This report has been updated on the 18th of December 2018 to include a disclaimer and foreword.

Background

The following report was completed for the International Baccalaureate Middle Years Programme (IB MYP) Chemistry (Grade 11) at Fairview International School Subang, Malaysia on 18th November 2016.

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18 November 2016

How fertilizer has changed the world

Plants are important to our daily lives. From photosynthesis, the process in which plants get food from by taking in Carbon Dioxide, Water and Sunlight comes the Oxygen that we need to stay alive and all the way to the food we eat and what animals eat as well. Plants will grow without any fertilizers, but it is important to know that plants all do not grow as tall or big as we desire and do not live as long as we desire either. Fertilizers play a very important part in our lives. Without fertilizers, we would forever be stuck on the four crop rotation system. First invented in medieval times, it was invented when the peasants observed that that certain staple crops at that time such as wheat, clover, turnips and barley would not grow extremely big, tall or more in numbers during certain periods of the year. They could observe that each period of the year, the weather was different as well. Therefore, they made a conclusion that the type of crop suitable for a good harvest was determined by the season. It was a successful system as it did increase the yield of crops. This was because the soil quality was different during the various seasons. When scientists started to study agriculture, they believed that humus (the organic matter that came from decomposed parts of plants grown in that soil before) were great contributors to plant nutrition. In the early 1850s, Chemist Justus von Liebig (1803–1883) was the first to denounce the theory of humus contributing greatly to the plants' nutrition and growth, stating that ammonia was important for plant growth as it

contained Nitrogen and he later publicly promoted how important inorganic materials were to plant growth. Liebig's work succeeded in exposition of questions for agricultural science to address over the next 50 years. In England, he attempted to implement his theory commercially through a fertilizer created by treating lime phosphate in bone meal with sulfuric acid, but he failed because it was not properly absorbed by crops. The crops couldn't absorb any of the bone meal because the soil was very alkaline, and the sulfuric acid inside only neutralized the soil. Bone meal will only be absorbed into the soil if the pH levels of the soil are below 7.0 (acidic soil) (Colorado State University, 2011). At that time in England, Sir John Bennet Lawes (1814–1900) was also experimenting with ways to improve plant nutrition and growth, but this time, organically. Using dead crops and manures at his farm at Harpenden and was able to produce a practical superphosphate in 1842 from the phosphates in rock and coprolites. He employed Sir Joseph Henry Gilbert, who had studied under Liebig at the University of Giessen, as director of research. To this day, the Rothamsted research station the pair founded still investigates the impact of inorganic and organic fertilizers on crop yields. In France a few years later, Jean Baptiste Boussingault (1802–1887) pointed out to people that the amount of nitrogen in various kinds of fertilizers is important, as Nitrogen was a key element required for all life forms and it gave a boost in height and size growth. Later on in 1927 is Norway, Erling Johnson developed an industrial method to produce nitrophosphate, which became to be known as the Odda process after his Odda Smelteverk of Norway. The process involved acidifying phosphate rock with nitric acid to produce Phosphoric acid and Calcium Nitrate ($CaNO_3$) which, once neutralized, could be used as a nitrogen fertilizer.

The Nitrogen based fertilizers which are made from Ammonia (NH_3) that we most commonly use and know today are made via only one process: The Haber Process, or less popularly called The Haber-Bosch Process. The Haber Process combines Nitrogen from the air with Hydrogen that is derived mainly from natural gas (methane) into ammonia. The reaction is reversible and the production of ammonia is exothermic. The process needs to occur at a high temperature and high pressure of around 200 times normal pressure (200 atm) in order for Nitrogen and Hydrogen to react. To speed up the reaction, Iron can be used as a catalyst. However, At each pass of the gases through the reactor, only around 15% of the Nitrogen and Hydrogen will turn into Ammonia. The rest are recycled over and over again until there is no more left. When the gasses are cooled down below 100°C, the Ammonia will turn to liquid state where it can be used as fertilizer directly via injection into the ground, or it can be used as a feedstock for all other Ammonia-based fertilizers, such as Ammonium Nitrate (NH_4NO_3), Diammonium Phosphate ($(NH_4)_2HPO_4$) and Anhydrous Ammonia (Ammonia Vapor). The Haber Process is quite expensive to perform as pipes that can withstand high pressure are required to be used in the manufacturing plant and there is a high maintenance cost as well. This reaction is reversible, meaning Ammonia can be turned back into Nitrogen and Hydrogen.

There are two types of fertilizers: Organic and Synthetic. Organic fertilizers are formed from decomposed plants and bodies of organisms that were once alive (e.g. fossils) and Synthetic or inorganic fertilizers are mainly comprised of gasses and chemicals. Decomposers such as fungi, which are bacteria that feed on live organisms that have died are able to turn organisms into inorganic compounds. An example of organic fertilizers would be

cow manure, which is commonly used in less developed countries as fertilizer in farms as synthetic fertilizer is too expensive to produce, import and purchase. One example of inorganic fertilizers would be Anhydrous Ammonia (Ammonia Vapor). This is one of the most commonly used type of fertilizer today. Ammonium Nitrate is actually the most widely used fertilizer in the world today, but with safety concerns towards it regarding the fact that it can be used as an explosive, the usage of it is slowly declining. Diammonium Phosphate is another fertilizer, which however can only be used in acidic soils as it will immediately reverse its reaction back into Ammonia under alkaline soil conditions. In long term usage, it will also make the soil more acidic naturally and therefore potentially do more harm than good. Anhydrous Ammonia is widely used as well as a fertilizer in many farms around the world, but as it is a vapor and a highly flammable one, transport for it is expensive and it reacts with the nutrients found in the soil to turn into a white vapor the moment it is pumped in.

Synthetic fertilizers are more easily and cheaply available than organic ones due to the fact that for organic fertilizers, the yield cannot be manipulated as much as like synthetic fertilizer manufacture. Towards the environment, synthetic fertilizers do much more harm than organic ones from manufacturing all the way to when they are injected into the farm soil. During the manufacturing process, harmful chemicals may be released as a result of chemical reactions. When we eat the food that has been injected or sprayed with these fertilizers, these chemicals, some harmful to our body if we take in too much, enter our bloodstream as well. On the other hand, organic fertilizers such as compost (heaps of dead plants or plant parts) and manure are in no way harmful to the environment at any time, and they contain quite a good amount of nutrients. Although in no way do they contain the same

amount of nutrients as opposed to synthetic fertilizers, they are still able to increase crop yields and boost plant growth. Overall, they are also safer to the health of humans as they all come from naturally occurring processes.

Fertilizer has changed the world in many ways. One major is our environment. The amount of crops yielded and plants grown have increased rapidly ever since the development of fertilizers and the way the world looks has changed as more and more parks can be opened at an ever expanding rate. However, manufacture of synthetic fertilizers have also contributed to greenhouse gas emissions and they have changed soil pH levels and landscapes. Fertilizer has also improved the economy of the world as without fertilizers, the farming industry would not progress that far due to long crop season rotations, and countries in tropical climates or countries with one season all year round wouldn't easily be able to grow food.

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