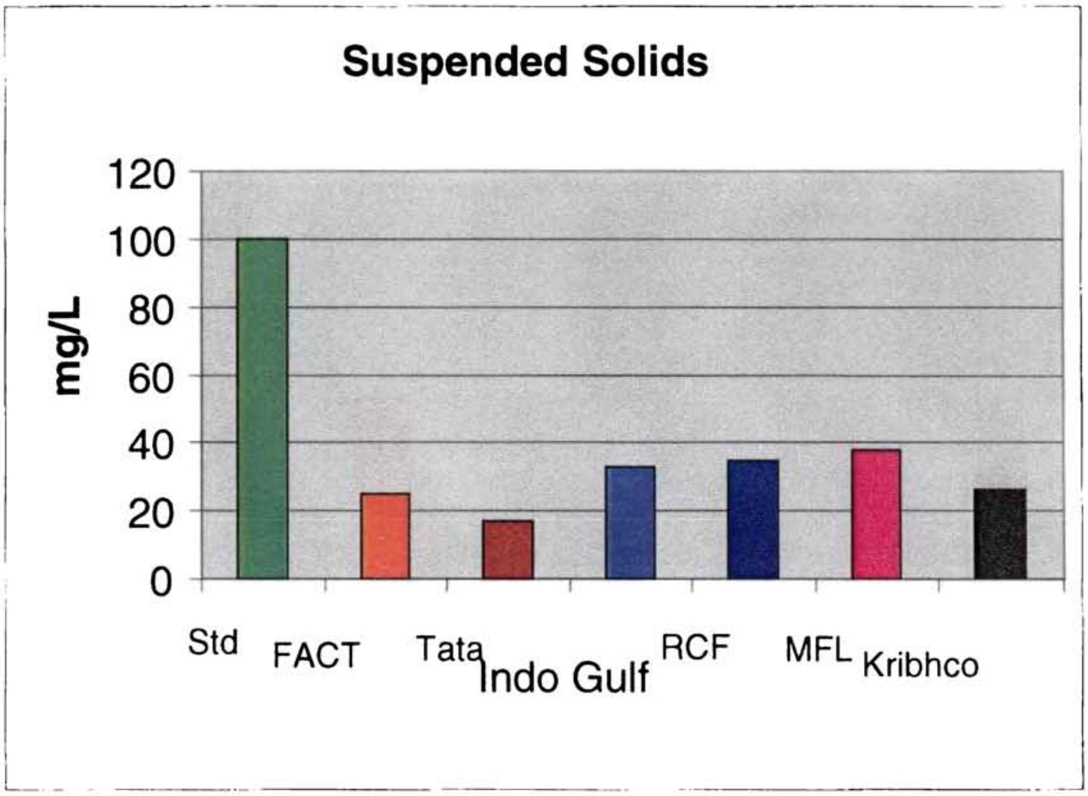


Fig.8.1: Key Effluent Characteristics

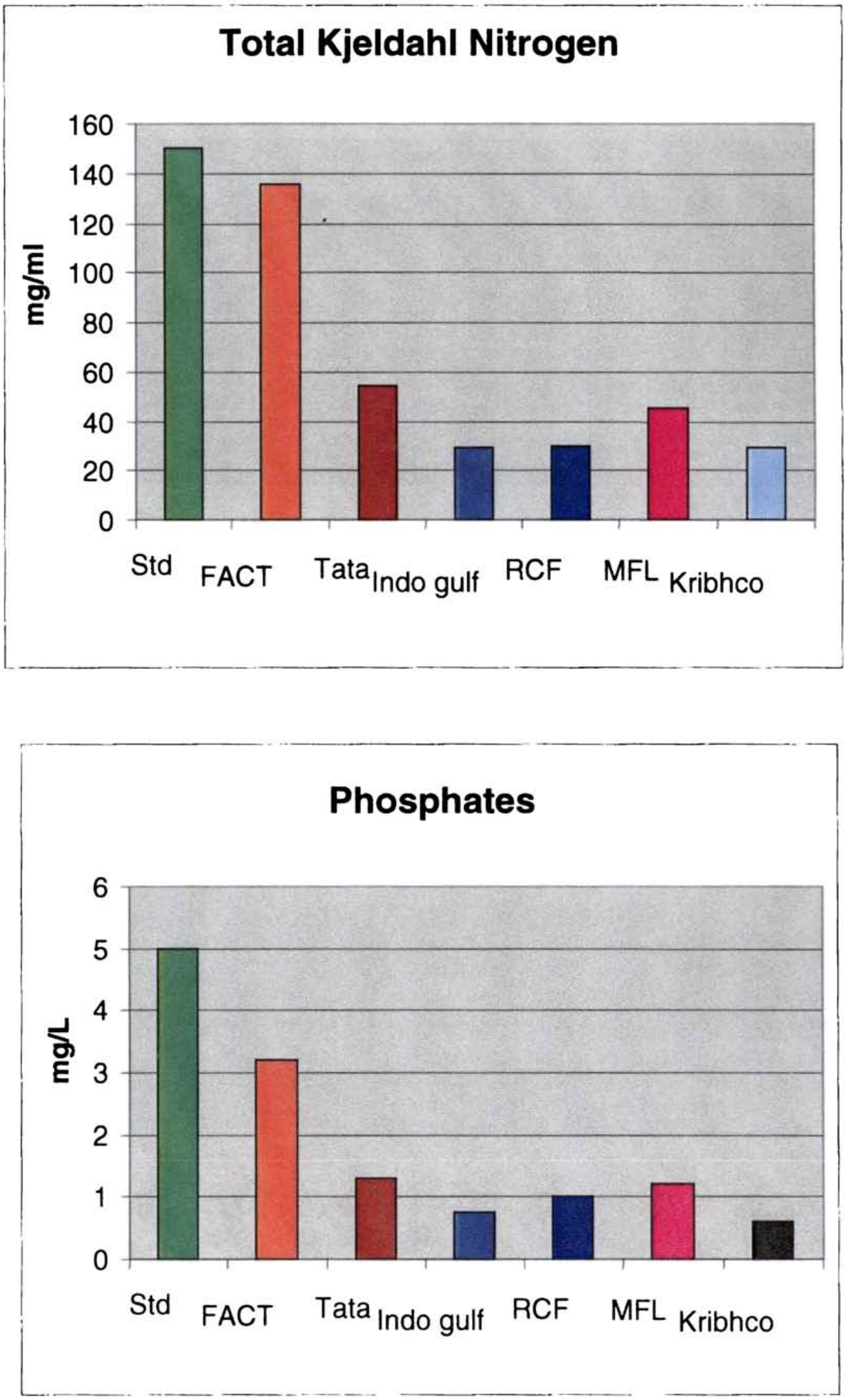
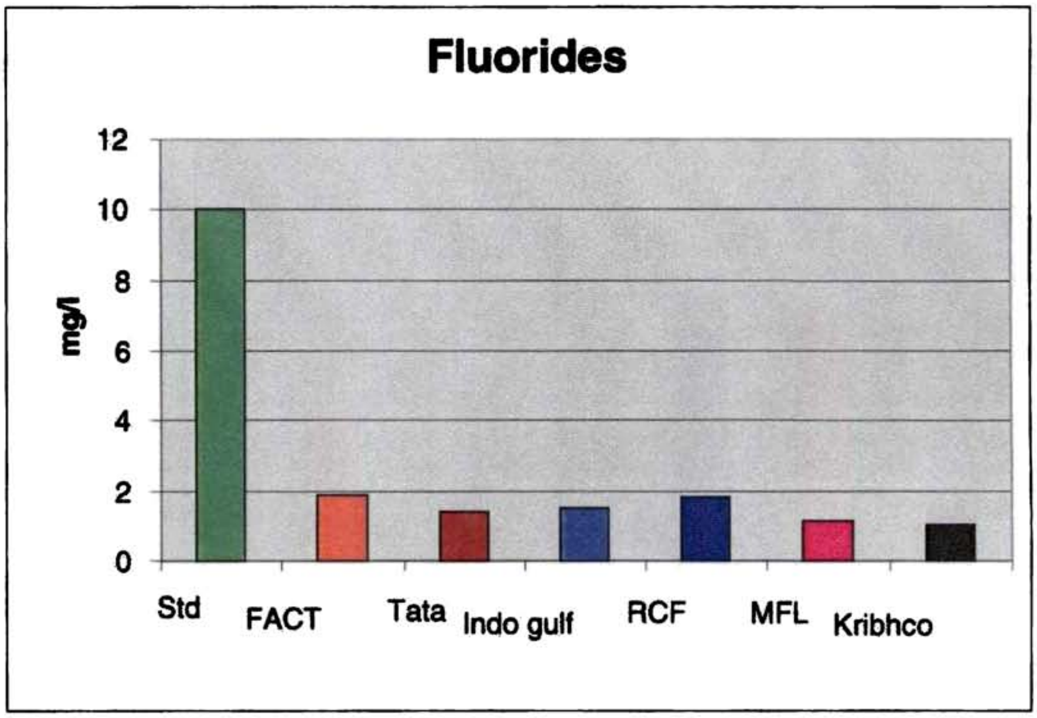


Fig.8.1: Key Effluent Characteristics



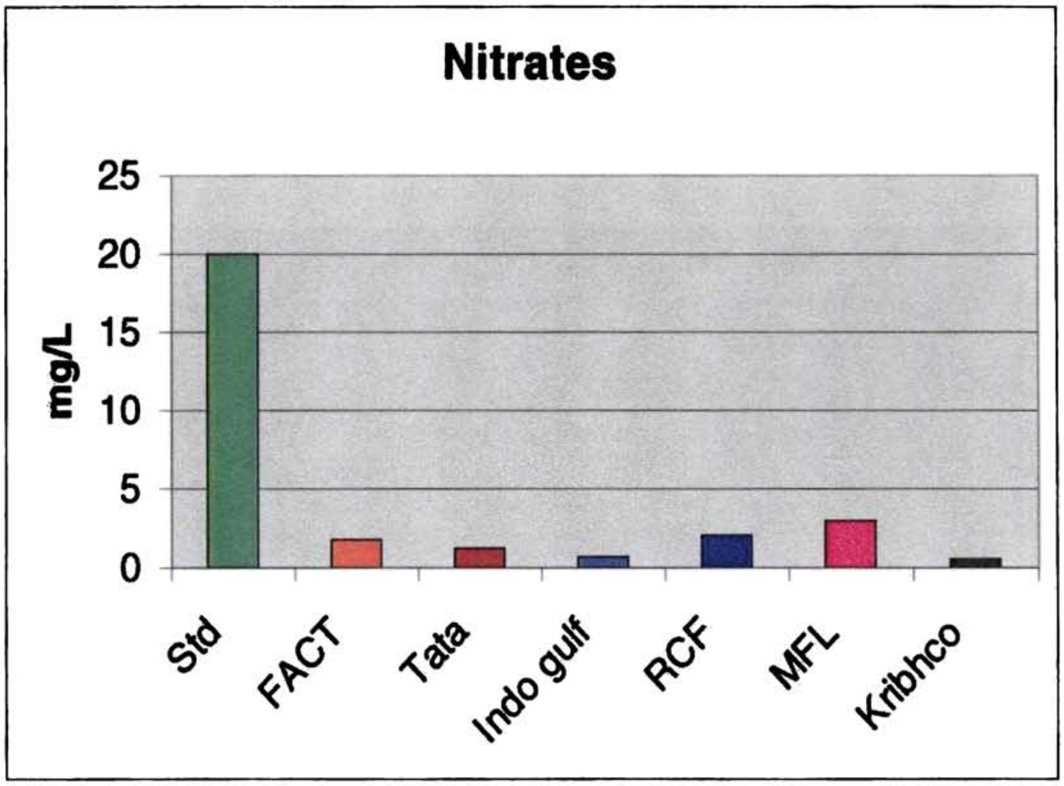
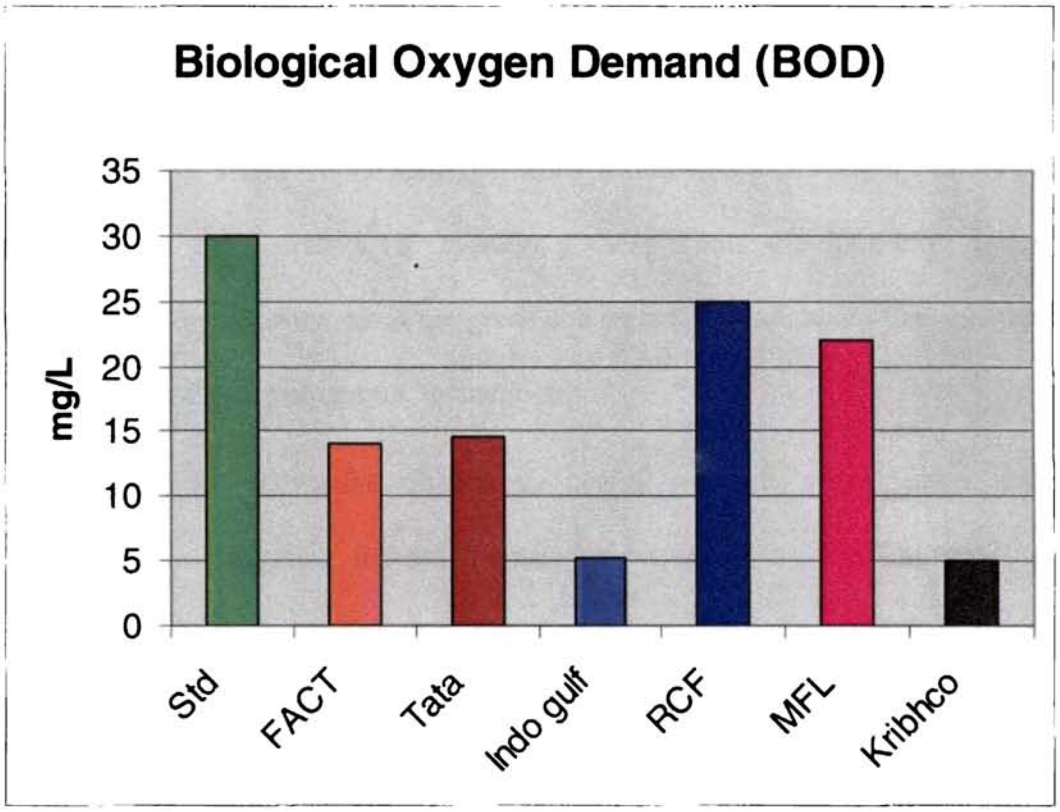


Fig.8.1: Key Effluent Characteristics



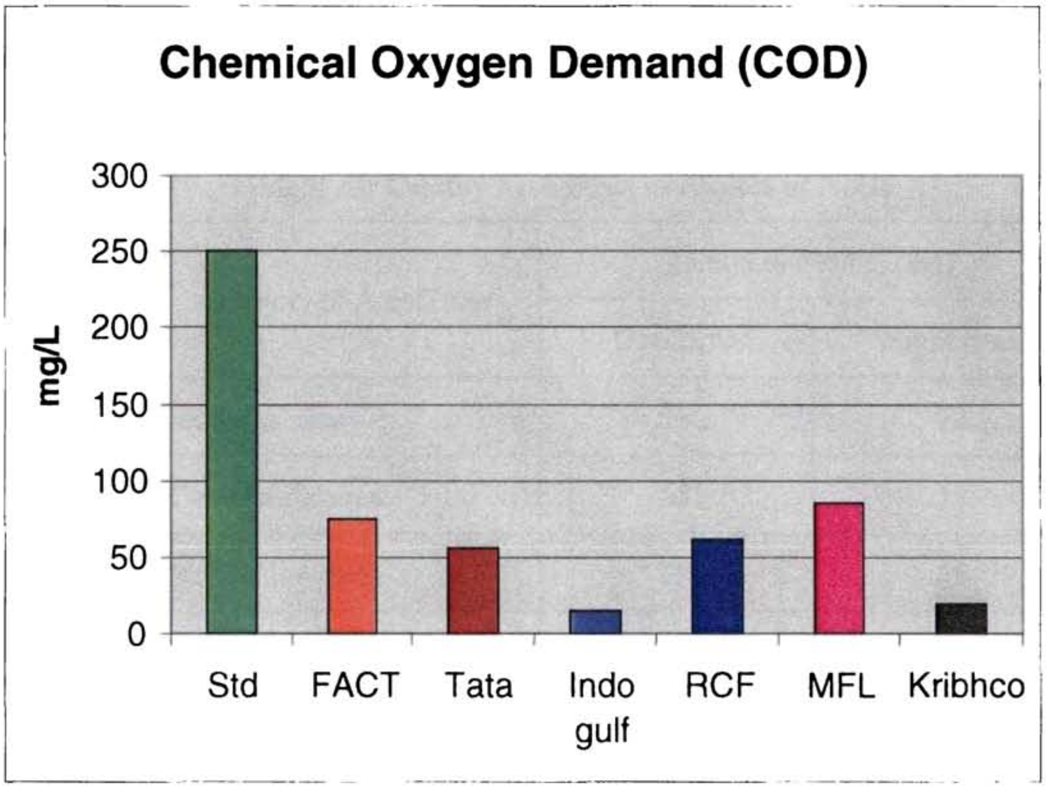


Fig.8.1: Key Effluent Characteristics

Table 8.3 indicates the Minimum National Standards (MINAS) for discharge of fertiliser plant effluents and emissions stipulated by the Central Pollution Control Board (CPCB). These are the statutory limits within which existing operators control pollutants in their streams. In specifying these limits the long-term impact of pollutants in the environment is not given due regard, instead most often it is the level achievable by the use of current technologies.

Table 8.4 shows the ambient air quality standards in respect of noise in different areas including industrial zones as prescribed by the Central Pollution Control Board. Most equipment in the plant are usually designed in such a way that the noise level emanating from their operation is less than 85 dB at a point one metre away from the source of the sound. Besides this design stipulation, proper enclosures are also provided for operator stations so that the exposure to noise shall not exceed 85 dB for 8 hours.

Table 8.4

Ambient Air Quality Standards in respect of Noise

Area Code	Category of Area/Zone	Limits in decibel (dB)	
		Day Time	Night time
(A)	Industrial area	75	70
(B)	Commercial area	65	55
(C)	Residential area	55	45
(D)	Silence Zone	50	40

Source: *Central Pollution Control Board*, 1998.

Notes:
1. Daytime shall mean from 6.00 a.m. to 10.00 p.m.
2. Night time shall mean from 10.00 p.m. to 6.00 a.m.
3. Silence zone is defined as an area comprising not less than 100 metres around hospitals, educational institutions and courts. The silence zones are zones which are declared as such by the competent authority.

Table 8.3

Effluent Characteristics Standards

Parameters	Minimum National Standards for Fertiliser Industry			
	Unit	Nitrogenous	Phosphatic	Complex
(1)	(2)	(3)	(4)	(5)
Total Suspended solids	mg/l max	100	100	100
Total Dissolved Solids	mg/l max			
Temperature	°C	5°C above recycling water		
pH		6.5—8.0	7.0—9.0	6.5—8.0
Biological Oxygen Demand	mg/l max			
Chemical Oxygen Demand	mg/l max			
Dissolved Oxygen	mg/l min			
Oil & Grease	mg/l max	10	10	10
Ammoniacal Nitrogen as N	mg/l max	50		50
Free Ammonia	mg/l max	4		4
Total Kjadahl Nitrogen as N		100		
Nitrate Nitrogen	mg/l max	20		20
Sulphate as SO_4	mg/l max			
Phosphate as P	mg/l max		5	5

(1)	(2)	(3)	(4)	(5)
Sulphide as S	mg/l max			
Fluoride as F	mg/l max		10	10
Chloride as Cl	mg/l max			
Cyanide as CN	mg/l max	0.2		0.2
Lead as Pb	mg/l max			
Selenium as Se	mg/l max			
Zinc as Zn	mg/l max			
Copper as Cu	mg/l max			
Nickel as Ni	mg/l max			
Cadmium as Cd	mg/l max			
Hexavalent Chromium as Cr	mg/l max	0.1	0.1	0.1
Mercury as Hg	mg/l max			
Arsenic as As	mg/l max	0.2		0.2
Sodium as Na	% max			
Iron as Fe	mg/l max			
Free Carbon dioxide CO2	mg/l max			
Phenol as C_6H_5 OH	mg/l max			
Residuel Chlorine as Cl	mg/l max			
Barium as Ba	mg/l max			
Vanadium as V	mg/l max	0.2		0.2

Table 8.5 provides European Emission Standards as prescribed by the European Fertiliser Manufacturers' Association (EFMA). European and North American emission and effluent standards for fertiliser industry are more or less similar to the Indian standards in the respective areas.

Analysis of the above results show that all the units are successful in controlling major pollutants below the specified standards. Certain plants have put up recovery or treatment facilities so that effective reduction of pollutants takes place well below the stipulations. All the plants studied have extensive facilities for end-of-pipe treatment of all effluents. Attempt to reduce the effluent generation at source in these plants largely depend on the technologies adopted. In all units management infrastructure exist for regular monitoring and reporting to authorities.

The specific consumption of energy, which measures the energy requirement per tonne of ammonia, a major intermediate input and urea, a finished fertiliser product, from plants have shown a continuous trend of reduction over these years. (Fig. 8.2 and 8.3).

Reduced energy consumption invariably contribute to achieving better environmental standards and result in gradual reduction in emissions, effluents and solid waste per tonne of product manufactured.

Major design changes will be required for further improvements and hence efforts in this line are limited unless it brings about economic incentive by way of increased productivity, lowering of energy consumption etc.

Table 8.5

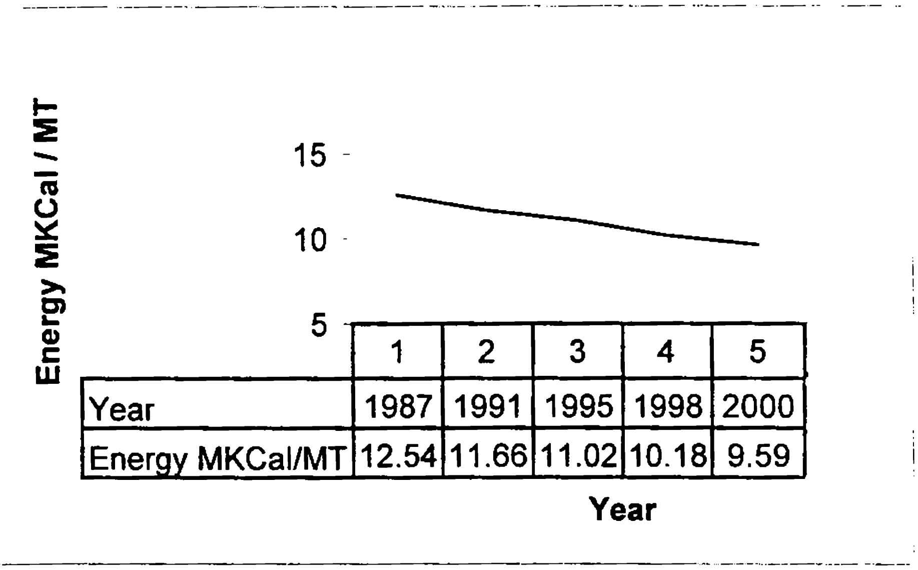
European Emission Standards

Emission Limit Values to water					
Plant	Emission	mg/l		kg/tonne of product	
(1)	(2)	(3)	(4)	(5)	(6)
		New	Existing	New	Existing
Ammonia	NH_3-N			0.1	0.1
Urea	Urea -N	1	150	0.0005	0.1
	NH_3-N	5	150	0.0025	0.1
Ammonium Nitrate	N	100	100	0.2	0.2
NPK-Nitrophosphate	P_2O_5	30	28	0.06	0.11
	NH_4-N	60	120	0.12	0.5
	NO_3-N	15	150	0.03	0.3
	Fluoride	26	13	0.05	0.2
NPK Mixed Acid	N	0	100	0	0.2
Emission Values to Air (EFMA)					
Plant	Emission	mg/Nm^3		kg/tonne of product	
		New	Existing	New	Existing
Ammonia	NOX	150	300	0.45	0.9
	SO_2	as for combustion plants			
Nitric Acid	NO_2	300	800	1.6	4.2
Sulphuric Acid	SO_2			2--4	10
	SO_3			0.15	0.6

(1)	(2)	(3)	(4)	(5)	(6)
Phosphoric Acid	Fluoride	5	30	0.4 of P_2O_5	
	Dust	10	150		
Urea					
Granulator	Urea Dust	50	70-80	0.25	0.35-0.4
	NH_3	50	130-165	0.25	0.65-0.83
Prill Tower	Urea Dust	50	100-150	0.5	1-1.5
	NH_3	50	65-100	0.5	0.65-1
Vents	NH_3			0.6	0.75
Ammonium Nitrate					
Granulator/Prilltower	NH_3	*10	*10		
	Particulates	*15	*15		
Neutaliser/Cooler/Drier	NH_3	50	50		particulates 0.5
	Particulates	30	30		NH_3 0.2
CAN	NH_3	50	50		
	Particulates	50	50		
NPK (Nitrophosphate)	NH_3	50	250	0.3	1
	NO_2	500	500	0.2	0.2
	Flouride	5	5	0.02	0.02
	Dust	50	50	0.3	0.3
NPK (mixed acid)	NH_3	50	50	0.2	0.2
	NO_2	70	70	0.3	0.3
	Flouride	5	5	0.02	0.02
	Dust	50	50	0.2	0.2

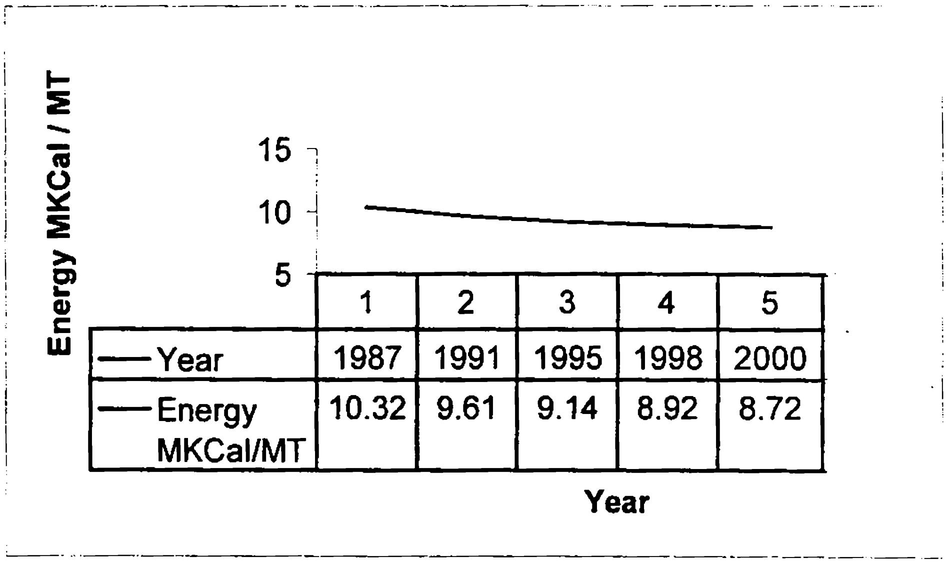
* 50 when insoluble solids are present

Source: *European Fertiliser Manufacturers' Association, Best Available Techniques*, 1995.



	1	2	3	4	5
Year	1987	1991	1995	1998	2000
Energy MKCal/MT	12.54	11.66	11.02	10.18	9.59

Fig. 8.2: Energy Consumption Trends—Ammonia Plants



	1	2	3	4	5
—Year	1987	1991	1995	1998	2000
—Energy MKCal/MT	10.32	9.61	9.14	8.92	8.72

Fig. 8.2: Energy Consumption Trends–Urea Plants

By early nineties of the last Century, extensive pollution control efforts have become common practice in the Indian fertiliser industry and most plants were able to comply with the Minimum National Standards for emissions and effluents set by the Central Pollution Control Board (CPCB). It was made possible through adoption of better technology and improved systems, which helped not only to reduce pollution but also conserve resources and reduce waste generation. There has been a reduction of 28% in water consumption of ammonia-urea plants and 38% in complex fertiliser plants over the last nine years. Also the wastewater discharged by fertiliser plants has been found to be well within the stipulated standards (FAI Website, 1999).

The average energy consumption of 25 ammonia plants commissioned upto 1987 has improved by 6.6% during the last ten years period. The improvement in energy consumption thus resulted in conservation of natural gas and petroleum feedstock and hence reduction in CO_2 emission, a green house gas which is considered as a major contributor to the global warming and climate change. Also there has been reduction of seven kilograms in the weighted average specific consumption of ammonia for making a tonne of urea. This means reduction in loss of ammonia to the environment. In the phosphatic sector the sulphur dioxide emission from sulphuric acid plant, upon adoption of the double conversion and double absorption (DCDA) technology, have steadily come down from 2.2 kilogram per tonne to 1.56 kilogram per tonne of sulphuric acid over nine years period as against the environmental protection standard of 4 kilogram sulphur dioxide per tonne of sulphuric acid. Other emissions like suspended particulate matter, fluorine, etc. have also registered a significant reduction (FAI, 1999).

In certain cases, as a method of control, the pollutant from effluents is stripped out to the atmosphere using air or steam resulting in air contamination. There is no control of pollution in converting the pollutant from water to air and it warrant for more efficient systems.

Reuse of treated effluents is limited in most plants though they claim that water conservation is achieved. This is mostly due to certain apprehension in the minds of the operators that some upsets in the waste water purification systems may lead to severe damages in other costly equipment.

During start up and shut down of plants effluent generation is high and provision is made in the pollution control systems of most plants to take care of such situations. Even though such excursions often cause public outcry and invite punitive action from statutory authorities. Such systems shall have built in provision for handling emergency situations also.

Gypsum ponds and stacks, though lined with impervious material still, cause leaching of pollutants to the water streams and ground water sources. In most of these plants heavy metals are not removed from the phosphoric acid produced. Phosphate rock being consumed in Indian plants mostly comes from Asia and Africa and unlike the Florida rock they have a lower content of radioactive impurities. Hence monitoring of radioactivity level of phosphogypsum is also not given the requisite priority and attention in most of the plants.

Much of the pollution prevention methods implemented by the units follow a prescriptive approach in which a standardized procedure built around questionnaires and check lists and it relies heavily on past solutions to pollution problems that are presumed similar to the one at hand. In its place a more descriptive approach in which process operators are challenged to define and study the pollution problems and derive their own ways of solving them is desirable.

There are substantial efforts towards Green Belt Development and maintaining greenery around these plants to reduce the impact of green house gases. Green belt development around fertiliser units, is an important step in the direction of sustainable environmental control. All the units studied undertook substantial efforts towards green belt development around the production units through planting of saplings and protecting vegetation around. Considerable efforts have been made by Rashtriya Chemicals and Fertilisers towards development of horticulture using factory effluents and use of sludge from effluent treatment unit as poultry feed and in blending fertilisers.

All units have established ISO 14000 Environment Management Systems and there is corporate environmental set up for regular monitoring and control. These systems are intended for continuous improvement of existing operations from the environmental angle. Certain units have adopted Zero Effluent Approach incorporating total recycle and reuse of effluents back to process. This approach still remains more a concept than its fruitful implementation to a reasonable degree of reliability.

These units have been successful in achieving the stipulations of the state and central pollution control authorities and other statutory agencies without many problems with the available technology and current efficiency of operation and management. Most of the environmental problems in these units are addressed exactly on the lines of those of the developed countries and similar results are achieved.

European and North American plant operators use the best available technology (BAT) in their plants for environmental control. Emission level for suspended particulate matter (SPM), oxides of nitrogen (NOx), and oxides of sulphur (SOx) etc., are more stringent in these countries than in India or other developing nations. European Fertiliser Manufacturers' Association (EFMA) specifies different standards for new and existing plants. In those countries both effluent specific standards and product specific standards are prescribed whereas in India, we have only industry specific effluent standards.

In India also the best available systems are employed in controlling and reducing pollution from fertiliser plants. These units do not contribute to further efforts in reducing the pollution effects beyond the limits prescribed by the pollution control boards (PCB). Potential for total recycle and zero effluent and emission have to be explored. Sustainable development demand such kind of an effort in order to enhance the carrying capacity of the geographical location and pave way for further industrialization. The western manufacturers are well ahead in this area. A change in this direction will necessitate a change in technology, which involve additional cost. Thus units who are capable meeting the requisite stipulations of the PCBs do not find any incentive in this regard.

All plants emit large quantities of carbon dioxide (CO_2), which is a major green house gas to the atmosphere. There are no emission standards for CO_2 as prescribed by the statutory bodies. Attempt to reduce green house gas emissions all over the globe to tackle climate change will bring in specific limits for CO_2 emissions also in future.

From the management angle it is desirable that the environmental friendliness of the industry shall improve year by year. This necessitates quantification of the extent of this improvement. None of the units have made an attempt in this manner. For this purpose existing environmental burden imposed by these units have to be quantified by suitable methods for every environmental aspect. No attempts are being done by any of the units in this regard.

Production of fertilisers and its balanced application are essential for maintaining food security in today's world. Additional production facilities will have to be built on new technologies, with least environmental impacts. The industry has learned several lessons in environmental management from the mistakes of the past and such knowledge on environmental issues and pollution prevention shall be incorporated in the design stage itself for the new plants.

Each new plant is more efficient than the last plant built in addressing environmental issues and there are efforts for continuously learning from collective experience. There is still a lot of work to be done on the efficient use of our resources and the balanced application of all fertilisers. There are many success stories in environment management in the fertiliser industry, but good news alone does not sell. The fertiliser industry in the country has to be very effective in promoting and defending themselves, if not the environmental movements can do a great deal of damage.

All manufacturers recognize that they are required to maintain a safe work environment for employees and neighboring community. Apart from ensuring utmost safety at the work place inside the factory, environment management plans are developed to tackle eventualities in case they occur. In general, the management of the production units are capable of mitigating the risk from most expected crisis situations, but not all. It is necessary that the operators shall keep on upgrading their environment management systems and must be cautious of the stringent future regulatory action by governments.

Information to the public regarding the environmental consequences of these plants are meagre and no effort is made from the part of the companies to explain the environmental burden and risk of the installation to them. No environmental report is published by the companies annually. In this context the Responsible Care—Environmental Reporting of the European Chemical Industry Council (CEFIC) may be considered as a model. The communities associated with these units have a right to know the environmental risk they are subjected to. This issue needs to be addressed at the national level itself. Provisions like the Superfund Amendments and Reauthorization Act (SARA) of the US to cope with Community Right To Know requirements have to be enacted and the concerned professionals shall do whatever necessary to allay the fear of the public.

The Government shall formulate country specific Best Available Techniques (BATs) for each industry including the fertiliser industry to facilitate continuous improvement in environmental management. Technically and economically feasible regulatory as well as non-regulatory measures, for the industry, also will help to improve environmental management in fertiliser production. Fiscal incentives may also be considered to encourage adoption of technologies that reduce pollution.

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Chapter 9

CONCLUSIONS AND RECOMMENDATIONS

The study covered the environmental aspects of a representative sample of 15 plants from six firms of the large scale sector of the Indian fertiliser industry. This study has identified the key issues in environmental protection in the production of fertilisers, the national and international norms and guidelines regarding pollution control in fertiliser industry, the extent to which these issues are tackled in operating plants in the country and the problems encountered in environmental management in fertiliser plants.

The study revealed that the firms have been successful in maintaining the characteristics of the effluents and emissions discharged from the plants within the limits of the stipulations of the regulatory authorities. Most of the environmental issues in the units are addressed exactly on the lines in the developed countries and follow guidelines that are compatible to similar international norms and practices. With regard to the discharged effluents and emissions similar results on the quality criteria are also achieved. In comparison with the best available practices for efficient pollution control in the industry, there is scope for further improvement. A change in this direction which involve additional investments is not a priority agenda before the Managements of the units, for the present, due to lack of financial incentive in this regard. Hence, for further improvements in this area, a policy guided approach is necessary.

Based on the above analysis, guidelines of a national environmental policy, which will foster development of fertiliser industry in the country to boost agricultural output without degrading the environment, is proposed. The following are the elements of the above Environmental Policy.

Vision on Environment, Health and Safety (EH & S) in Fertiliser Processing

Existing operations and continued growth and development of the fertiliser industry in the country are an essential requirement for increasing agricultural productivity especially because of the developing nature of our economy. The industry is characterized by major environmental impacts and safety concerns. In order to facilitate the above growth perspective, a conducive Environment, Health and Safety (EH&S) policy support for the industry at the Government level is required.

Commitment of the Top Management

The first and foremost guiding principle of an environmental policy facilitating growth of the industry is the unstinted commitment, involvement and action oriented approach of the top management of the organisation in achieving the set environmental goals. This commitment will ensure maintaining and enhancing a company-wide organisational structure and culture that recognises and encourages the full and active participation of all employees in the systematic management of health, safety, and environmental issues. Binding rules regarding the organisation and management of any task being related to health, safety and environmental matters shall be established at Chief Executive level.

Develop EH & S Policy Statement

Every fertiliser company shall be required to formulate an Environment, Health and Safety policy statement depending upon the nature and scale of its operation and specifying its current thinking and aspirations of the future. They shall adopt a national pollution prevention policy that encourages source reduction and environmentally sound recycling as a first option, but that also recognizes safe treatment, storage and disposal practices as important components of an overall environment protection strategy.

The company shall implement, and continuously improve health safety and environment management systems and develop standards that reflect best industry practices to minimize the risk of disturbances in consequence of its operations as well as minimized consumption of raw materials and energy.

Set Environmental Targets

The environmental targets, i.e., the qualitative and quantitative changes that are to be brought about to bring in more environment friendliness in the industry and acceptance to the community around are to be analysed. Steps that are envisaged for minimizing environmental impacts, reducing emissions of toxic gases and those causing global warming and improving the current levels of employee health, safety and pollution prevention are to be specified. Attempts for improving energy efficiency, resource productivity and use of renewable source of energy and raw material need special mention in the policy. The target must also address achieving zero accidents at work places, reducing incidents of work related diseases and overall reduction of the risk exposure to the employees as well as the community around. The target shall focus achieving sustainable development and eco-efficiency as a new business perspective for the industry through production and innovation integrated environmental protection, responsible product stewardship and aiming total quality improvements.

Incorporate State of Art Control Strategies

The National policy shall provide for the use of legal, financial and social instruments which influence the behavior of companies, citizens, public bodies and authorities for achieving the objectives of the policy. Existing and innovative control mechanisms such as statutory provisions, stipulations of the various regulatory bodies may be used. Fertiliser industry may be asked to go for the currently best available technology for pollution abatement. During the interim phase current strategy of monitoring comparison with set standards and penal action wherever required shall continue. Plants shall be operated to standards that comply with the requirements of appropriate national and international legislation and codes of practice.

Ensure Effective Risk Management

It is necessary that the management shall ensure that potential health, safety, and environmental risks associated with the activities are assessed early to minimize and manage adverse effects and to identify opportunities for improvement.

Upgrade Staff Training

Necessary and state of art training may be given to the concerned people responsible for environmental management. This should include keeping them abreast of the new developments, technologies and practical tools, accident investigation, environmental impact prediction, selecting appropriate protective equipment, implementing emergency response plans as and when necessary and so on. They may be trained to learn from previous incidents and similar experiences. They must be made conversant in the corporate environmental management systems and the proposed action plan for its implementation. In short, necessary capabilities must be available inhouse with all organizations to tackle probable emergency situations that are likely to arise.

Ensure Regular Monitoring

The policy shall call for regular and meticulous environmental performance monitoring to keep track of the environmental burden imposed by the company and watch the direction of its progressing trends. Quantitative as well as qualitative approaches may be used for this purpose. Emissions, waste streams, hazardous waste, disturbance, resource depletion etc., shall be addressed accordingly. Commitments towards targets for Responsible Care and social responsibility may also have to be assessed.

The current operations should be regularly and systematically assessed and audited for the purpose both of identifying and correcting any element which may put human beings, property or the natural environment at risk of nuisance or damage and of establishing a basis of safety related improvements of processes and products.

Any new process and product as well as any new information of existing processes and products should be thoroughly analysed with regard of their health, safety and environmental implications.

The concerned authorities should be kept well informed of the operations and of their health, safety and environmental implications. Any incident entailing a risk of environmental disturbances or of conflict with existing regulations should be promptly reported to the proper authority.

Provide Public Information

Necessary provision may be made for sharing information on health safety and environment with the public is to be incorporated in the policy. The policy shall provide for involvement of the community and working with active environmental groups in the region in bettering the environmental situation and thereby enhancing public perception of the industry.

Through candid and personally formulated information, the public should be made acquainted with the operations of the company, its as such, related benefits and risks as well as the measures taken to minimize those risks. Uncertainty and anxiety among them should be addressed attentively. Care for the safety and health of the employees and the public should be given priority.

Publish Annual Environmental Reports

The policy shall call for annual environmental status reports along with the financial performance reports. The feedbacks on these reports from the concerned stakeholders may be used for continued improvement of existing systems. The policy document shall be integrated with the National Environmental Plan of the Country.

Appendix I

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Appendix II

QUESTIONNAIRE ON ENVIRONMENTAL MANAGEMENT IN THE FERTILISER INDUSTRY

1. Will the application of mineral fertilisers and the concept of sustainable agriculture go hand in hand to meet our growing demand of food grains? What will happen if we do away with it?

2. What is your considered view on the future of the Chemical Fertiliser Industry all over the world and also in India? Will the environmental impacts of the manufacturing processes put constraints on its further expansion and building up of new capacities?

3. How does factors such as depletion of natural resources, excessive demand for water, energy etc., affect the growth of the industry?

4. How far considerations such as safety of the public and other environmental issues relating to huge size fertiliser plants act as constraints in limiting fertiliser production?

5. With the technological advancement of the present day plants producing fertilisers, efficiency of effluent and emission control, waste disposal and overall safety of the installations have considerably improved. Do you think this is a well balanced development?

6. With the kind of pollution abatement and environmental controls as available today in the industry is it possible to reduce adverse impacts to a reasonably acceptble level? Do you consider further improvement essential for continued growth?

7. Assessing the growth of the industry for the past 30-40 years, do you agree that the industry is making consistent efforts to contain the adverse environmental impacts and there has been many success stories also?

8. Do you foresee developments in biotechnology and bio-fertilisers as a challenge for the mineral fertiliser industry from the environmental angle?

9. Quite different from the earlier technologies available for production, now-a-days welcome changes such as attempts to reduce the harshness of the chemical reactions, use of improved metallurgy, operation at lower temperatures and pressures, reduction in storage of toxic inventories, going for less toxic materials as substitutes etc., have become very common in the manufacturing sector. In your opinion how far these developments add on to the environment friendliness of the industry?

10. How far the Indian fertiliser industry been successful in achieving the environmental standards compared to those in North America or Europe?

11. How about the role of environmental regulatory authorities in the country? How far legislation in this area has been successful?

12. All the fertiliser production units in the country are now-a-days equipped with Emergency Management Plans to tackle onsite crisis situations. Do you consider these plans as foolproof and workable when in demand?

13. Though most of the effluents from fertiliser plants are safely treated and let out, problems such as hazards from plants and storages, disposal of phosphogypsum, spent catalysts and toxic metal bearing sludge, radioactivity, disposal of old plants, global warming and ozone depletion etc., continue to worry the industry. How far, in your opinion, these issues will be resolved in the future?

14. To what extent integration of Indian fertiliser industry with that of the global industry have taken place?

15. What in your opinion are the key elements from the environmental point of view to be addressed while formulating a national level fertiliser policy?

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