

Environmental, Health, and Safety Guidelines for Nitrogenous Fertilizer Production

Introduction

The Environmental, Health, and Safety (EHS) Guidelines are technical reference documents with general and industry-specific examples of Good International Industry Practice (GIIP)¹. When one or more members of the World Bank Group are involved in a project, these EHS Guidelines are applied as required by their respective policies and standards. These industry sector EHS guidelines are designed to be used together with the **General EHS Guidelines** document, which provides guidance to users on common EHS issues potentially applicable to all industry sectors. For complex projects, use of multiple industry-sector guidelines may be necessary. A complete list of industry-sector guidelines can be found at: www.ifc.org/ifcext/enviro.nsf/Content/EnvironmentalGuidelines

The EHS Guidelines contain the performance levels and measures that are generally considered to be achievable in new facilities by existing technology at reasonable costs. Application of the EHS Guidelines to existing facilities may involve the establishment of site-specific targets, with an appropriate timetable for achieving them.

The applicability of the EHS Guidelines should be tailored to the hazards and risks established for each project on the basis of the results of an environmental assessment in which site-

¹ Defined as the exercise of professional skill, diligence, prudence and foresight that would be reasonably expected from skilled and experienced professionals engaged in the same type of undertaking under the same or similar circumstances globally. The circumstances that skilled and experienced professionals may find when evaluating the range of pollution prevention and control techniques available to a project may include, but are not limited to, varying levels of environmental degradation and environmental assimilative capacity as well as varying levels of financial and technical feasibility.

specific variables, such as host country context, assimilative capacity of the environment, and other project factors, are taken into account. The applicability of specific technical recommendations should be based on the professional opinion of qualified and experienced persons.

When host country regulations differ from the levels and measures presented in the EHS Guidelines, projects are expected to achieve whichever is more stringent. If less stringent levels or measures than those provided in these EHS Guidelines are appropriate, in view of specific project circumstances, a full and detailed justification for any proposed alternatives is needed as part of the site-specific environmental assessment. This justification should demonstrate that the choice for any alternate performance levels is protective of human health and the environment. .

Applicability

The EHS Guidelines for Nitrogenous Fertilizer Production include information relevant to facilities that produce ammonia-based nitrogenous fertilizers, including ammonia (NH₃), urea, nitric acid (HNO₃), ammonium nitrate, calcium ammonium nitrate (CAN), ammonium sulfate and mixed nitrogenous fertilizers, such as urea-ammonium sulfate (UAS) and urea ammonium nitrate (UAN) liquid fertilizers (28, 30 or 32 percent nitrogen (N)). This document is organized according to the following sections:

- Section 1.0 — Industry-Specific Impacts and Management
- Section 2.0 — Performance Indicators and Monitoring
- Section 3.0 — References and Additional Sources
- Annex A — General Description of Industry Activities

1.0 Industry-Specific Impacts and Management

The following section provides a summary of the most significant EHS impacts associated with nitrogenous fertilizer facilities which occur during the operational phase, along with recommendations for their management. Recommendations for the management of EHS issues common to most large industrial facilities during construction and decommissioning phases are provided in the **General EHS Guidelines**.

1.1 Environment

Potential environmental issues associated with nitrogenous fertilizer manufacturing include the following:

- Air emissions
- Wastewater
- Hazardous materials
- Wastes
- Noise

Air Emissions

Air emissions from nitrogenous fertilizer manufacturing facilities typically consist of greenhouse gases (GHGs – typically carbon dioxide and nitrous oxide), other gaseous inorganic compounds, and particulate emissions, especially particulate matter less than 10 microns in aerodynamic diameter (PM10) from prilling.

Guidance for the management of small combustion source emissions with a capacity of up to 50 megawatt thermals (MWth), including guidelines for exhaust emissions, is provided in the **General EHS Guidelines**.

Process Emissions from Ammonia Production

Process emissions from ammonia plants consist mainly of natural gas, hydrogen (H₂), carbon dioxide (CO₂), ammonia (NH₃), and carbon monoxide (CO). Hydrogen sulfide (H₂S) may be present depending on the fuel used. Fugitive emissions of NH₃ from storage tanks, valves, flanges, and tubing may also occur, especially during transportation or transfer. Non-routine emissions associated with process upsets or accidents may contain natural gas, carbon monoxide (CO), hydrogen (H₂), carbon dioxide (CO₂), volatile organic compounds (VOCs), nitrogen oxide (NO_x), and NH₃.

Emission prevention and control measures include the following:

- Use synthesis NH₃ purge gas treatment to recover NH₃ and H₂ before combustion of the remainder in the primary reformer;
- Increase the residence time for off-gas in the high-temperature zone of the primary reformer;
- Ammonia emissions from relief valves or pressure control devices from vessels or storages should be collected and sent to a flare or to wet scrubber;
- Install leak detection methods to detect fugitive emissions of ammonia from process and storage;
- Implement maintenance programs, particularly in stuffing boxes on valve stems and seals on relief valves, to reduce or eliminate releases.

Carbon dioxide (CO₂) removal in ammonia production facilities generates concentrated CO₂ emissions. Ideally, ammonia and urea facilities are integrated, whereby the ammonia process-derived CO₂ can be consumed almost completely if the produced ammonia is transformed into urea. In addition, production of nitrogenous fertilizers is an energy intensive process typically requiring significant use of energy from fossil

fuels, and resulting in significant generation of greenhouse gases. Recommendations for the management of GHGs, in addition to energy efficiency and conservation, are addressed in the **General EHS Guidelines**.

Process Emissions from Urea Production

Process emissions from urea plants consist mainly of ammonia (NH_3) and dust. Fugitive emissions of NH_3 from tanks, valves, flanges, and tubing may also occur. Prilling towers and granulators are a major source of emission of urea dust. The final product is prilled or granulated requiring a large volume of cooling air, which is subsequently discharged to the atmosphere.

Recommended emission prevention and control measures include the following:

- Reduction of dust emissions by producing granular rather than prilled product;
- Installation of prilling towers with natural draft cooling instead of towers with forced/induced draft air cooling;
- Scrubbing of off-gases with process condensate prior to discharge to atmosphere, and reprocessing the recovered urea solution;²
- Use of baghouse filters to prevent the emission of dust laden air from transfer points, screens, bagging machines, etc., coupled with an urea dust dissolving system which allows recycling of urea to the process;
- Flash melting of solid urea over-size product which allows urea recycling to the process;

² Wet scrubbers can achieve an efficiency of 98 percent for dust removal (see IPPC BREF (2006)). The low partial pressure of NH_3 present in the discharged air results in low NH_3 scrubbing/recovery efficiencies. Efficiency can be increased by acidification and the resultant ammonia solution should be then reused in the process

- Collection of solid urea spillages on a dry basis, avoiding washing of surfaces;
- Connection of both safety relief valves/seals of the ammonia/urea pumps, and tank vents to a flare.

Process Emissions from Nitric Acid Manufacturing

Process emissions from nitric acid plants consist primarily of nitric oxide (NO), nitrogen dioxide (NO_2), and nitrogen oxide (NO_x) from the tail gas of the acid absorption tower, nitrous oxide (N_2O), trace amounts of nitric acid (HNO_3) mist from the filling of acid storage tanks, and ammonia (NH_3).

Recommendations to prevent and control NO_x emissions include the following:

- Ensure that a sufficient air supply is provided to the oxidizer and absorber;
- Ensure that high pressure conditions are maintained, especially in nitric acid production absorption columns;
- Prevent high temperatures in the cooler-condenser and absorber;
- Develop a maintenance program to prevent operation with faulty equipment such as compressors or pumps that lead to lower pressures and leaks, and decrease plant efficiency;
- Reduce NO_x emissions by increasing the efficiency of the existing process absorption tower or incorporating an additional absorption tower;³
- Apply a catalytic reduction process to treat tail gases from the absorption tower;⁴

³ Efficiency can be improved by increasing the number of absorber trays, operating the absorber at higher pressures, or cooling the weak acid liquid in the absorber.

⁴ Tail gases may be heated to ignition temperature, mixed with fuel (e.g., natural gas, hydrogen, naphtha, carbon monoxide, or ammonia) and passed over a catalyst bed (e.g., vanadium pentoxide, platinum, zeolite) (IPPC BREF (2006)). Catalytic reduction can achieve better NO_x reduction than extended absorption.

- Install active molecular sieves to catalytically oxidize NO to NO₂ and selectively adsorb NO₂, returning the thermally stripped NO₂ to the absorber;⁵
- Install wet scrubbers with an aqueous solution of alkali hydroxides or carbonates, ammonia, urea, potassium permanganate, or caustic chemicals (e.g. caustic scrubbers with sodium hydroxide, sodium carbonate, or other strong bases), recovering NO and NO₂ as nitrate or nitrate salts.⁶

Recommendations to prevent and control N₂O emissions include the following:

- Install selective catalytic reduction (SCR) units operating around 200°C with various catalysts (platinum, vanadium pentoxide, zeolites, etc.) or, less frequently, non-selective catalytic reduction (NSCR) units;
- Integrate a decomposition chamber in the burner to reduce the production of N₂O by increasing the residence time in the oxidation reactor;⁷
- Use a selective de-N₂O catalyst in the high temperature zone (between 800 and 950 °C) of the oxidation reactor;⁸
- Install a combined N₂O and NO_x abatement reactor between the final tail gas heater and the tail gas turbine. The reactor consists of two catalyst layers (Fe zeolite) and an intermediate injection of NH₃.⁹

Acid mist emissions should not occur from the tail-gas of a properly operated plant. Small amounts, which may be present in the absorber exit gas streams, should be removed by a

⁵ This approach may require special provisions to control fouling of the sieve bed.

⁶ Although effective, this control option may have high costs and not be financially feasible under normal circumstances. Any cost evaluations should include the treatment of the spent scrubbing solution.

⁷ IPPC BREF (2006)

⁸ Ibid.

⁹ Ibid.

separator or collector prior to entering the catalytic reduction unit or expander.

Process Emissions from Ammonium Nitrate and Calcium Ammonium Nitrate Manufacturing

Process emissions consist mainly of ammonia and dust from neutralizers, evaporators, prill towers, granulators, driers and coolers. Fugitive emissions of ammonia arise from storage tanks and process equipment.

Recommendations to prevent and control emissions include the following:

- Install steam droplet separation techniques (e.g., knitted wire, mesh demister pads, wave plate separators and fiber pad separators using, for example, polytetrafluoroethylene (PTFE) fibers) or scrubbing devices (e.g., packed columns, venturi scrubbers and irrigated sieve plates) to reduce emissions of ammonia and ammonium nitrate in the steam from neutralizers and evaporators.¹⁰ A combination of droplet separators and scrubbers should be used to remove ammonium nitrate particulate emissions. Nitric acid should be used to neutralize any free ammonia;
- Treat and re-use contaminated condensate using techniques including stripping with air or steam with the addition of alkali to liberate ionized ammonia if required, or use distillation and membrane separation processes such as reverse osmosis;¹¹
- Adopt the lowest practical melt temperature to reduce emissions of ammonia and ammonium nitrate (and calcium carbonate in calcium ammonium nitrate (CAN) production) from prilling and granulation emissions;

¹⁰ Ibid.

¹¹ Ibid.

- Remove ammonia emissions from prilling and granulation by neutralization in a wet scrubber. Wet scrubbers normally use an acid circulating solution. The solution from a wet scrubber will normally be recycled to the process;
- Remove ammonium nitrate fumes from prilling through scrubbing;
- Remove small particles of ammonium nitrate (miniprills), carried out with the air stream through cyclones, bag filters and wet scrubbers;
- Adopt an enclosed granulation process instead of prilling technique where feasible;¹²
- Install an extraction, capture and filter system for ventilation air from areas with dust-generating product-handling activities to prevent fugitive emissions of particulates.

Wastewater

Industrial Process Wastewater

Process water discharges from nitrogenous fertilizer manufacturing plants are limited typically to acid wash from scheduled cleaning activities and purges, effluents from wet scrubbers, accidental releases, leaks of small quantities of liquids from product storage tanks, and acidic and caustic effluents from the boiler feed water preparation.

Effluents from Ammonia Plants

During normal operations, plant discharges may include releases of process condensates or scrubbing effluents of waste gases containing ammonia and other byproducts. Process condensates typically arise from condensation between shift reactors and absorption of carbon dioxide, and from carbon

¹² Granulation requires a more complicated process, but the quantity of air to be treated is smaller than in prilling, and abatement equipment needed is less sophisticated. Ammonium nitrate particles are coarser and can be abated with a combination of dry cyclones or bag filters and wet scrubbers, instead of more sophisticated candle filters.

dioxide overheads. Such condensates may contain ammonia, methanol, and amines (e.g., methylamines, dimethylamines and trimethylamines). In partial oxidation, soot and ash removal may impact water discharges if not handled adequately.

Recommended pollution prevention and control measures include the following:

- Condensates should be steam-stripped to reduce the ammonia content, and re-used as boiler make-up water after an ion exchange treatment or sent to a wastewater treatment plant for treatment with other ammoniacal streams. Steam-stripper emissions may require additional ammonia emissions controls;
- Ammonia absorbed from purge and flash gases should be recovered in a closed loop to avoid the occurrence of aqueous ammonia emissions;
- Soot from gasification in partial oxidation processes should be recovered and recycled to the process.

Effluents from Urea Plants

An urea plant generates a significant stream of process water containing NH₃, CO₂ and urea (e.g., a 1,000 tons per day (t/d) plant generates approximately 500 cubic meters per day (m³/d) of process water). Other sources are ejector steam, flush, and seal water.

Recommended pollution prevention and control measures include the following:

- Improve evaporation heater/separator design to minimize urea entrainment;
- Remove NH₃, CO₂, and urea from the process water in a process water treatment unit, and recycle the gases to the synthesis to optimize raw material utilization and reduce effluents;

- Provide adequate storage capacity for plant inventory to prepare for plant upset and shutdown conditions;
- Install submerged tanks to collect plant washings and other contaminated streams from drains for recycling to process or conveying to the process water treatment unit.

Effluents from Nitric Acid Plants

Liquid effluents from a nitric acid plant include the following:

- Dilute ammonium nitrite/ nitrate solution from periodic washing (typically once per day) of the NO_x compressor and from the cooler-condenser drain for a period after plant start-up;
- Aqueous ammonia solution from evaporator blowdown;
- Blow-down of water containing dissolved salts from the steam drum;
- Occasional emissions from the purging and sampling of nitric acid solutions.

Recommended pollution prevention and control measures include the following:

- Steam-inject the NO_x compressor to avoid any liquid effluent;
- Arrange for acidification during start-up to avoid the need to drain the cooler-condenser;
- Conduct steam stripping to recover the ammonia into the process and limit emissions of aqueous ammonia from the evaporator blowdown.

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

Ammonium nitrate (AN) / calcium ammonium nitrate (CAN) plants produce a surplus of water to be treated for discharge or possibly recycled to other units in the nitrogenous fertilizers

production complex. Their process effluents typically include condensates containing up to 1percent ammonia and up to 1percent ammonium nitrate from reactors (neutralizers) and evaporator boil-off, and ammonium nitrate and nitric acid from plant wash-down. Unabated emissions into water can be up to 5,000mg AN as N/l and 2,500mg NH₃ as N/l (6 and 3 kilograms per ton (kg/t) of product respectively).¹³

Pollution prevention and control measures for AN/CAN plants include the following:

- Internally recovery of ammonium nitrate and ammonia (e.g. scrubber liquor from the granulation plant air cleaning section being recycled through the further evaporation stages on the granulation plant);
- Integrate AN/CAN plants with nitric acid production;
- Treat steam contaminated with ammonia or ammonium nitrate, before condensation, by droplet separation techniques and scrubbing devices (as discussed under Air Emissions in this document);
- Treat process water (condensate) by stripping with air or steam with the addition of alkali to liberate ionized ammonia as needed; ion exchange; distillation; or membrane separation processes.

Process Wastewater Treatment

Techniques for treating industrial process wastewater in this sector include filtration for separation of filterable solids; flow and load equalization; sedimentation for suspended solids reduction using clarifiers; ammonia and nitrogen removal using physical-chemical or biological nitrification-denitrification treatment methods; dewatering and disposal of residuals in designated waste landfills. Additional engineering controls may

¹³ IPCC BREF (2006)

be required for capturing ammonia from air stripping operations and for odor control.

Management of industrial wastewater and examples of treatment approaches are discussed in the **General EHS Guidelines**. Through use of these technologies and good practice techniques for wastewater management, facilities should meet the Guideline Values for wastewater discharge as indicated in the relevant table of Section 2 of this industry sector document.

Other Wastewater Streams & Water Consumption

Guidance on the management of non-contaminated wastewater from utility operations, non-contaminated stormwater, and sanitary sewage is provided in the **General EHS Guidelines**. Contaminated streams should be routed to the treatment system for industrial process wastewater. Recommendations to reduce water consumption, especially where it may be a limited natural resource, are provided in the **General EHS Guidelines**.

Hazardous Materials

Nitrogenous fertilizer facilities use and manufacture significant amounts of hazardous materials, including raw materials and intermediate/final products. The handling, storage, and transportation of these materials should be managed properly to avoid or minimize the environmental impacts. Recommended practices for hazardous material management, including handling, storage, and transport, are presented in the **General EHS Guidelines**.

Wastes

The most common hazardous wastes produced by these facilities are spent catalysts after their replacement in scheduled turnarounds of gas desulphurization, ammonia plants, and nitric

acid plants.¹⁴ The most common non-hazardous wastes are nitrogen-containing dust particulates from prilling and granulators dust control systems.

Recommended management strategies for spent catalysts include the following:

- Proper on-site management, including submerging pyrophoric spent catalysts in water during temporary storage and transport until they can reach the final point of treatment to avoid uncontrolled exothermic reactions;
- Return to the manufacturer for regeneration or recovery;
- Off-site management by specialized companies that can recover the heavy or precious metals through recovery and recycling processes whenever possible, or who can otherwise manage spent catalysts or their non-recoverable materials according to hazardous and non-hazardous waste management recommendations presented in the **General EHS Guidelines**.

Recommended management strategies for recovered dust and off-spec products include the following:

- Recycling to their specific production units or to fertilizer mixing units in the manufacturing plant;
- Providing to third party users (merchants and farmers) for their subsequent utilization.¹⁵

Storage and handling of hazardous and non-hazardous wastes should be conducted in a way consistent with good EHS practice for waste management, as described in the **General EHS Guidelines**.

¹⁴ An ammonia plant with a capacity of 1,500 tons per day may generate about 50 m³/yr of spent catalyst.

¹⁵ Fertilizer regulations in the European Union (EU) and other countries include requirements on the quality of ammonium nitrate that should be followed in case of reuse of this byproduct. Guidance is provided for producers, importers, distributors and merchants by EFMA (2003 and 2004).

Noise

Typical sources of noise emissions include large size rotating machines such as compressors and turbines, pumps, electric motors, air coolers, rotating drums, spheroidizers, conveyors belts, cranes, fired heaters, and from emergency depressurization. Guidance on noise control and minimization is provided in the **General EHS Guidelines**.

1.2 Occupational Health and Safety

The occupational health and safety issues that may occur during the construction and decommissioning of nitrogenous fertilizer facilities are similar to those of other industrial facilities, and their management is discussed in the **General EHS Guidelines**.

Facility-specific occupational health and safety issues should be identified based on job safety analysis or comprehensive hazard or risk assessment, using established methodologies such as a hazard identification study [HAZID], hazard and operability study [HAZOP], or a quantitative risk assessment [QRA]. As a general approach, health and safety management planning should include the adoption of a systematic and structured approach for prevention and control of physical, chemical, biological, and radiological health and safety hazards described in the **General EHS Guidelines**.

The most significant occupational health and safety hazards occur during the operational phase of a nitrogenous fertilizer facility and primarily include:

- Process Safety
- Chemical hazards
- Fire and explosion hazards.
- Ammonia storage

Process Safety

Process safety programs should be implemented, due to industry-specific characteristics, including complex chemistry reactions, use of hazardous materials (e.g., toxic, reactive, flammable or explosive compounds) and multi-step organic synthesis reactions are conducted.

Process safety management includes the following actions:

- Physical hazard testing of materials and reactions;
- Hazard analysis studies to review the process chemistry and engineering practices, including thermodynamics and kinetics;
- Examination of preventive maintenance and mechanical integrity of the process equipment and utilities;
- Worker training;
- Development of operating instructions and emergency response procedures.

Chemical Hazards

Toxic chemicals in the nitrogenous fertilizer facilities include ammonia, nitric acid vapor, gaseous formaldehyde, and urea or AN dust. Threshold values associated with specific health effects can be found in internationally published exposure guidelines (see Monitoring below).

Recommendations to prevent and control the exposures include the following:

- Installation of gas detectors in hazard areas, wherever possible;
- Avoid nitric acid spills or take precautions to control and minimize them. Nitric acid is highly corrosive and any form of dermal contact should be avoided;

- Provide adequate ventilation in all areas where ammonia, nitric acid and aqueous formaldehyde is handled;
- Provide air extraction and filtration in all indoor areas where urea and AN dust can be generated.

Fire and Explosions

Common causes of fire and explosions in nitrogenous facilities include:

- Fires and explosions due to accidental release of synthetic gas in ammonia plants;
- Formation of explosive gas mixture in the inert gas scrubbers and ammonia release in urea facilities;
- Explosions of air/ammonia mixture and nitrite/nitrate salts in nitric acid plants;
- Initiation of fire and explosion by ammonium nitrate, an oxidizing agent in the AN plants;
- Fires of fertilizer products or dust contaminated with oil or other combustible materials in the presence of a heat source.

Recommendations to prevent and control fire and explosion hazards include the following:

- Install leak detection units and other devices (alarm detection systems, such as automatic pH monitoring in nitric acid plants) to detect releases early;
- Segregate process areas, storage areas, utility areas, and safe areas, and adopting of safety distances.¹⁶
- Limit the inventory which may be released through isolation of large inventories from facility operations, and isolation and blowdown of pressurized flammable gases inventories;

¹⁶ Safety distances can be derived from site-specific safety analyses (e.g., API, NFPA). Refer also to IFA/EFMA Handbook for the Safe Storage of Ammonium Nitrate Based Fertilizers (1992) for guidance on design and operational management.

- Remove potential ignition sources;
- Implement procedures to avoid and control hazardous gas mixtures, for instance reducing below 10 parts per million (ppm) hydrogen content in CO₂ feed in urea plants,
- Control the ammonia-to-air ratio with automatic shut-off valves in nitric acid plants;
- Avoid pressurizing large quantities of nitric acid for loading/unloading;
- Use carbon austenitic stainless steel for nitric acid tanks, vessels and accessories;
- Design AN/CAN storage according to internationally recognized guidance and requirements.¹⁷ These requirements generally cover the storage areas with respect to their structural and operational requirements. An adequate fire detection and fighting system should be installed;
- Remove or dilute the release and limiting the area affected by the loss of containment.

Ammonia Storage

The potential for toxic releases in handling and storage of liquid ammonia should be minimized by adopting the following measures:

- Avoid siting ammonia storage tanks close to installations where there is a risk of fire or explosion;
- Use refrigerated storage for large quantities of liquid ammonia since the initial release of ammonia in the case of line or tank failure is slower than in pressurized ammonia storage systems;
- Implement and maintain a specific Emergency Management Plan providing guidance on emergency

¹⁷ See EC Fertilizer Directives EC 76/116 and EC 80/876, and the COMAH Directive 96/82/EC.

measures to protect both operators and local communities in the event of toxic ammonia releases.

decommissioning phases common to those of other large industrial facilities are discussed in the **General EHS Guidelines**.

1.3 Community Health and Safety

The most significant community health and safety hazards during the operation of nitrogenous fertilizers facilities relate to:

- Management, storage and shipping of hazardous products (ammonia, nitric acid, ammonium nitrate), with potential for accidental leaks/releases of toxic and flammable gases;
- Disposal of wastes (off-spec products, sludge).

Plant design and operations should include safeguards to minimize and control hazards to the community, including the following measures:

- Identify reasonable design leak cases;
- Assess the effects of potential leaks on surrounding areas, including groundwater and soil pollution;
- Assess potential risks arising from hazardous material transportation and select the most appropriate transport routes to minimize risks to communities and third parties;
- Select plant location with respect to the inhabited areas, meteorological conditions (e.g. prevailing wind directions), and water resources (e.g., groundwater vulnerability). Identify safe distances between the plant area, especially the storage tank farms, and the community areas;
- Identify prevention and mitigation measures required to avoid or minimize community hazards;
- Develop an Emergency Management Plan with the participation of local authorities and potentially affected communities.

Additional guidance on the management of community health and safety impacts during the construction and

2.0 Performance Indicators and Monitoring

2.1 Environment

Emissions and Effluent Guidelines

Tables 1 and 2 present emission and effluent guidelines for this sector. Guideline values for process emissions and effluents in this sector are indicative of good international industry practice as reflected in relevant standards of countries with recognized regulatory frameworks. These guidelines are achievable under normal operating conditions in appropriately designed and operated facilities through the application of pollution prevention and control techniques discussed in the preceding sections of this document.

Emissions guidelines are applicable to process emissions. Combustion source emissions guidelines associated with steam and power generation activities from sources with a capacity equal to or lower than 50 thermal megawatts thermal input (MWth) are addressed in the **General EHS Guidelines** with larger power source emissions addressed in the **EHS Guidelines for Thermal Power**. Guidance on ambient considerations based on the total load of emissions is provided in the **General EHS Guidelines**.

Effluent guidelines are applicable for direct discharges of treated effluents to surface waters for general use. Site-specific discharge levels may be established based on the availability and conditions in the use of publicly operated sewage collection and treatment systems or, if discharged directly to surface waters, on the receiving water use classification as described in the **General EHS Guidelines**. These levels should be achieved, without dilution, at least 95 percent of the time that the plant or unit is operating, to be calculated as a proportion of annual operating hours. Deviation from these levels in consideration of

specific, local project conditions should be justified in the environmental assessment.

Table 1. Air Emissions Levels for Nitrogenous Fertilizers Manufacturing Plants

Pollutant	Unit	Guideline Value
Ammonia Plants¹		
NH ₃	mg/Nm ³	50
NO _x	mg/Nm ³	300
PM	mg/Nm ³	50
Nitric Acid Plants		
NO _x	mg/Nm ³	200
N ₂ O	mg/Nm ³	800
NH ₃	mg/Nm ³	10
PM	mg/Nm ³	50
Urea / UAN Plants		
Urea (prilling/granulation)	mg/Nm ³	50
NH ₃ (prilling/granulation)	mg/Nm ³	50
PM	"	50
AN / CAN Plants		
PM	mg/Nm ³	50
NH ₃	mg/Nm ³	50
Notes:		
1. NO _x in flue-gas from the primary reformer. The other emissions are from process, prilling towers, etc. NO _x in all types of plants: temperature 273K (0°C), pressure 101.3 kPa (1 atmosphere), oxygen content 3% dry for flue gas.		

Resource Use, Energy Consumption, Emission and Waste Generation

Table 3 provides examples of resource consumption/generation indicators for energy in this sector. Industry benchmark values are provided for comparative purposes only and individual projects should target continual improvement in these areas.

Table 2. Effluents Levels for Nitrogenous Fertilizers Manufacturing Plants

Pollutant	Unit	Guideline Value
pH	S.U.	6-9
Temperature Increase	°C	<3
Ammonia Plants		
NH ₃	mg/l	5
Total nitrogen	mg/l	15
TSS	mg/l	30
Nitric Acid Plants		
NH ₃	mg/l	5
Total Nitrogen	mg/l	15
TSS	mg/l	30
Urea Plants		
Urea (prilling/granulation)	mg urea/l	1
NH ₃ (prilling/granulation)	mg/l	5
AN / CAN Plants		
AN	mg/l	100
NH ₃	mg/l	5
Total Nitrogen	mg/l	15
TSS	mg/l	30

Table 3. Resource and Energy Consumption/Generation

Product	Unit	Industry Benchmark
Ammonia	GJ lower heating value (LHV)/ton NH ₃	28.4 to 32.0 ⁽¹⁾
Urea	GJ/ton urea	0.4-0.45 ^{(1) (2)}
AN/CAN	KWh/ ton AN/CAN	25-60/10-50 ^{(1) (2)}
	kg Steam/ton AN/CAN	0-50/150-200 ⁽¹⁾
Nitric Acid (Energy Generation)	GJ/ton HNO ₃ (100%)	2.4 – 1.6 ⁽²⁾ (BAT – Average)
Sources:		
1. European Fertilizer Manufacturers Association (EFMA) (2000)		
2. EU IPPC Reference Document on Best Available Techniques in Large Volume Inorganic Chemicals – Ammonia, Acids and Fertilizers Industries (2006)		

Environmental Monitoring

Environmental monitoring programs for this sector should be implemented to address all activities that have been identified to have potentially significant impacts on the environment, during normal operations and upset conditions. Environmental monitoring activities should be based on direct or indirect indicators of emissions, effluents, and resource use applicable to the particular project.

Monitoring frequency should be sufficient to provide representative data for the parameter being monitored. Monitoring should be conducted by trained individuals following monitoring and record-keeping procedures and using properly calibrated and maintained equipment. Monitoring data should be analyzed and reviewed at regular intervals and compared with the operating standards so that any necessary corrective actions can be taken. Additional guidance on applicable sampling and analytical methods for emissions and effluents is provided in the **General EHS Guidelines**.

2.2 Occupational Health and Safety

Occupational Health and Safety Guidelines

Occupational health and safety performance should be evaluated against internationally published exposure guidelines, of which examples include the Threshold Limit Value (TLV®) occupational exposure guidelines and Biological Exposure Indices (BEIs®) published by American Conference of Governmental Industrial Hygienists (ACGIH),¹⁸ the Pocket Guide to Chemical Hazards published by the United States National Institute for Occupational Health and Safety (NIOSH),¹⁹ Permissible Exposure Limits (PELs) published by the Occupational Safety and Health Administration of the United

¹⁸ Available at: <http://www.acgih.org/TLV/> and <http://www.acgih.org/store/>

¹⁹ Available at: <http://www.cdc.gov/niosh/hpg/>

States (OSHA),²⁰ Indicative Occupational Exposure Limit Values published by European Union member states,²¹ or other similar sources.

Accident and Fatality Rates

Projects should try to reduce the number of accidents among project workers (whether directly employed or subcontracted) to a rate of zero, especially accidents that could result in lost work time, different levels of disability, or even fatalities. Facility rates may be benchmarked against the performance of facilities in this sector in developed countries through consultation with published sources (e.g. US Bureau of Labor Statistics and UK Health and Safety Executive)²².

Occupational Health and Safety Monitoring

The working environment should be monitored for occupational hazards relevant to the specific project. Monitoring should be designed and implemented by accredited professionals²³ as part of an occupational health and safety monitoring program. Facilities should also maintain a record of occupational accidents and diseases and dangerous occurrences and accidents. Additional guidance on occupational health and safety monitoring programs is provided in the **General EHS Guidelines**.

²⁰ Available at: http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARD&p_id=9992

²¹ Available at: http://europe.osha.eu.int/good_practice/risks/ds/oe/

²² Available at: <http://www.bls.gov/iif/> and <http://www.hse.gov.uk/statistics/index.htm>

²³ Accredited professionals may include Certified Industrial Hygienists, Registered Occupational Hygienists, or Certified Safety Professionals or their equivalent.

3.0 References and Additional Sources

Australian Government, Department of the Environment and Heritage. 2004. Emission Estimation Technique Manual for Inorganic Chemicals Manufacturing. Version 2.0. Canberra:

European Commission. 2006. European Integrated Pollution Prevention and Control (IPPC) Bureau. Reference Document on Best Available Techniques (BAT) in Large Volume Inorganic Chemicals – Ammonia, Acids and Fertilizers. Final Draft. October 2006. Seville: EIPPCB.

European Fertilizer Manufacturers' Association (EFMA). 2004. Guidance for Safe Handling and Utilization of Non-Conforming Solid Fertilizers and Related Materials for Fertilizer Importers, Distributors and Merchants. Brussels: EFMA Available at <http://www.efma.org/publications>

EFMA. 2003. Guidance for Safe Handling and Utilization of Non-Conforming Fertilizers and Related Materials for Fertilizer Producers. Brussels: EFMA Available at <http://www.efma.org/publications>

EFMA. 2002. Recommendations for the Safe and Reliable Inspection of Atmospheric, Refrigerated Ammonia Storage Tanks. Brussels: EFMA Available at <http://www.efma.org/publications>

EFMA. 2000a. Best Available Techniques for Pollution Prevention and Control in the European Fertilizer Industry. Production of Ammonia. Booklet No. 1. Brussels: EFMA Available at <http://www.efma.org/publications>

EFMA. 2000b. Best Available Techniques for Pollution Prevention and Control in the European Fertilizer Industry. Production of Nitric Acid. Booklet No. 2. Brussels: EFMA Available at <http://www.efma.org/publications>

EFMA. 2000c. Best Available Techniques for Pollution Prevention and Control in the European Fertilizer Industry. Production of Urea and Urea Ammonium Nitrate. Booklet No. 5. Brussels: EFMA Available at <http://www.efma.org/publications>

EFMA. 2000d. Best Available Techniques for Pollution Prevention and Control in the European Fertilizer Industry. Production of Ammonium Nitrate and Calcium Ammonium Nitrate. Booklet No. 6. Brussels: EFMA Available at <http://www.efma.org/publications>

EFMA. 1998. Guidelines for Transporting Nitric Acid in Tanks. Brussels: EFMA Available at <http://www.efma.org/publications>

International Fertilizers Industry Association (IFA)/EFMA. 1992. Handbook for the Safe Storage of Ammonium Nitrate Based Fertilizers. Paris and Zurich: IFA/EFMA. Available at <http://www.efma.org/publications>

German Federal Ministry of the Environment, Nature Conservation and Nuclear Safety (BMU). 2002. First General Administrative Regulation Pertaining the Federal Immission Control Act (Technical Instructions on Air Quality Control – TA Luft). Bonn: BMU. Available at http://www.bmu.de/english/air_pollution_control/ta_luft/doc/36958.php

German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU). 2004. Promulgation of the New Version of the Ordinance on Requirements for the Discharge of Waste Water into Waters (Waste Water Ordinance - AbwV) of 17. June 2004. Berlin: BMU. Available at http://www.bmu.de/english/water_management/downloads/doc/3381.php

Intergovernmental Panel on Climate Change (IPCC). 2006. Special Report. Carbon Dioxide Capture and Storage, March 2006. Geneva: IPCC. Available at <http://www.ipcc.ch/pub/online.htm>

Kirk-Othmer, R.E. 2006. Encyclopedia of Chemical Technology. 5th Edition. New York, NY: John Wiley and Sons Ltd.

United Kingdom (UK) Environment Agency. 1999a. IPC Guidance Note Series 2 (S2) Chemical Industry Sector. S2 4.03: Inorganic Acids and Halogens. Bristol: Environment Agency. Available at <http://www.environment-agency.gov.uk/>

UK Environment Agency. 1999b. IPC Guidance Note Series 2 (S2) Chemical Industry Sector. S2 4.04: Inorganic Chemicals. Bristol: Environment Agency. Available at <http://www.environment-agency.gov.uk/>

UK Environmental Agency. 2004. Sector Guidance Note IPPC S4.03. Guidance for the Inorganic Chemicals Sector. Bristol: Environment Agency. Available at <http://www.environment-agency.gov.uk/>

United States (US) Environment Protection Agency (EPA). 40 CFR Part 60, Standards of Performance for New and Existing Stationary Sources: Subpart G—Standards of Performance for Nitric Acid Plants. Washington, DC: EPA. Available at <http://www.gpoaccess.gov/cfr/index.html>

US EPA. 40 CFR Part 418. Subpart B—Ammonia Subcategory. Washington, DC: EPA. Available at <http://www.gpoaccess.gov/cfr/index.html>

US EPA. 40 CFR Part 418. Subpart C—Urea Subcategory. Washington, DC: EPA. Available at <http://www.gpoaccess.gov/cfr/index.html>

US EPA. 40 CFR Part 418. Subpart D—Ammonium Nitrate Subcategory. Washington, DC: EPA. Available at <http://www.gpoaccess.gov/cfr/index.html>

US EPA. 40 CFR Part 418. Subpart E—Nitric Acid Subcategory. Washington, DC: EPA Available at <http://www.gpoaccess.gov/cfr/index.html>

US EPA. 40 CFR Part 418. Subpart F—Ammonium Sulfate Subcategory. Washington, DC: EPA. Available at <http://www.gpoaccess.gov/cfr/index.html>

US EPA. 40 CFR Part 418. Subpart G—Mixed and Blend Fertilizer Production Subcategory. Washington, DC: EPA. Available at <http://www.gpoaccess.gov/cfr/index.html>

Annex A: General Description of Industry Activities

Ammonia-based nitrogenous fertilizers manufacturing activities include the production of ammonia (NH_3), urea, nitric acid (HNO_3), ammonium nitrate (AN), calcium ammonium nitrate (CAN), ammonium sulfate and mixed nitrogen fertilizers, such as urea compounds (e.g., urea-ammonium sulfate (UAS), urea aluminum sulfate), obtained adding sulfur compound (ammonium sulfate or aluminum sulfate) to the urea melt, and urea ammonium nitrate (UAN) liquid fertilizers (28, 30 or 32 percent N).

Ammonia

Natural gas reforming with steam and air is the simplest and most effective method used to produce ammonia synthesis gas, and is commonly used by the industry.

Ammonia is produced by an exothermic reaction of hydrogen and nitrogen. This reaction is carried out in the presence of metal oxide catalysts at elevated pressure. Catalysts used in the process may contain cobalt, molybdenum, nickel, iron oxide/chromium oxide, copper oxide/zinc oxide, and iron. The ammonia product in liquified form is stored either in large atmospheric tanks at temperature of -33 degrees centigrade, or in large spheres at pressures up to 20 atmospheres at ambient temperature. The raw material source of nitrogen is atmospheric air and it may be used in its natural state as compressed air or as pure nitrogen from an air liquefaction plant. Hydrogen is available from a variety of sources such as natural gas, crude oil, naphtha, or off gases from processes such as coke oven or refineries.

Ammonia production from natural gas includes the following process steps: removal of trace quantities of sulfur in the feedstock; primary and secondary reforming, carbon monoxide shift conversion, removal of carbon dioxide, methanation, compression, ammonia synthesis, and ammonia product

refrigeration. Carbon is removed in the form of concentrated CO_2 , which can be used for urea manufacture or other industrial purposes to reduce its release to the atmosphere.

Another form of ammonia production is through partial oxidation of heavy fuel oil or vacuum residue. Two other non-conventional processes include:

- Addition of extra process air to the secondary reformer with cryogenic removal of the excess nitrogen
- Heat-exchange autothermal reforming²⁴

Liquefied ammonia from production plants is used either directly in downstream plants or transferred to storage tanks. From storage, the ammonia can be shipped to users by road tanker, rail tank car, or ship. One of three methods are typically used for ammonia storage:

- Fully-refrigerated storage in large tanks with a typical capacity of 10,000 to 30,000 tons (up to 50,000 tons). The tanks can be single containment single-wall tanks with bunding, double containment tanks with two vertical walls, or full containment closed storage tanks with two walls;
- Pressurized storage spheres or cylinders with a capacity up to about 1,700 tons;
- Semi-refrigerated tanks.

Urea

The synthesis of urea involves the combination of ammonia and carbon dioxide at high pressure to form ammonium carbamate, which is subsequently dehydrated by the application of heat to form urea and water. The first step is fast and exothermic and essentially goes to completion under reaction conditions used

²⁴ This process route is a recent technology which is under development and has some environmental advantage because of the reduced need for firing in the primary reformer and the potential to lower energy consumption.

industrially. The second step is slower and endothermic, and does not go to completion. Conversion (on a CO₂ basis) is usually in the order of 50-80 percent and increases with increasing temperature and NH₃/CO₂ ratio.

Two commercial stripping systems are used: one using CO₂ and the other using NH₃ as the stripping gases. The urea solution arising from the synthesis/recycle stages of the process is subsequently concentrated to an urea melt for conversion to a solid prilled or granular product.

With the prilling technique, the concentrated (99.7 percent) urea melt is fed to a rotating bucket/shower-type spray head located at the top of the prilling tower. Liquid droplets are formed which solidify and cool on free fall through the tower against a forced or natural up-draft of ambient air. The product is removed from the tower base to a conveyor belt. Cooling to ambient temperature and screening may be used before the product is transferred to storage. Mean prill diameters typically range from 1.6-2.0 millimeters (mm) for prilling operations. Conditioning of the urea melt and "crystal seeding" of the melt may be used to enhance the anti-caking and mechanical properties of the prilled product during storage/handling.

With granulation, a less concentrated (95-99.7 percent) urea feedstock is used. The lower feedstock concentration allows the second step of the evaporation process to be eliminated and simplifies the process condensate treatment. This process involves the spraying of the melt onto recycled seed particles or prills circulating in the granulator. Air passing through the granulator solidifies the melt deposited on the seed material. Processes using lower concentration feedstock require less cooling air since some heat is dissipated from urea crystallization as additional water evaporates. Usually, the product leaving the granulator is cooled and screened prior to transfer to storage. Conditioning of the urea melt prior to spraying may also be used to enhance the storage/handling

characteristics of the granular product. Aqueous formaldehyde injection may be used for incorporation of formaldehyde in the final product as a conditioning agent at levels varying from 0.05 - 0.5 percent.

Nitric Acid

The production stages for nitric acid manufacture include the following: vaporizing liquid ammonia; mixing the vapor with air and burning the mixture over a platinum/rhodium catalyst; cooling the resulting nitric oxide (NO) and oxidizing it to nitrogen dioxide (NO₂) with residual oxygen; and absorbing the nitrogen dioxide in water in an absorption column to form nitric acid. Larger-capacity plants normally have dual-pressure design (i.e., medium-pressure combustion and high-pressure absorption), while smaller plants may have combustion and absorption conducted at the same pressure. High pressure in the absorption column reduces the nitrogen oxide (NO_x) emissions, although catalytic reduction is needed to meet commonly applied emission limits.

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

Ammonium nitrate (AN) is used extensively as a nitrogenous fertilizer, although it is also used as an explosive. Ammonium nitrate is produced by the reaction between gaseous ammonia and aqueous nitric acid. The production process comprises three main unit operations: neutralization, evaporation, and solidification (prilling and granulation). Neutralizers may be free-boiling vessels, circulating systems, or pipe reactors. Ammonium nitrate solution from neutralization may be used in various ways, in down-stream plants, sold as such and formed into solid ammonium nitrate by prilling or granulation. Ammonium nitrate is mixed with a solid filler, mainly calcium carbonate (limestone or dolomite), added prior to the formation of the droplets, when Calcium Ammonium Nitrate (CAN) is being produced.

The evaporator removes almost all the water in the AN solution to the acceptable water content relevant to the process used in the manufacture of the finished product (normally below 1 percent for a prilled product up to 8 percent for the feed to some granulation processes). Ammonium nitrate feed is processed through a prilling plant.

During granulation in rotary pans and drums, "Spherodizers", pugmills and fluidized beds, hot concentrated solution of AN is sprayed. No further drying of the granules is normally required. The granules are screened and the fines and crushed oversize are returned to the granulator.

Granular products, containing either ammonium or calcium sulfate, are also manufactured. The final solid fertilizer products may leave the production site either as loose bulk or in a variety of pack sizes.

Ammonium Sulfate

Formerly, ammonium sulfate ((NH₄)₂SO₄) was produced synthetically through the direct reaction of ammonia with sulfuric acid and other industrial processes, such as reaction between ammonium carbonate (NH₄CO₃) and calcium sulfate (Ca₂SO₄). Currently, the main volumes of ammonium sulfate are produced as a by-product from caprolactam, acrylonitrile, SO₂ abatement, and coke production.

In synthetic production, ammonium sulfate crystals are formed by combining anhydrous ammonia and sulfuric acid in a reactor and circulating the ammonium sulfate liquor through a water evaporator. The crystals are separated from the liquor in a centrifuge and fed either to a fluidized bed or to a rotary drum dryer and are screened before bagging or bulk loading.

In acrylonitrile and caprolactam production, excess ammonia/sulfuric acid are reacted with sulfuric acid/ammonia, producing an ammonium sulfate solution that can be sold as

fertilizer. Crystallization is the only way to obtain solid reusable ammonium sulfate. The ammonium sulfate recovery section also includes facilities to allow the removal of organics and catalyst fines.