AMMONIUM NITRATE SAFETY
SUMMARY REPORT OF THE WORKSHOP HELD ON
30 JANUARY – 1 FEBRUARY 2002, ISPRA, ITALY

M. Wood and S. Duffield

From 30 January to 1 February 2002 the Major Accident Hazard Bureau of the European Commission's Joint Research Centre in Ispra, Italy hosted a workshop on ammonium nitrate safety. The workshop was specifically convened to address concerns raised about current practice relative to prevention of ammonium nitrate incidents following the catastrophic incident on 21st September 2001 at the Grande Paroisse site in Toulouse, France. The incident killed 30 people, 8 of whom were outside the establishment, and injured over 2.500 - a number of them very seriously – and caused material damage provisionally thought to be between €1.5 and 2.3 billion. The purpose of the workshop was to review current theory and practices for preventing industrial incidents involving ammonium nitrate with the view to strengthening existing technical and policy measures.[1]

Approximately 90 representatives of government and industry attended the workshop, representing over 20 different countries. With the exception of Luxembourg, all Member States were represented. Additionally, there were representatives from Norway, Switzerland, two accession countries (Estonia and Lithuania), Canada and the United States. Participation was almost evenly divided between government and industry, and also included specialists from research organisations. Experts from both the fertiliser and explosives industries were present.

The expected outcome of the workshop was to review and generate a common understanding of ammonium nitrate hazards and related hazard reduction strategies among industry and government experts. In particular, the workshop aimed to focus on the properties of ammonium nitrate as they related to potential causes of chemical incidents, the conditions under which these properties might present significant risk, and the recommended strategies for reducing the risk and preventing such incidents. This information could then be used to form a consensus on what further measures, at the government level and in the private sector, might be necessary to reduce risks associated with ammonium nitrate.

The programme opened with a presentation from the French competent authorities on the preliminary findings and recommendations derived from their investigation of the Toulouse incident. Various experts from industry and competent authorities followed with presentations on other relevant incidents and experiences, best practices and research findings pertaining to ammonium nitrate. A final set of presentations

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[1] Note: This document aims to summarise the workshop information and results for participants as well as stakeholders who were not present. It is intended to aid policy discussions and general risk communication efforts. For this reason the information on ammonium nitrate safety presented herein is of a general nature. It is not technical guidance and should therefore not be considered as a technical reference on the safe management of ammonium nitrate or its hazardous properties. For those who require this type of information for practical purposes, Annex 2 contains a list of appropriate sources.

focused on current regulatory and research efforts for reducing ammonium nitrate risk.

Preliminary Findings and Recommendations of the Toulouse Investigation
France, represented by the Ministry of Environment, began its presentation with a discussion of immediate actions taken by the French government in response to the incident. By the time of the workshop, it had already deployed various measures to substantially increase the level of government resources devoted to control of major hazards in the future. In addition, the government, under the auspices of the Ministry of Environment, had just completed an in-depth and broad-based reflection on the adequacy of current French and European laws and practices for controlling major hazards, including industry practices. The effort specifically targeted management and inspection practices applied to ammonium nitrate hazards, and management of land use planning around existing hazardous installations (all substances). As an important input to the reflection, the French government hosted a series of national and regional debates in autumn 2001 to learn and discuss the principal concerns and recommendations of various stakeholders, at national, regional and local level, resulting from the Toulouse incident.

The preliminary results of investigation of the incident were another important input to the process of reflection. A number of separate inquires of the Toulouse investigation had been undertaken by various parties, including the Ministry of Environment's General Inspectorate and Parliament. The workshop presentation focused on the findings of the General Inspectorate's investigation[2], and included a technical analysis provided by the French research institute, Institute National de l'Environnement Industriel et des Risques (INERIS).

As described in the presentation, the Grande Paroisse factory is situated on a 70 ha site to the south of Toulouse about 3 km from the city centre on the left bank of the Garonne river. It employs 470 people. The factory produced fertilisers and a variety of chemical products. From natural gas, the factory produced ammonia (1150 t/d) then nitric acid (820 t/d), urea (1,200 t/d) and ammonium nitrate. The factory also produced various other chemicals. The production of ammonium nitrate consisted of 850 t/d of granules for fertilisers, 400 t/d of granules for industrial use (mainly for the manufacture of ammonium nitrate/fuel oil explosive used in quarries and civil engineering) and nitrogenous solutions (1,000 t/d). The hazardous substances stored at the plant consisted of ammonia (both cryogenically and under pressure), chlorine and ammonium nitrate compounds (in bulk, sacks and hot solution). Next to or within close proximity to the installation are three other chemical manufacturing facilities and an explosives manufacturer.

Important findings from the General Inspectorate's investigation include the following:

- It is not yet known what caused the explosion. Given the storage conditions and type of ammonium nitrate stored at the source of the blast, it is thought that a source of energy would have been required to detonate the substance. The report could not speculate on the nature of the energy source.

[2] Barthelemy, F., Hornus, H., Roussot, J., Hufschmitt, J-P., and Raffoux, J-F. Accident on the 21st of September 2001 at the Grande Paroisse factory in Toulouse. Report of the General Inspectorate for the Environment. Ministry of Environment. Affair no. IGE/01/034. Paris, France. 24 October 2001.

- An analysis of the consequences of the explosion based on the distortion of various structures, damage to the buildings, broken windows, suggests that the power of the explosion was comparable to that of 20 to 40 tonnes of TNT. Between 40 and 80 tonnes of ammonium nitrate would have had to have detonated in order to produce such a blast.
- The explosion produced a crater measuring about forty metres in diameter and seven metres in depth in relation to the natural ground.
- The Northern part of the site was devastated and this led to the destruction of a number of tanks containing ammonium nitrate solution and nitric acid causing pollution of the Garonne river. The tank containing a hot solution of 95% ammonium nitrate was damaged but did not leak.
- There was no domino effect beyond these impacts; nearby facilities storing pressurised ammonia, liquid ammonia and chlorine were not severely affected.
- The amount of material damage outside the site was considerable. Some neighbouring buildings were destroyed and further away many were badly damaged. Windows were broken at a distance of several kilometers from the place where the explosion occurred.
- The explosion occurred in a storage facility for discarded "off-spec" product, that is, product that did not meet established product specifications. The facility was authorised for 500 t and contained between 300 and 400 t of the product on the day of the explosion.
- The running of the building was supervised by Grande Paroisse's dispatch department and sub-contracted to outside firms.
- The day before the explosion 15 to 20 t of ammonium nitrate containing an additive that had been manufactured and was at the qualification stage were brought into this building. Also, products resulting from the packing of ammonium nitrates and from the manufacturing workshops were brought into this store.

Following the investigation report, the French government authorised the inspection of all plants and storage facilities with quantities of ammonium nitrate exceeding the upper tier threshold under Seveso II. The purpose of the inspections was to identify and correct any failures in management of ammonium nitrate risks at these facilities. In addition, two technical work groups, composed of representatives of the professional employers' federation and manufacturers, three expert bodies, inspectors of classified facilities, and other organisations, were convened to analyse and produce recommendations for improving current practices aimed at reducing ammonium nitrate risks. One work group focused on practices at production installations, including any on-site storage facilities, the other on stand-alone storage facilities, i.e., those not part of a production site. The inspection and work group activity arrived at a disturbing conclusion: that production and storage installations fail, in the majority of cases, to identify the risks associated with sub-standard ammonium nitrate products, and consequently they do not address these risks at all, or at the most, manage the risks very poorly. Therefore, it was further concluded that this category of product must receive specific and explicit consideration in regulatory classification schemes that play a role in preventing ammonium nitrate incidents.

Supported by these findings, from the Toulouse incident and subsequent studies, the French authorities presented a set of issues pertaining to ammonium nitrate for the experts to consider and address within the workshop, including the adequacy of ammonium nitrate coverage under Seveso II, the adequacy of safety regulations and practices applied to off-spec ammonium nitrate products, and the adequacy of risk assessment and inspection practices for managing ammonium nitrate risks. They also urged improvement in information exchanges between Member States on the risks associated with ammonium nitrates and the launching of a European-level debate on appropriate measures for reducing ammonium nitrate risks in ports and marshalling yards.

Following the French presentation, various presenters from the European Fertilizer Manufacturers Association (EFMA) and European competent authorities contributed expert knowledge relative to the social and economic importance of ammonium nitrate, its properties and potential hazards as well as practices and regulations in use to control the hazards.

Ammonium Nitrate: Production and Economic Importance

As a substance, ammonium nitrate[3] has a long history (it was first produced in 1659). It is a "dual-use" substance from which either fertilisers or explosives can be produced. It is produced at a large scale throughout the world (over 20 million tons in 1998) with over a third of this production based in Europe (over 7 million tonnes in 1998). It is without doubt important for western society. It is an easily absorbed and efficient source of nitrogen for plants and particularly suitable to growth conditions of the European climate. Its efficient absorption rate means that it is relatively friendly to the environment relative to other manufactured fertilisers; the amount of nitrogen lost to the atmosphere is normally low.

Commercial products made from ammonium nitrate, as a raw material, can be classified within two main categories, with very specific processes and uses, one being high-density prills or granules used as fertilisers (marketed in France as *ammonitrate*, referring to the French NFU 42-001 norm), and the other being low-density porous prills or granules (named "industrial or technical ammonium nitrate"), mainly used for the production of ANFO (Ammonium Nitrate+Fuel Oil) explosives.[4,5]

[3] Terminology: For the purposes of this paper, the term "ammonium nitrate" refers to all forms of ammonium nitrate substances and preparations. The term "ammonium-nitrate based fertilisers" encompasses ALL such fertilisers regardless of AN content. "Straight-N fertilisers" refers to fertilisers with >80% ammonium nitrate content by weight. When the information presented applies to a specific class or classes of ammonium nitrate, these will be identified more specifically, e.g., by the name of the type or class. In some cases, for simplicity's sake, the abbreviation AN will sometimes be used to denote "ammonium nitrate".

[4] UNIFA (The Association of French Fertiliser Manufacturers). The safety of AN-based fertilisers. Issue paper. Paris, France January 2002

[5] It should be noted that the products involved in the Toulouse explosion were products not complying with the commercial standards of these two categories, and ammonium nitrate from diverse recycling procedures. It is quite probable they did not comply with the specifications of the French NFU 42-001 norm.

The fertiliser industry further divides ammonium nitrate-based fertilisers into three types A, B and C. In addition, industrial grade ammonium nitrate compounds are sometimes classified as type D. Type A fertilisers contain the highest concentrations of ammonium nitrate (AN).

Chemically speaking, both products essentially contain ammonium nitrate, but their physical forms are very different, producing different effects.

Ammonium nitrate-based fertilisers are dense and non-porous. This structure helps preserve their intrinsic physical properties throughout their life cycle, from production to crop spreading, including passage through intermediate storage and various distribution channels. They show a low absorption potential for contaminants, and a high resistance to detonation. In contrast, ammonium nitrate used for the production of explosives is purposely produced with a high porosity, for better oil absorption, which results in a higher sensitivity to detonation, as is desirable for ANFO production.

Potential Hazards Associated with Ammonium Nitrate[6]

Ammonium nitrate has a complex behaviour and not surprisingly has undergone extensive research as a chemical substance. There are three main hazards associated with ammonium nitrate: fire due to its oxidising nature, decomposition and explosion. The most important parameters that influence the presence of the hazard are particle (prill, granule) size, particle density/bulk density/porosity, purity, nitrogen content and confinement.

Fire

Ammonium nitrate itself does not burn. As an oxidiser, however, it can support combustion and intensify a fire even in the absence of air, but only as long as fuel or combustible matter is also present. Gases are then emitted, especially nitrogen oxides and ammonia, both toxic. Indeed, the toxic effects (oxides of nitrogen [NOx], the most toxic of which is NO_2) of a fire currently dominate the risk assessments because the frequency of an explosive event is considered to be very low. In addition, ammonium nitrate melts at 169°C, when pure. The melting absorbs some of the energy received and the melted product often flows away and escapes the external energy source.

Decomposition

Pure ammonium nitrate can undergo thermal decomposition if it receives enough energy. Gases are then emitted, especially nitrogen oxides and ammonia, both toxic. With proper ventilation, the decomposition stops as soon as the energy flow stops. The decomposition rate is not dangerously high at moderate temperatures, and the overall thermal effect is not significant since the exothermic reactions are accompanied by endothermic disassociation, which can in turn give rise to a steady state reaction provided the gases produced can escape freely and the system is adiabatic. The decomposition is catalysed by a number of substances such as chlorides, which can affect the above balance.

[6] A more detailed account of hazards and safe storage associated with ammonium nitrate-based fertilisers exists in the *Handbook for the Safe Storage of Ammonium Nitrate Based Fertilizers* (EFMA, 1992).

Due to this catalytic effect, certain types of compound fertilisers (i.e., NPK) containing nitrogen, phosphate and potassium chloride can exhibit self-sustaining decomposition behaviour. Moreover, under certain conditions, the presence of combustible materials may also lead to a spontaneous heating reaction as the materials are slowly oxidised. If the initial temperature is high enough, thermal decomposition of the fertiliser may result.

Explosion

Ammonium nitrate can produce an explosion by one of three mechanisms: heating in confinement[7], run-away reaction, and detonation. Heating in confinement is a risk when ventilation is inadequate. The rapid decomposition of the ammonium nitrate leads to a considerable pressure build-up that can eventually cause an explosion. Also, ammonium nitrate in the molten state is more sensitive to initiation than the solid material.

A runaway reaction is achieved when the heat generated by the reaction exceeds the heat loss by a dangerously high margin. For pure ammonium nitrate, these circumstances are difficult to achieve given its low decomposition rate and endothermic effect when unconfined.

Uncontaminated ammonium nitrate is very difficult to detonate. Neither flame, nor spark nor friction can cause a detonation. Initiation by shock wave requires a large amount of energy. The degree of resistance is strongly dependent on the presence of voids or bubbles in the substance, hence the bulk density, and the degree of contamination by organic matter or fuel.

Another very important factor is the minimum dimension or diameter of the ammonium nitrate charge. As the size of the ammonium nitrate bulk heap or stack increases, its vulnerability to detonation increases. The critical charge diameter is the minimum diameter necessary to sustain a detonation. High density ammonium nitrate has a very large critical charge diameter making fully fledged detonation in storage very difficult, >7m at a bulk density of $1.0 g/cm^3$. It is therefore very resistant and can only be detonated by a strong stimulus and very close confinement.

[7] Note: "Confinement" has a specific technical meaning in this context. For example, under certain conditions aqueous solutions of ammonium nitrate, can produce a type of "confinement" that increases the sensitivity of ammonium nitrate to of detonation. To avoid producing this and other unsafe conditions, detailed technical guidance on safety management practices for ammonium nitrate should be consulted.

Table 1. Significant Accidents Involving Ammonium Nitrate - Post 1950[8]

Date/Place	Activity/Description	Product	Accident Type/Casualties
1954 Red Sea	**Sea Transport.** Fire in ships hold, AN fertiliser + paper + organic/copper product. Explosions, ship abandoned and destroyed.	AN Fertiliser	Fire, Explosion No injury
1960 Traskwood, USA	**Rail Transport.** Wagons derailed, fire. Hydrocarbons conc. nitric acid and AN involved. Explosion.	AN Fertiliser	Fire, Explosion No injury
1963 Traskwood, USA	**Rail Transport.** Derailment, oil spillage + fire. AN involved. No explosion.	AN Fertiliser	Fire No injury
1966 USA	**Storage**. AN fertiliser, also pesticides and combustible materials. Fire. Smoke affected fire fighters. Explosion.	AN Fertiliser	Fire, Explosion No injury
1967 USA	**Rail Transport**. 50 t AN in paper bags in wagons with wooden interior, fire, left to burn out.	AN Fertiliser	Fire No injury
1973 USA	**Storage**. Severe fire in AN store of wooden structure, fuel tank in payloader. Difficulty with fire fighting. A few tonnes of AN exploded. Main heap – 14000 t, unaffected. .	AN Fertiliser	Fire, Explosion No injury
1978 USA	**Storage**. 500 t AN in a warehouse fire. Store burnt out completely. No explosion.	AN Fertiliser	Decomposition (SSD) Fire No injury
1982 UK	**Storage**. Major fire, wooden furniture stored near AN fertiliser, toxic fumes released. 750-1000 evacuated. Deflagration in AN.	AN Fertiliser	Fire No injury
1998 Kentucky, USA	**Storage**. A warehouse with 4000 t AN in basement on fire; allowed to burn out. 2 explosions believed to be in propane cylinders. 2500 evacuated. No injury.	AN Fertiliser	Fire No injury
2000 Florida, USA	**Road Transport.** Collision between AN truck and gasoline tanker. AN truck driver killed due to collision. Fire allowed to burn out.	AN Fertiliser	Fire 1 killed (impact)
1963 Holland	**Storage.** 4000 t of NPK in bulk store, SSD, release of toxic fumes.	NPK Fertiliser	Decomposition (SSD)
1965 Atlantic Ocean	**Sea Transport.** SSD in NPK load, water applied. Load shifted causing boat to capsize.	NPK Fertiliser	Decomposition (SSD) 3 drowned
1975 Germany	**Storage**. SSD in bulk NPK initiated by welding, 1000 residents evacuated.	NPK Fertiliser	Fire, Explosion No injury
1987 France	**Storage**. SSD in bulk 1450 t NPK. Major release of toxic fumes. 20,000 local residents evacuated. Bulk AN not affected.	NPK Fertiliser	Decomposition (SSD) No injury
1988 Yugoslavia	**Storage**. SSD in bulk NPK. 17000 t in storage. 12000 residents evacuated.	NPK Fertiliser	Decomposition (SSD) No injury
1972 Australia	**Road Transport.** Semi-trailer with low density AN on fire, also oil load, too remote for fire fighting. Explosion.	AN Industrial	Fire, Explosion 3 killed
1997 Brazil	**Road Transport**. Truck loaded with AN caught fire and stopped on side of a narrow road. A petrol tanker tried to pass, caught fire and exploded. Subsequent AN detonation probably triggered by an exploding propane bottle on the trailer. A coach full of passengers was parked close to the scene of incident. Several passengers fatally injured.	AN Industrial	Fire, Explosion Several passengers fatally injured.
1972 France	**Road Transport.** AN solution tanker. Decomposition in lagging. Contaminated with organics & AN, explosion, hot AN solution released.	AN Solution	Explosion 2 fatally burnt

[8] Heather, David. A review of past ammonium nitrate accidents and lessons learned. European Fertilizer Manufacturers Association. Presentation at the "Workshop on Ammonium Nitrate". 30 January to 1 February, 2002. European Commission Joint Research Centre. Ispra, Italy.

Low density ammonium nitrate is relatively much more sensitive to detonation. It has a much smaller critical charge diameter and requires a correspondingly much smaller booster for detonation.

The ammonium nitrate content also effects the explosive potential. Research has shown that the explosion hazard is reduced if the ammonium nitrate content is limited to, for example, 90% (31.5%N), with a further reduction if this limit is lowered to 80% (28%N). It must be recognised however, that a potential explosion hazard (although somewhat reduced), still remains. Historically 28% N i.e. 80% AN appears to have been used as a threshold at which material is assumed to have significant explosive properties, although it has not been possible to determine the precise basis for this figure. This uncertainty about the precise cut-off point was a factor in solutions proposed during workshop discussions on how to strengthen measures to prevent ammonium nitrate incidents.

The phenomenon of Deflagration to Detonation Transition (DDT) can develop in a large fire or violent decomposing mass, given the right conditions. However, both pure and contaminated (or fueled) ammonium nitrate require very high pressures for this to occur. This condition is not likely to be met in normal storage. Nonetheless, it is important to mention that, even in so-called normal storage conditions, decomposition of the ammonium nitrate can still occur.

In summary, the two principal major accident hazards associated with solid ammonium nitrate are:

(i) Emission of toxic gases, principally oxides of nitrogen (NO_x), resulting from thermal decomposition

(ii) Explosion, resulting from rapid deflagration, or detonation

Accident History

Ammonium nitrate has been involved in numerous accidents, either explosions or fires releasing toxic fumes. The accidents occurred in fixed installations as well as during transport. While in the period before 1950, a number of very serious explosions involving a high number of fatalities occurred ("Oppau", 1921, over 500 dead), through new anti-caking treatment techniques and better controls, accidents with fatalities diminished drastically after 1950. Today, an accident like the one in Toulouse must be considered a "high consequence" but "low probability" event.

That the Toulouse incident did occur, however, illustrates that there is still a misperception in some quarters that safe handling and storage of ammonium nitrate requires little vigilance once proper conditions are initially established. Moreover, the influence of particular factors on the stability of ammonium nitrate is perhaps less widely appreciated than it should be. In fact, the incident suggests that there is a distinct possibility that the complexity of the behaviour of ammonium nitrate is underestimated by many facility operators, more so than previously thought.

Table 2: Ammonium Nitrate Classifications [9,10]

Type/UN Classification General Description	Chemical Composition	Hazardous Properties	Principles of Safety
Fertiliser Type A **UN/ADR Class 5.1** Ammonium nitrate and ammonium nitrate-based high nitrogen fertilisers—High density, low porosity	**A 1** Mixtures of ammonium nitrate with added matter which is inorganic and chemically inert towards ammonium nitrate. ≥ 90%[11] AN and ≤ 0,2% of total combustible material > 70% but < 90% AN and ≤ 0,4% of total combustible material **A 2** Mixtures of ammonium nitrate with calcium carbonate and/or dolomite with >80% but < 90% and ≤ 0,4% of total combustible material **A 3** Mixtures of ammonium nitrate/ammonium sulphate with >45% but ≤ 70% AN and ≤ 0,4 % combustible material **A 4** Mixtures containing nitrogen/phosphate or nitrogen/potash with > 70% but < 90% AN and ≤ 0,4 % of total combustible material	– Oxidising – Non-combustible – May decompose – High resistance to detonation	– avoid contamination – avoid sources of fire/heat – avoid sources of explosion – avoid confinement
Fertiliser Type B **UN/ADR Class 9** NPK (nitrogen-phosporus-potassium compounds) fertilisers	Non-segregating mixtures containing: – nitrogen (nitrate)/phosphate or nitrogen (nitrate)/potash or – complete fertilisers containing nitrogen (nitrate)/phosphate/potash with ≤ 70% AN and ≤ 0,4% of total added combustible material, – or with ≤ 45% of AN with unrestricted combustible material	– decomposes when heated – self-sustaining decomposition (continues even when heat source is removed) – **Note:** If the UN Trough Test shows that a Type B fertiliser does not have a risk of self-sustaining decomposition, the fertiliser is classified as Type C.	– avoid contamination – avoid sources of fire/heat – avoid confinement
Fertiliser Type C **Unclassified** Fertilisers not capable of self-sustained decomposition, e.g., ammonium nitrate mixtures with calcium carbonate, dolomite, ammonium sulphate, or potash (depending on nitrogen content)	– Mixtures of AN with calcium carbonate and/or dolomite containing ≤ 80% AN and ≤ 0,4% total combustible material – Mixtures of ammonium nitrate/ammonium sulphate containing ≤ 45% AN and ≤ 0,4% total combustible material – Fertilisers conforming to the Type B composition and which do not exhibit the property of self-sustaining decomposition	– decomposes when heated – decomposition stops when heat source is removed	– avoid contamination – avoid sources of fire/heat – avoid confinement
Industrial Grade Explosive **UN/ADR Class 1** Low density, high porosity prills – combined with fuel oil	– Ammonium nitrate (AN) with more than 0,2 % combustible materials – AN- fertilisers with sensitivity greater than ammonium nitrate with 0,2 % combustible materials – Explosive preparations of AN	– detonates after rapid decomposition (deflagration to detonation) – detonates due to external shock or heat source	– avoid contamination – avoid sources of explosion – avoid sources of fire/heat – avoid confinement

9 Van Balken, Hans. Best practices for storage and handling of ammonium nitrate fertilizers. European Fertilizer Manufacturers Association. Presentation at the "Workshop on Ammonium Nitrate". 30 January to 1 February, 2002. European Commission Joint Research Centre. Ispra, Italy.

10 This chart contains only general information on hazardous properties and best safety practices. For detailed guidance, please consult the Handbook for the Safe Storage of Ammonium Nitrate Based Fertilizers and other sources of practical guidance listed in Annex 2.

11 All percentages refer to concentrations by weight.

Safety Principles

The hierarchy of safety measures prioritises best practices in the order of inherent safety measures first, followed by measures aimed at accident prevention, controlling accident severity and mitigation of accident effects. For ammonium nitrate, inherent safety is the leading purpose of manufacturing specifications relative to the porosity, prill size, amount of combustible material and other properties that affect the hazard potential of ammonium nitrate.

Beyond inherent safety, several recommended management practices are aimed at accident prevention, including:

- Elimination/minimisation of the presence of combustible materials and incompatible substances (such as explosives) in close proximity to the ammonium nitrate. For example, storage buildings should be kept free of debris and clutter, maintaining clean floors and generally good housekeeping. Co-storage of combustible materials in the same location is discouraged. It was mentioned that the elimination of combustible materials in a stack could be reasonably accomplished following the increasingly popular use of 'big bags', i.e., up to 1 tonne polypropylene fabric containers. The European Ammonium Nitrate Directive 80/876 in fact requires supplies to the final user to be in packaged form to minimise the risk of contamination.

- Control of ignition sources. For example, hot work, smoking, vehicle maintenance and similar activities should not take place within close proximity of the stored materials. Location of electric equipment should be considered carefully if allowed at all.

- Avoidance of moisture absorption.

In terms of incident control, one practice recommended is to limit stack size. Such limits seek to avoid the possibility that the diameter of a pile will exceed the critical charge diameter of the ammonium nitrate product. Another practice is to avoid strict confinement of the storage area; proper ventilation limits the progress of decomposition should it occur.

Best practices for handling and storing ammonium nitrate have been the subject of ongoing study and research for years within industry, government and academia. Revision and publication of best practices is generally led by the various fertiliser industry associations throughout the world although many government authorities also publish guidelines. It is an ongoing challenge to ensure that all operators of ammonium nitrate manufacturing and storage facilities are aware of and have accurate information on the hazardous properties of ammonium nitrate. That all such facilities have access to new information concerning ammonium nitrate, such as improvements to existing practices, testing methods, and hazard alerts is an equally demanding task.

Legislation and Regulation

Recognising that there are different forms of ammonium nitrate, the existing legislative and regulatory regimes seek to permit only very detonation-resistant forms and mixtures of ammonium nitrate as fertilisers. In addition, safety regulations, for example, the Seveso II

Directive also promote safety by imposing greater safety requirements on the manufacturers and distributors that handle them.

Regulations at the European Level

Ammonium nitrate-based fertilisers have stringent controls under European law. The European Directive 80/876/CE, adopted in 1980, is intended to ensure that straight nitrogen fertilisers containing more than 80% ammonium nitrate comply with safety specifications relative to their physicochemical properties, and to guarantee that they are particularly safe as regards the risk of explosion. Various physico-chemical criteria are specified, such as limits concerning porosity, amount of combustible material contained, pH, size grading, maximum levels of chlorine and copper contained. Substances conforming to these requirements are allowed to be labelled as "EEC Fertilisers". EEC ammonium nitrate-based fertilisers can only be supplied to the final user in packaged form, in recognition of the risk of contamination associated with bulk quantities. Annex II of the legislation describes the EU detonability test, which is not mandatory in all member states and can be used to verify the resistance to detonation.

The Seveso II Directive covers ammonium nitrate as a named substance, listing it in two categories according to two separate definitions and corresponding thresholds. The first category applies to industrial-grade ammonium nitrate, assigned a lower-tier threshold of 350 tonnes and an upper-tier threshold of 2,500 tonnes. The second category applies to ammonium nitrate fertilisers with > 28% nitrogen content, assigned lower-tier and upper-tier thresholds of 1,250 and 5,000 metric tons respectively.

The UN/ADR (Accord Européen Relatif au Transport International des Marchandises Dangereuses Par Route or European Agreement concerning the International Carriage of Dangerous Goods by Road) classifies both ammonium nitrates and industrial-grade ammonium nitrate as Class 5.1, "Oxidising". Sea shipments must pass the UN's resistance to detonation test, which has been made identical to the EU detonation test.[12]

The European Directive 96/61/EC of 24 September 1996 concerning integrated pollution prevention and control (IPPC) contains a requirement to implement best environmental practices for ammonia acids and fertilisers. The IPPC Directive is framework legislation with the goal of achieving a high level of protection for the environment as a whole. Production facilities covered under the Directive can only receive operating permits if they meet the conditions for applying "best available techniques" (BAT) to address environmental and safety concerns. The European Commission is currently leading expert work groups charged with developing best available technology reference documents (BREFs) for covered industries.

Chemical installations for the production of basic inorganic chemicals, which includes ammonium nitrate and ammonium nitrate-based fertilisers, are required to comply with the IPPC Directive. Moreover, the Directive specifically requires that prevention of accidents and mitigation of their consequences be taken into consideration when determining appropriate BATs. Hence, it is expected that the IPPC Directive will provide additional

[12] A detailed account of safety tests designed for ammonium nitrate-based fertilisers exists in the handbook *Selected Tests Concerning the Safety Aspects of Fertilizers* (EFMA, 1992).

reinforcement for the application of best safety practices in ammonium nitrate production facilities.

Table 3. Legislation for Ammonium Nitrate and Ammonium Nitrate Preparations

UN ADR[13] Class 5.1 Oxidisers:	Establishes requirements for transport of oxidising substances and preparations in Europe, including ammonium nitrate and ammonium nitrate preparations with $\geq$ 45% ammonium nitrate content by weight. These standards have been adopted into European Union legislation. *Verification Test:* UN Solid Oxidiser Test (note: not a mandatory test)
UN ADR Class 1 Explosives	Establishes UN standard for transporting explosive substances and articles in Europe These standards have been adopted into European Union legislation. *Verification (non-mandatory except as noted) Tests:* UN Detonation Test, 2(a) (Shock sensitivity) (mandatory for sea shipments) UN Koenen test, 2(b) (Heating under confinement) Time/pressure test, 2(c) (Ignition under confinement)
EU Directive 80/876/CE	Establishes requirements for marketing ammonium nitrates $\geq$ 28% nitrogen content by weight in Europe. Must meet criteria for porosity, combustible ingredients, pH particle size, chlorine and heavy metal content *Verification Test:* EU Detonation Test (not mandatory for marketing products under EU law, but mandatory in some Member States)
EU Directive 96/082/CE (Seveso II Directive)	Establishes requirements for controlling major hazards at industrial facilities, including installations that handle or store ammonium nitrate and ammonium nitrate compounds, and simple and composite ammonium nitrate-based fertilisers with > 28% nitrogen content.

Testing Methods

For certain ammonium nitrate fertilisers, mainly those which share Type A or B characteristics, sensitivity in relation to particular hazards cannot be ascertained solely by the composition and characteristics of the particular subject. Properties such as pH, size grading, porosity and other qualities may be strong indications of the presence, or the absence of a particular hazard, but not necessarily determinant. For this reason particular tests have been designed to ascertain various tendencies, in particular, detonation, heating in confinement, ignition in confinement and oxidation.

[13] Accord Européen Relatif au Transport International des Marchandises Dangereuses Par Route (European Agreement concerning the International Carriage of Dangerous Goods by Road).

Test methods specified by the international authorities and organisations, e.g. the United Nations, the European Commission and the International Maritime Organisation (IMO), are most commonly used within the Member States. Within the European Union, AN fertilisers are required to pass a detonation test (the EU Detonation Test) to be marketed as a European Community fertiliser ("EEC").

The UN tests for ammonium nitrate include the UN Solid Oxidiser Test (to determine the tendency towards oxidation), the IMO Trough Test (to test self-sustaining decomposition behaviour), and the IMO Resistance to Detonation Test (to determine detonation sensitivity).

In many cases, existing regulations, including the EU Directive 80/876/CE on Ammonium Nitrate, do not require that documentation of test results accompany transported products. The regulations rely on self-classification by the manufacturer or shipper based on the accepted testing protocols.

Some workshop experts also pointed out that incomplete understanding of the hazardous behaviour of ammonium nitrate, especially the contribution of particular characteristics of a substance, were responsible for some weaknesses in the available testing methods. For example, it was noted that it is still not possible to gauge degree of sensitivity to detonation using existing testing methods. The testing proves that a substance has tripped a particular pre-selected threshold of sensitivity, and not how close or how far from the threshold the actual sensitivity of the substance lies. It was generally agreed by the workshop that the EU detonability test was more rigorous than the UN detonability test.

Country comparison

The Member States present at the workshop each provided a brief description of the volume of trade and production of ammonium nitrate products and, in some cases, the legislative framework for preventing ammonium nitrate accidents. Norway, Estonia, Canada and Switzerland also gave brief reports on uses and practices associated with ammonium nitrate in their countries. In addition, there were also detailed presentations from Germany, the Netherlands and France, on ammonium nitrate safety in these Member States and the United Nations Environment Programme (UNEP) gave a presentation on community awareness of safety risks, including ammonium nitrate, in Europe and other regions.

All countries present had producers of ammonium nitrate or ammonium nitrate fertilisers operating within their borders. Many Member States stressed the need to improve safety practices in a way that would not impose significant additional costs on ammonium nitrate producers. The disappearance of ammonium nitrate producers from the EU could in fact create a greater safety risk, by increasing the circulation within the EU of non-EU ammonium nitrate products. It is often much more difficult for authorities to control and verify the quality of imports as opposed to products of EU origin.

There is also a common concern about risks associated with ammonium nitrate-based fertilisers (both straight-N and those with < 80% AN) in transit; products are often present in harbours and distribution centres in large quantities.

Some countries, such as Italy and Denmark, have only recently begun allowing ammonium nitrate-based fertilisers to be commercially distributed in their countries. The volume of fertilisers in these marketplaces has grown dramatically in the last ten years, approaching nearly 60.000 tonnes annually in Denmark and around 30-40.000 tonnes produced and 40.000 to 50.000 imported annually in Italy, for example. Some countries, such as Norway and Finland, still do not use straight-N fertilisers.

In addition, many Member States described safety provisions for ammonium nitrate that exceed requirements under European law, that is, the Seveso II Directive or the Ammonium Nitrate Fertilisers Directive. Testing requirements for safety of ammonium nitrate-based products also vary between Member States. In some Member States, such as France, the EU detonability test is mandatory and documentation must accompany product shipments. Belgium uses its own test, reportedly more stringent than that of the EU.

Austria
Legislation addressing ammonium nitrate safety in Austria dates back to 1935, however, special provisions are limited to the distance between stacks. Austria has four ammonium nitrate fertiliser plants; straight-N ammonium nitrate fertilisers are not used in Austria. Ammonium nitrate is also an ingredient in the production of laughing gas and chip boards. Production is often primarily via batch process and therefore, storage of unused ammonium nitrate is common. Hazards of contaminated products have not (up until now) been habitually considered within Seveso II assessments although they have been indirectly addressed through an emphasis on adherence to good housekeeping practices.

Belgium
In Belgium a quantity of 300 kg of ammonium nitrate is considered hazardous and requires a permit from local authorities. Handling of quantities $\geq$ 300 t of straight-N fertilisers requires a permit from the Ministry of Explosives. The EU detonation test is mandatory in these situations. The Belgian detonation test, arguably more rigorous than the EU test, is used to determine the classification of ammonium nitrate products intended for commercial distribution. Moreover, Belgium does not allow commercial distribution of straight-N fertilisers.

Denmark
Denmark has one site that produces NPK (and NP and NK) fertiliser but none of Type B classification. Straight-N fertiliser is not produced.

Finland
Use of ammonium nitrate-based fertilisers in Finland is generally low; and straight-N fertilisers are not used at all. A considerable volume of ammonium nitrate is also transported across Finnish roads and railways which is a safety concern.

Greece
Greece has one installation that produces ammonium nitrate-based fertiliser, including straight N fertiliser. This installation is classified as a top-tier site under the Seveso II Directive.

Ireland
Ireland regulates ammonium nitrate under the Explosives Act of 1875. This Act covers the manufacture, transport and storage of explosive substances and products. The law applies equally to those substances that the government has named as explosive, even if technically it is not sold as an explosive product. In 1972 ammonium nitrate was classified as an explosive for security purposes because it can be used in making bombs. Production or storage of ammonium nitrate requires a license; there is no minimum threshold.

Italy
In Italy straight-N fertiliser is classified as a dangerous substance. A 1999 decree requires the safe handling of such fertilisers and its provisions are aimed at preventing industrial incidents and ensuring public safety. Italian regulation also requires harbours that handle ammonium nitrate to adhere to strict safety requirements. Of the 150.000 t of ammonium nitrate products imported into Italy each year, approximately 110-120.000 enter via its harbours..

Norway
Importers from the United Kingdom and Eastern Europe must show the results of the UN detonation test. No serious accidents involving ammonium nitrate have occurred since the 1960's in Norway.

Portugal
Two establishments in Portugal produce ammonium nitrate: one produces $\geq$ 90% AN solution and the other produces an ammonium nitrate-based fertiliser of < 80% AN. The facilities are covered under Seveso II. No major concerns about ammonium nitrate handling have yet been raised in Portugal but in principle improved guidelines for best safety management practices would be supported.

Spain
Spain reported that ammonium nitrate is a widely used fertiliser in Spain an that it has four production plants in addition to products imported from Eastern European countries and Algeria. Spanish authorities are struggling to balance their concerns about the quality and safety of imported products against the expectations of the farmers who want to purchase fertiliser at low prices and are opposed to stringent measures for that reason. Spain is preparing a regulation that would make the EU detonation test mandatory in Spain, which would mean that fertilisers with high ammonium nitrate content placed on the market in Spain must be accompanied by documentation showing results of the detonation test.

Sweden
Sweden has one manufacturer of straight nitrogen, low-density fertiliser and it is covered under the Seveso II Directive. It also has several producers of ammonium nitrate-based fertilisers that must comply with certain safety requirements (relative to confinement, temperature increase and contamination), but are not covered under Seveso II. Permits are required for handling ammonium nitrate in quantities greater than 10 tonnes and no more than 50 tonnes per building is allowed.

In addition a substantial volume of straight nitrogen fertilisers is imported. Import volume has generally grown in the last ten years and at one point reached 200.000 tonnes. Currently the import volume is about 100.000 tonnes per year.

United Kingdom
The United Kingdom has 3 manufacturing sites and 10 storage sites where ammonium nitrate is used or handled that are classified as upper-tier sites under Seveso II. All dangerous substances on site must be addressed in the safety report and worst-case scenarios for each substance must be identified. The United Kingdom also has 20 lower-tier sites that handle ammonium nitrate products.

There is considerable legislation covering ammonium nitrate and intensive consultation between national and local authorities on safety distances in the United Kingdom regarding facilities that store and handle ammonium nitrate. In addition to Seveso II, UK legislation also requires port areas to adhere to particular safety requirements to prevent ammonium nitrate incidents. The UK has produced a best practice guidance document for ensuring the safe storage and handling of ammonium nitrate substances and the guidance can be used as a basis for enforcement decisions.

Switzerland
Switzerland has one facility that produces ammonium nitrate materials. It is covered under the Protection Against Major Accidents Ordinance which covers facilities handling ammonium nitrate in quantities greater than 20 t.

Estonia
Estonia has one fertiliser storage facility located in a harbour area. It is expected that it will be covered under the Seveso II Directive.

Canada
Canada currently regulates use and handling of ammonium nitrate under the National Fire Code of Canada. It is expected that future legislation at the national level and also in the province of Quebec will soon impose more stringent accident prevention and emergency response requirements on the storage and handling of ammonium nitrate. The proposed national legislation would impose a requirement on facilities with quantities above a certain threshold (proposals to fix the threshold somewhere between 1 and 50 tonnes were being discussed) to identify the quantity and location of dangerous substances on site and report on measures taken to prevent accidents and mitigate their effects. The proposed Quebec legislation is largely based on the U.S. Risk Management Program Rule, with similar reporting elements and focus on local risk communication and management.

The Regulatory Structure in Germany
Germany has a comprehensive regulatory structure for preventing ammonium nitrate incidents. Notably, requirements for ensuring safe handling of ammonium nitrate substances in storage (and transportation internal to a site) are particularly well-defined in the Dangerous Substances Law. The ammonium nitrate classifications provided under this law bear a close resemblance to the UN ADR classifications . According to this law, the threshold of application for Type A substances and for Types B through D are 100 kg and 1 tonne, respectively. Type D refers to aqueous solutions and suspensions of ammonium nitrate fertilisers which are not hazardous but capable to detonate in crystallised form. Safety requirements vary according to the sub-classification.

However, fertilisers with greater than 28% (80% ammonium nitrate content) by weight are no longer used in Germany; therefore, Type A fertilisers are practically non-existent. This exclusion means that no fertiliser production or storage installations fall under the Seveso II Directive. Germany has not had any major accidents involving ammonium nitrate for decades. The country has not noticed any adverse economic effects connected with the prohibition against Type A fertilisers.

As for safety requirements, certain general provisions apply to all types of ammonium nitrate substances. Requirements for Type A substances, which in Germany is usually industrial ammonium nitrate rather than fertilisers, also include a minimum safety distance. In addition, they establish minimum standards for pile size and thickness of barricades around the storage, and require notification to authorities. Some requirements are waived or reduced if the EU detonation test indicates the substance is not detonable.

Germany's Explosives Law contains additional safety provisions for industrial grade ammonium nitrate substances and other ammonium-nitrate substances that are highly explosive, including ammonium nitrate with more than 0,2 % combustible materials (UN-Nr. 0222) and ammonium nitrate-based fertilisers with a sensitivity greater than ammonium nitrate with 0,2 % combustible materials (UN-Nr. 0223).

The Federal Dangerous Goods Act and the Emission Control Law also contain provisions for preventing ammonium nitrate incidents. Notably, plants handling or storing more than 500 tonnes of ammonium nitrate are required to hold a public hearing prior to receiving approval under the Emission Controls Law.

The Dutch survey
Following the Toulouse incident, the Netherlands conducted inspections of all ammonium nitrate storage and production facilities. On the production side, four large fertiliser plants and ten plants for blending and coating were identified and inspected. No manufacturers of industrial-grade ammonium nitrate were identified. On the storage side, 20 distribution centres (bulk storage) and 300 shops (bagged storage) with ammonium nitrate-based fertiliser, 55 storage facilities for industrial-grade ammonium nitrate, a few transportation firms and users of industrial-grade ammonium nitrate (for NO_2 production) were identified and inspected.

On the production side, there appeared to be no serious detonation hazards and practices were by and large satisfactory. One plant was criticised for its handling of off-spec materials and a general finding was that there was not enough attention to the possible transformation of type C fertiliser into type B when type C-fertiliser is being coated or blended.

Regarding storage facilities and shops handling ammonium nitrate-based fertilisers, inspections revealed a wide range of situations. In some cases the storage conditions were excellent and operators showed a good knowledge of the hazards and appropriate hazard reduction strategies. In others, even basic knowledge about ammonium nitrate risks was lacking. In addition, some were located very near urban areas. However, there were no detonation hazards.

Among facilities storing and handling industrial-grade ammonium nitrate, general knowledge concerning the hazards and hazard reduction practices appeared to be severely lacking. Moreover, detonation hazards were identified at some of the warehouses. Also,

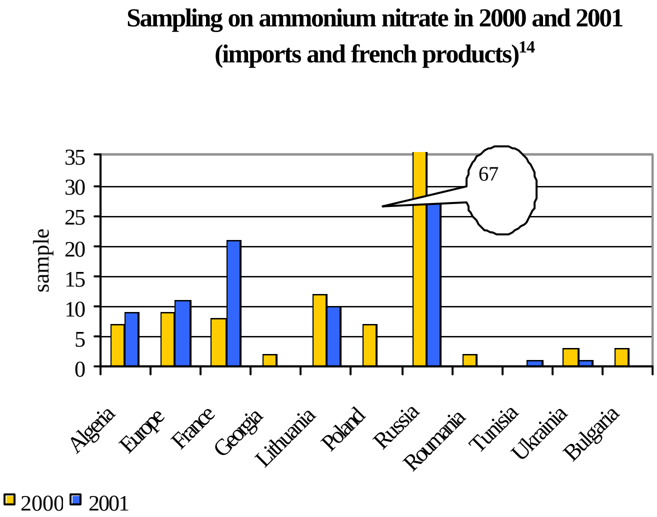

Figure 1

distances between storage facilities and surrounding urbanised areas proved to be sometimes in violation of national guidelines. Disturbing differences in testing methods applied to products ready for transport versus storage were uncovered. In general the inspections raised doubts about product quality, testing procedures and labelling (imports in particular).

France: Challenges in Ports and Marshalling Yards

France provided an overview of challenges it faced in regard to ports and marshalling yards and imported ammonium nitrate-based fertilisers. France receives imports from a number of countries within Eastern and Central Europe, including Russia, Lithuania, Poland, the Ukraine, Bulgaria, Georgia, and Romania, and also from Tunisia and Algeria. There are approximately six or seven ports, along the English Channel and the Mediterranean Sea, at which these products can first enter the country.

Documentation of the EU detonation test results must accompany high ammonium nitrate content fertilisers that are marketed in France. The French government operates an anti-fraud programme that verifies, by targeting and test sampling particular shipments, that labelling and documentation accompanying these imports are in conformance with French requirements. (French products passing through these distribution centres may also be tested.) Verification includes testing products for the detonability. France tests only a handful of the products that travel through its ports every year; however, these tests indicate a possible non-conformance rate of 10% or higher among shipped products overall, although this has declined somewhat from five years ago when 20% of all products tested failed compliance verification.[14] Products from both inside and outside Europe have been found to be out of conformance with the French law.

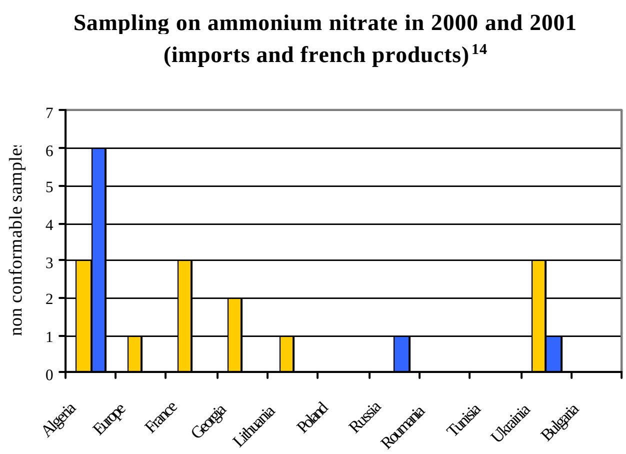

Figure 2

[14] Ambroise, J-J. Ammonium nitrate risks in ports and marshalling yards. Direction Générale—Concurrence, Consommation, et Répression des Fraudes (France). Presentation at the "Workshop on Ammonium Nitrate". 30 January to 1 February, 2002. European Commission Joint Research Centre. Ispra, Italy.

Similar to France, other countries showed concern about the authenticity of documentation, listing its various properties and verifying test results, accompanying imported shipments of ammonium nitrate products. Particular unease centred on the difficulty of assuring that the documentation was based on the actual product being shipped, rather than a product sample from another product batch whose specifications complied with legal requirements. In some countries the concern is intensified because the amount of imported fertilisers outweighs home production.

Awareness of Ammonium Nitrate Risks
The United Nations Environment Programme (UNEP) argued that the information needs of the users, the communities near processing plants and transport routes, and environmental regulatory authorities in general, should also be considered in decisions surrounding ammonium nitrate storage and production facilities. It suggested that there was little knowledge in the general public or even among key stakeholders about the hazard potential of ammonium nitrate or the Toulouse incident. Moreover, it was argued that successful sharing of technical information with these stakeholders could be a key contributor to the development of rational and effective prevention, mitigation and emergency response plans within communities. Review processes of complex technical information that is intended to improve public decision-making should thus include a community interface at an early stage. This inclusion would not necessarily aim to bring new scientific information into the debate. Rather, its central purpose would be to ensure that the review is viewed as credible, that the data is comprehensible to the public and that it considers also those questions that the community wants answered.

Practices and Policies for Controlling Ammonium Nitrate Hazards: Problems and Concerns
In their presentations (on the Toulouse incident and on ammonium nitrate imports), the French authorities raised several issues concerning current practices for preventing and mitigating the effects of ammonium nitrate incidents. In addition, various other experts, (for example, the Dutch authorities) reinforced the conclusions of the French authorities and also suggested further problems that should be addressed in light of the accident in France.

The following summarises the major problems and concerns raised at the workshop:

<u>Adequacy of risk assessment and inspection practices for ammonium nitrate production and storage facilities</u>**.** Following Toulouse the French authorities reviewed assessment and prevention practices to determine possible weaknesses in the current understanding of ammonium nitrate risks and in relevant risk-reduction strategies. From this review they concluded that current practices, both on the side of operators and inspectors, tended to overlook certain hazards associated with ammonium nitrate. Like the Dutch survey, they determined that risks associated with sub-standard or “off-spec” products were, in the majority of cases, not identified. Therefore, risk assessments of ammonium nitrate storage facilities did not take into adequate consideration the possibility that an off-spec product, removed into storage, may have a composition or structure that renders it more hazardous than the standard quality product. Consequently, the potential hazard was poorly addressed or not addressed at all.

Consistent with the Dutch findings, the French authorities also determined that many operators considered detonation of ammonium nitrate substances and preparations to be extremely unlikely. Before Toulouse, it was often excluded as a possibility in both risk assessments and inspections of ammonium nitrate production and storage facilities. The French authorities noted that the potential for detonation of ammonium nitrate is only present in unique conditions. However, it argued that consistent attention to this possibility, in risk assessments, safety reports and inspections, for example, would help to sustain efforts to prevent creation of these conditions. This view was generally supported by the other experts at the workshop.

Awareness of risks associated with ammonium nitrates where ammonium nitrate products are handled and stored. The French and Dutch studies pointed to the distinct possibility that awareness of the hazards surrounding ammonium nitrate, and particularly types of ammonium nitrate preparations and substances, may be far less widespread among facility operators than was originally thought. Despite the efforts of the fertiliser industry and competent authorities, safety management of ammonium nitrate storage in some facilities appears to be driven in good part by assumptions and misperceptions about the hazardous properties of ammonium nitrate and what should be considered safe conditions.

Moreover, it was thought that greater awareness in surrounding communities concerning the potential hazard associated with ammonium nitrate and appropriate strategies for reducing the hazard could be beneficial. In particular, such knowledge could provide for more balanced and informed decision-making involving these facilities within their local communities.

Identifying sub-standard products and associated hazards**.** From a technical standpoint, determining the hazard potential of ammonium nitrate products can also be challenging. The complex behaviour of ammonium nitrate has been the subject of rigorous research for decades but there are still factors contributing to this behaviour that are inadequately understood. Greater knowledge concerning the way in which some key factors, both intrinsic and extrinsic, function to influence the behaviour of ammonium nitrate could considerably enhance prevention efforts.

Notably, composition, although it is a strong indicator, is not an absolute indicator of hazard potential for a wide range of ammonium nitrate products. To compensate, test protocols have been developed and used with relative success, permitting judgements concerning hazard potential of particular products to be made with an acceptable certainty. Despite the effectiveness of the test protocols, their ability to provide detailed information on the degree and sensitivity of the hazard associated with an ammonium nitrate product is limited, thereby serving a narrow albeit essential function. At the workshop it was argued that precise and detailed information about the hazard potential of particular products will remain elusive until understanding of particular behavioural factors related to ammonium nitrate is improved.

Enforcing product standards aimed at hazard reduction**.** Several experts commented on the difficulty of identifying sub-standard products and their hazardous properties. For government authorities the problem is largely a practical one. The relatively high annual volume of ammonium nitrate fertiliser imports into Europe poses a significant challenge for government surveillance efforts. It particularly elevates the importance of enforcing European-wide standards of quality, with detonability standards being of highest concern. Detonation tests for ammonium nitrate products are not mandatory throughout the European Union at this time.

Moreover, in some Member States where detonation testing is mandatory, substandard products can still go unidentified by authorities. For example, it is not that difficult to swap test results from a product of acceptable detonability, over to that of another product that has failed the detonability test. Hence, these sub-standard products can enter the market under the guise of a higher quality product.

Proposed Improvements for Controlling Ammonium Nitrate Hazards

To address the above concerns, a number of possible improvements were introduced at the workshop. The workshop did not have time to fully debate many of these proposals and so in many cases the question as to whether they will be adopted in various guidelines or requirements was left open-ended. The following paragraphs summarise the alternatives presented.

Broadening Coverage of Ammonium Nitrate in the Seveso II Directive

Legislative recommendations aimed at broadening coverage by lowering the thresholds for specific categories of ammonium nitrate. This approach supported findings in recent French and Dutch studies that the potential for a serious ammonium nitrate hazard existed in a large number of facilities, many of whom were not covered by the Directive or whose Seveso classification did not depend on the basis of their ammonium nitrate content. This change would specifically provide greater assurance that appropriate management practices are applied in these facilities and rigorously verified by the competent authorities. It was acknowledged that this alternative would incur additional costs to industry.

Figure 3: Ammonium Nitrate Coverage in the Seveso II Directive

Column 1	Column 2	Column 3
Dangerous Substances	Qualifying quantity (tonnes) for the application of	
	Articles 6 & 7	Article 9
Ammonium nitrate	350	2500
Ammonium nitrate	1250	5000

NOTES

1 Ammonium nitrate (350/2500)

This applies to ammonium nitrate and ammonium nitrate compounds in which the nitrogen content as a result of the ammonium nitrate is more than 28% by weight (compounds other than those referred to in Note 2) and to aqueous ammonium nitrate solutions in which the concentration of ammonium nitrate is more than 90% by weight.

2. Ammonium nitrate (1250/5000)

This applies to simple ammonium-nitrate based fertilizers which comply with Directive 80/876/EEC and to composite fertilizers in which the nitrogen content as a result of the ammonium nitrate is more than 28% in weight (a composite fertilizer contains ammonium nitrate with phosphate and/or potash).

The principal proposals can be summarised as follows:

- Range of Coverage. It was suggested that the Seveso Directive be expanded to cover all ammonium nitrate, ammonium nitrate compounds, simple ammonium nitrate-based fertilisers, and composite fertilisers (e.g., NPK), even if nitrogen content as a result of the ammonium nitrate is less than 28% by weight. This proposal would address two issues: it would reduce risk associated with the uncertainties surrounding conditions that make ammonium nitrate sensitive to detonation, and it would promote best practices to reduce potential for contamination that could lead to detonation. In addition, this proposal included the possibility for maintaining higher thresholds for packaged products (sacks, big bags), in the assumption that they are much less susceptible to contamination, therefore less likely to encourage detonation, than loose product.

- Off-spec products. A further suggestion was to submit all sub-standard (off-spec) products explicitly to the Seveso II Directive assigning them threshold levels consistent with those of generic explosive substances threshold (Category 5), 10 and 50 tonnes for the lower and upper tier, respectively. In this way, facilities that maintain stores of discarded sub-standard product would be required to comply with the Seveso II Directive. Such a modification would close a perceived gap in Seveso II coverage, which currently ignores the existence of large stocks of off-spec ammonium nitrate product.

- Classification as an Explosive. Another proposal was to broaden the scope of Seveso II such that ammonium nitrate and Type A1 ammonium nitrate fertilisers would be classified as Category 5 Explosives. Such a modification would lower the thresholds for these substances from 350/2500 tonnes (lower/upper tier) to 10/ 50 tonnes.

  Making thresholds for industrial grade ammonium nitrate (Type D) equivalent to Category 5 Explosives was also proposed. This suggestion was supported in part by the Dutch survey which observed poor awareness and application of effectiveness prevention practices in facilities storing industrial grade ammonium nitrate.

- Classification as an Oxidiser. Alternatively, it was suggested that Type A ammonium nitrate substances and preparations be categorised as Category 3 Oxidisers, lowering thresholds to 50/200 tonnes (lower/upper tier).

Improving Product Quality Assurance
Two standards predominantly influence the hazardous properties of ammonium nitrate products within the European Union, the UN ADR protocol for transportation of dangerous goods and the EU Directive 80/876/CE specifying minimum product standards. In particular, these Directives impose safeguards to prevent products with explosive potential from being transported or entering the marketplace, thereby exposing the public to the hazard.

Both the UN and the EU frameworks have established a specific detonability test that the authorities must use if testing is required to verify that particular products meet detonability standards. However, manufacturers and shippers are not currently obligated to produce test results on detonation potential for ammonium nitrate products under both the UN protocol and EU law (although some Member States require it).

It was thus proposed that the EU detonability test should become mandatory for all ammonium nitrate products intended for market in the European Union (necessitating a modification to EU Directive 80/876/EC). It was acknowledged that such testing would represent an additional cost, possibly significant, to the industry.

A second proposal was to replace the UN detonation test with the EU detonability test in the UN ADR protocol, as the EU test was generally recognised by the workshop experts as the more rigorous test. A desire to encourage research to improve the usefulness of the EU test was also indicated. Such research would focus on furthering understanding of the parameters (i.e., physical properties) that influenced the explosive potential of ammonium nitrate.

Modifying Product Standards

In addition to suggestions encouraging limited nitrogen content of ammonium nitrate products, there was also a suggestion to fix or encourage a minimum prill density (1.00g/cc) for ammonium nitrate fertilisers. This proposal was based on findings that detonability depends strongly on the relationship between critical diameter (of a stack) and prill density. Low densities have low critical diameters; moreover, critical diameter changes dramatically in proportion to small increments of change in prill density (as little as an 0.1g/cc change can have a proportionally large effect on the size of the critical diameter). By fixing minimum prill size, the maximum safe stack diameter can also be fixed. Thus installations would not have to individually calculate appropriate stack sizes; rather safety would be a simple matter of maintaining stack sizes within the pre-set limit. It was noted that such an approach, if adopted, would require many companies to reconfigure their product formulas. Furthermore, this provision would have no impact on the safety of sub-standard products.

Improving Safety Practices

Another set of proposals centred on strengthening industry best practices for preventing ammonium nitrate incidents. A general suggestion was made to modify the current EFMA guidelines to more fully address the hazard potential of contaminated and sub-standard products. Furthermore, it was suggested that the EU should officially adopt a set of recommended safety guidelines for ammonium nitrate, most probably based on EFMA guidelines. In addition, it was thought that safety report requirements and inspection policies of competent authorities under Seveso II should generally be modified to acknowledge hazards associated with ammonium nitrate and ammonium nitrate fertilisers.

In line with these proposals was a suggestion to establish an “EEC mark” for ammonium nitrate production and storage facilities, that would be awarded to particular installations that demonstrate adherence to strict safety and product quality standards.

Furthering Research Efforts

Various topics centering on properties of ammonium nitrate preparations and the handling of such preparations were acknowledged to merit further study, including:

- The stability of ammonium nitrate, in particular, its compatibility with other chemicals, and sensitivity to impurities and contaminants,
- New fertilisers, for example, complex fertilisers with high ammonium nitrate content,
- Mechanisms of explosive decomposition,
- Propensity of ammonium nitrate to detonate from molten AN to AN granules in bulk.

Improving Public Understanding of Ammonium Nitrate Hazards
There was a suggestion that the workshop could play a role in increasing public acceptance of government and industry efforts to address the Toulouse incident and, more generally, ammonium nitrate hazards. At the same time the information presented in the workshop might be of use in risk management decisions at the local level communities and by other stakeholders not present at the workshop. It was therefore proposed that the presentations and results from the workshop be made publicly available via the Internet. It was also suggested that future expert discussions about legal requirements and best practices surrounding ammonium nitrates should include stakeholders from the public domain.

Workshop Recommendations
Against this background, the following actions were decided at the workshop:

– The fertiliser industry (mainly represented by EFMA) would, within the eight to ten weeks following the workshop, present guidance on the safe handling and storage of "off spec" materials. Furthermore, the existing EFMA and international guidance would be revised in a multi-stakeholder approach (involving public authorities and environmental NGOs) with a view to integrate the different existing and missing elements (missing are, for example, chapters on sub-contracting, information to the public and compliance monitoring) into a safety management system. This activity might take 1 to 1 ½ years. Moreover, the topic of safe production, handling and storage of ammonium nitrate will be worked into the BREF for Large Volume Inorganic Chemicals under preparation in the EIPPC Bureau in Seville.

– The ongoing codification of around 25 different pieces of legislation on fertilisers into one single Directive is ongoing (COM(2001) 508 final). This encompasses Council Directive of 15 July 1980 on the approximation of the laws of the Member States relating to straight ammonium nitrate fertilisers of high nitrogen content (80/876/EEC). The French delegation would propose in Council to render the detonation test described in Annex II of this directive mandatory. It was also recognised that the actual test method is rather burdensome and that research should be carried out to develop new test methods.

– The current definition and threshold levels for ammonium nitrate in the Seveso II Directive should be revised in order to take better account of both the detonation potential and the fire hazard of fertilisers. A proposal for a modification would be introduced which can then be taken into account in the revision of the scope of the Seveso II Directive currently underway.

– Workshop proceedings, including presentations and papers and the final report, will be placed on the website of the Major Accident Hazards Bureau at the European Commission. Links to the web page to the web sites of other expert organisations will be encouraged, such as that of UNEP's APELL (Awareness and Preparedness for Emergencies on a Local Level) Programme.

Annex 1: A list of the workshop presentations
Annex 2: A list of scientific and technical publications relevant to ammonium nitrate safety

ANNEX 1

PRESENTATIONS

Workshop on Ammonium Nitrate
30 January to 1 February 2002
European Commission, Joint Research Centre, Ispra, Italy

An hierarchy of control measures for the storage and handling of ammonium nitrate
Adams, W. David. Health and Safety Executive, United Kingdom

Practices for managing ammonium nitrate risks (United Kingdom)
Adams, W. David. Health and Safety Executive, United Kingdom

The toxic effects from a fire involving ammonium nitrate
Adams, W. David. Health and Safety Executive, United Kingdom

Ammonium nitrate risks in ports and marshalling yards
Ambroise, Jean-Jacques. Direction Générale--Concurrence, Consommation, et Répression des Fraudes, France

Public involvement in regulation of ammonium nitrate: The role of the APELL process
Balkau, Fritz. United Nations Environment Programme

The major hazard in Toulouse September 21st, 2001.
Gilbert, Dominique. Ministère de l'Aménagement du Territorie et de l'Environnement, France

Memorandum of the French authorities and the General Inspection report
Gilbert, Dominique. Ministère de l'Aménagement du Territorie et de l'Environnement,, France

Range of actions undertaken within this industrial sector after the major hazard: Proposals
Gilbert, Dominique. Ministère de l'Aménagement du Territorie et de l'Environnement,, France

Bibliography survey and laboratory tests on ammonium nitrate thermal decomposition
Granger, Jean-François. Grand Paroisse, France (EFMA)

The best available techniques reference document (BREF) for large volume inorganic chemicals – ammonia acids and fertilisers
Harrison, Andrew. European Commission

A review of past ammonium nitrate accidents and lessons learned
Heather, David. Fertilizer Manufacturers Association, United Kingdom (European Fertilizer Manufacturers Association --EFMA)

Ammonium nitrate safety tests
Kiiski, Harri. Kemira Agro, Finland (EFMA)
Legard, Torbjorn. Norsk Hydro, Norway (EFMA)

Analysis of explosion effects further to the accident of 21 September 2001 in Toulouse
Kordek, Marie-Astride. INERIS, France

Grande Paroisse plant : buildings 221-225
Kordek, Marie-Astride. INERIS, France

Ammonium nitrate fertilizer grade : Liability to detonation
Kordek, Marie-Astride. INERIS, France

Research program on ammonium nitrate (INERIS)
Kordek, Marie-Astride. INERIS, France

Regulations for storage and transportation of ammonium nitrate and fertilisers based on ammonium nitrate in Germany
Michael-Schulz, Heike. Bundesanstalt für Materialforschung und -pruefung (BAM), Germany

Ammonium nitrate storage (Canada)
Reiss, Robert. Environment Canada

Ammonium nitrate: production and economic importance, properties and potential hazards
Shah, Kish D. Terra Nitrogen Ltd., United Kingdom (EFMA)

Best practices for storage and handling of ammonium nitrate fertilizers
Van Balken, Hans. European Fertilizer Manufacturers Association, Belgium

Detonation properties of ammonium nitrate
Van Der Steen, Albert. TNO Prin Maurits Laboratory, The Netherlands
Kersten, Ronald. TNO Prin Maurits Laboratory, The Netherlands
DeJong, Ed. TNO Prin Maurits Laboratory, The Netherlands

Ammonium nitrate production and storage in the Netherlands: The Dutch policy on safety
Van der Veen, H. Ministry of Environment, The Netherlands
Uijt de Haag, P. National Institute for Public Health and the Environment. The Netherlands.
Bottelberghs, P. H. Ministry of Environment. The Netherlands.

The "Toulouse" follow-up from a European perspective: Update on DG-Environment actions
Wettig,Jürgen. European Commission.

Additional papers

Dr. Andrzej Kolaczkowski assisted in the review of this document and provided the following study as an additional reference on this subject:

Kolaczkowski A., Pekalski A., Meissner Z., *Estimation of the liability to detonating of prilled ammonium nitrate,* J. Loss Prevention, 13/6, 2000, pp. 555-561].

Annex 2

Technical Guidance

UK Health and Safety Executive

Storage and Handling of Ammonium Nitrate Fertilisers. Health and Safety Executive. United Kingdom. 2001. http://www.hse.gov.uk/pubns/indg230.pdf

European Fertilizer Manufacturers Association/International Fertilizer Industry Association

Handbook for the Safe Storage of Ammonium Nitrate Based Fertilizers. European Fertilizer Manufacturers Association, Brussels. International Fertilizer Industry Association. Paris 1992.

Selected Tests Concerning the Safety Aspects of Fertilizers. European Fertilizer Manufacturers Association, Brussels. International Fertilizer Industry Association. Paris 1992.

Best Available Technique Series for production of ammonium nitrate products. European Fertilizer Manufacturers Association, Brussels. 2000.

No. 1 Ammonia
No. 2 Nitric Acid
No. 3 Sulphuric Acid (updated in collaboration with ESA)
No. 4 Phosphoric Acid
No. 5 Urea and Urea Ammonium Nitrate (UAN)
No. 6 Ammonium Nitrate (AN) and Calcium Ammonium Nitrate (CAN)
No. 7 NPK Compound Fertilizers by the Nitrophosphate Route
No. 8 NPK Compound Fertilizers by the Mixed Acid Route

These guidance documents can be downloaded from the website of the European Fertilizer Manufacturers Association. http://www.efma.org/ *Ordering information for hard copies of the document is also available. Also see the website of the International Fertilizer Industry Association* http://www.fertilizer.org/ifa/ *for additional publications.*

European Directives

Council Directive 80/876/EEC of 15 July 1980 on the approximation of the laws of the Member States relating to straight ammonium nitrate fertilizers of high nitrogen content. Official Journal L 250, 23/09/1980 P. 0007 – 0011. For more information please visit the website of DG-Enterprise (European Commission) http://europa.eu.int/comm/enterprise/chemicals/fertilizers/fertil.htm.

Council Directive 96/82/EC of 9 December 1996 on the control of major-accident hazards involving dangerous substances. Official Journal L 010, 14/01/1997 P. 0013 – 0033. For more information please visit the website of the Major Accident Hazards Bureau (European Commission) http://mahbsrv.jrc.it/Framework.html

Council Directive 96/61/EC of 24 September 1996 concerning integrated pollution prevention and control. Official Journal L 257 , 10/10/1996 P. 0026 – 0040. For more information, please visit the website of the European Integrated Pollution Prevention and Control (IPPC) Bureau at http://www.jrc.es/