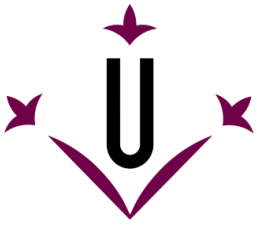

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Commentary

Future of ammonium nitrate after Beirut (Lebanon) explosion

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Dear Editor,

Ammonium nitrate (NH_4NO_3) is a chemical compound that is mostly found as a colorless and/or white to gray crystalline solid, odorless beads, and easily soluble in water. The molecular weight, specific gravity, melting, and boiling point of NH_4NO_3 are 80.06, 1.725 g cm, 169.51 ^oC, and 210 ^oC, respectively (Rao, 2014). Higher temperature (> 210 ^oC) easily decomposes NH_4NO_3 and producing toxic gasses, especially nitrogen oxides, and may also cause an explosion (Han et al., 2015). At room temperature, pure NH_4NO_3 neither flammable or combustible, but when heated, normally, it is decomposed into non-explosive gases such as oxygen. Nevertheless, it can also be decomposed into explosive material by detonation (Xia et al., 2019). Ammonium nitrate is strongly oxidant that easily detonates under certain circumstances, which include higher temperature (> 210 ^oC), confinement, and impurities (Health Safety Executive, 2004).

By 2050, we will have an estimated 9-10 billion mouths to feed. Considering that more than 2 billion already rely on nitrogen (N) fertilizer and reactive N inputs to agriculture, our ability to meet continuing growth in demand will be somewhat determined by our ability to enhance yields through effective N use. Therefore, reactive N is going to be essential. Nitrogen is considered an essential element for plant growth and different processes, for example, photosynthesis. Ammonium nitrate is widely used as a nitrogenous chemical fertilizer in the agriculture sector due to its high concentration of N content (34%). It is also used in insecticides, herbicides, as a freezing mixture, an absorbent for N oxides, an oxidizer in rocket propellants, and a nutrient for antibiotics and yeast production (Rao, 2014).

On the other hand, NH_4NO_3 is not officially classified as an explosive, however, under certain conditions it is possible to detonate; compounds of this kind are unofficially marked as "tertiary explosives". Ammonium nitrate is used in blasting the rocks, quarrying, mining, and in civil construction (Oommen and Jain, 1999). When NH_4NO_3 mixes with fuel oil, formed ANFO (ammonium nitrate fuel-oil), and it is considered the main component for industrial explosive material production (Marlair and Kordek, 2005). Almost 80% NH_4NO_3 explosive materials used in North American countries due to its low cost and high stability, and this material has also been used in improvised explosive devices (The National Academies and The Department of Homeland Security, 2005). Different organic and inorganic N impurities such as urea, guanidinium salts formate, sodium, phosphate, potassium, and carbonate may also change the thermal stability of NH_4NO_3. Particularly, contaminants of potassium chloride may play a catalytic role in the decomposition of NH_4NO_3.

Different types of hazard that is associated with NH_4NO_3 are SSD (self-sustained decomposition), explosion, and fire. Detonation ability of NH_4NO_3 under strong impulse has been associated with a number of industrial disasters. The first-ever blast that happened on April 2, 1916, a factory in Uplees, Faversham, UK, where 700 tons of NH_4NO_3 was stored. The blast at the Explosives Loading Company killed 115 people. In 1921, in Upper Silesia at the releasing of the sintered ammonium saltpeter from the wagon by means of the classic blasting with dynamites several wagons with this saltpeter blew up but the largest disaster in the chemical industry took place on September 21, 1921 in a factory that manufactured fertilizers in Oppau: the sintered nitrate fertilizer (equimolar mixture of NH_4NO_3 and ammonium sulphate) was disintegrated by means of 25 blast holes and after more than 20,000 successful blasting operations, a detonation of 4500 tons of the fertilizer took place and 509 people were killed, 1917 persons were injured and

1,036 buildings were totally destroyed in the town Oppau (the crater was 96 m wide, 165 m long and 18.5 m deep). Exactly 80 years after the explosion in Oppau, i.e. on the morning of September 21, 2001, in the French company AZF (Azote de France) in Toulouse about the 390-450 tons of the 'off-spec' NH_4NO_3 exploded in the storage area of the company (Dechy et al., 2004) (there was speculation about sabotage). On Dec. 1994, a massive explosion laid to waste the production of NH_4NO_3 at Terra Industries (including killing of the four managers) due to a thermal explosion of a 65 w/w % solution of NH_4NO_3 (Kirschner, 1994). The high content of chlorides in this solution, its aeration, its acidity, and its local overheating might be causes. Prof. Kolaczkowski presented a study (Kolaczkowski et al., 1981) in which he calculated that spontaneous degradation is capable of already the 55 % solution of NH_4NO_3 provided that the appropriate catalyst for this happening is present. It is widely known that chlorides, chromates, ferric cations, cobalt and acid compounds have a synergetic effect on the NH_4NO_3 decomposition while sulphates and urea have inhibiting influence here (Manelis, 2003). On April 17, 2013, in West Fertilizer Plant, Texas, USA, that was associated with 270 tons of NH_4NO_3 and killed 15 people with > 250 people injured (West Fertilizer Plant, 2013). On August 12, 2015, Chinese authorities claimed the first explosion had been triggered when the summer heat caused a highly flammable compound called nitrocellulose to spontaneously ignite. In this blast, approximately 800 tons of NH_4NO_3 stored near the seaport of Tianjin, China. The explosion caused 110 casualties, with 798 people wounded.

The more recent blast happened on August 4, 2020, in the Beirut, Lebanon, where 2,750 tons of the explosive NH_4NO_3 stored at a warehouse near to seaport for six years without proper safety controls. Till now, at least 220 people were killed, 7,000 wounded, and hundreds have been reported missing in a massive explosion, and the blast caused up to US$10–15 billion USD worth of damage (CNN, 2020). If the 2,750 tons figure is

accurate, that would make the NH_4NO_3 explosion larger than the 1947 Texas City Disaster, when a consignment of 2,300 tons of ammonium nitrate exploded, killing nearly 500 people (Texas, 1947).

Normally, it is considered that NH_4NO_3 is a valuable chemical fertilizer that helps to produce healthy food for humans, but it must be handle responsibly. As the world is suffering from the Covid-19 pandemic, in this crisis world can't bear any other crisis. According to the Mordor Intelligence report, the market for NH_4NO_3 is expected to grow up to 4%, particularly in the agriculture industry by 2025. Due to this growing consumption, proper precautionary measurements should be adopted to avoid explosive blast like Beirut to save the human lives as well as other infrastructure losses. The world must need to give proper attention and consideration to overcome this big concern. For this, we are recommending precautionary measurements that are ordinary but must be adopted now.

Every government should have to do proper legislation at the country level about NH_4NO_3 production, storage, transportation, and uses. Firstly, we should recommend that the manufacturing of NH_4NO_3 should be banned, but "if necessary," then all fertilizer manufacturing plants should be located outside the urban towns. Moreover, agricultural and chemical scientists should prepare a proper alternative source of NH_4NO_3 to avoid explosive blasts without disturbing the crop yield. Each government at the country level should ban the manufacturing of NH_4NO_3 for explosive materials, particularly in improvised explosive devices. Anyone who is handling NH_4NO_3 should be fully advised with the nature of the hazardous chemical material. Proper labeling and storage can also overcome NH_4NO_3 explosions. For storage, fireproof sprinklered buildings with concrete floors should be used, but these warehouses should not be located near the urban towns. To prevent the thermal decomposition, the average temperature within any NH_4NO_3

container cannot be exceeded 54.4 ^{o}C and should be checked carefully. Last but not least, "if we really need NH_4NO_3, then we just need to pay good attention to what we're doing with it to save the human lives as well as the atmospheric environment."

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