Fertilisers and Nutrient Pollution: Analytical Essay

Introduction and Importance

In modern agriculture, chemical fertilisers are increasingly significant to food security, which is related to sustainability concerns in society. Chemical fertilisers are artificial compounds produced from non-renewable sources with the exact ratio of nutrients required by plants. With the burgeoning global population, using fertilisers is an effective way of decreasing harvesting time and maintaining the availability of food to consumers. However, excessive and inefficient use of fertilisers leads to negative long-term effects to soil structure and plants themselves. The nutrients contained in fertilisers may contain harmful substances including toxic heavy metals, which are not needed by plants (Savci, 2012). This leads to eutrophication and pollution as they are leached into waterways. Therefore, this review is important because eutrophication promotes the rapid growth of algal blooms on the surface of the water, which reduce dissolved oxygen and release toxins, disrupting the ecosystem and killing aquatic animals. In addition, the unabsorbed nitrogen lowers the pH of soil and makes it more acidic, making the soil in the area less favourable to other crops and reducing the nutritional value of the yield (Buckler, 2017).

Population growth and economic profit are commonly accepted reasons for using chemical fertilisers. With the rapid growth of global population, farmers have started using high-yielding seeds and applying a vast amount of chemical fertilisers to feed all people, especially in developing countries. High demand encourages the development of intensive agriculture, with farmers showing preference to single commercial crops to increase productivity. Intensive agriculture means that specific single commercial crops have replaced mixed planting, such that their ability to resist pests is diminished (Figuerola et al., 2015). Sharma and Singvi (2017) explore a similar idea, concluding that single and large-scale planting forces farmers to increase the use of fertilisers to increase food productivity. They also propose that bacteria play a crucial role in plant growth, and mixed cultivation can maintain the right balance of bacteria. Conversely, single planting destroys this balance and fertilisers need to make up for the effects of bacteria. Thus, modern agriculture has become a vicious cycle. However, compared to ensuring productivity to feed a growing population, people in business prefer to pay more attention to the profit gained from agriculture. Marie Darnadury et al. (2016) conclude that fertilisers and pesticides can increase crop productivity and shrink the growth cycle. This means the cost of production decreases and farmers can gain more profit from crops. Moreover, to produce high-nutrition crops and fruits, chemical fertilisers are applied to highlight some characteristics, such as acidity or sweetness (Bourn and Prescott, 2002). Farmers are then able to increase the price of crops and fruits.

This illustrates the impacts of the increasing use of chemical fertilisers in agriculture. Despite the fact that chemical fertilisers are important in industrial agriculture, their drawbacks outweigh their advantages. Hence, further research and implementation of methods to improve effective use of fertilisers and reduce the effects of nutrient pollution is needed.

Fertiliser pollution has strong dynamic characteristics, including randomness, intermittency, and uncertainty of variation range. In addition, non-point source pollution does not have inlet conditions for pollution, and it is generally impossible to measure. Therefore, when establishing

the water quality model of non-point source pollution, many factors are considered, such as geological features, soil types, rainfall and runoff characteristics, and human activities. It has an additional impact on fertiliser pollution. The main manifestation of chemical fertiliser pollution is nitrogen and phosphorus pollution. In the process of fertilisation, people often apply excessive amounts of fertiliser, so that a large amount of excess nitrogen and phosphorus enter the soil and water. These compounds are slowly circulated and degrade soil and water, resulting in eutrophication. It is thus necessary to understand the mechanism and characteristics of nitrogen and phosphorus in soil and water, study the absorption process of nitrogen and phosphorus by plants, and study the degradation rules and characteristics of nitrogen and phosphorus by microorganisms to reduce or avoid pollution by chemical fertilisers.

The impact of chemical fertilisers on soil quality is multifaceted. Firstly, in terms of the physical properties of soil, the application of chemical fertilisers leads to soil structure deterioration, increased bulk density and porosity reduction. Secondly, the application of chemical fertilisers may lead to a decrease in the amount and activity of beneficial microorganisms in the soil. Finally, due to the harmful components of some fertilisers, excessive application will cause corresponding pollution to the soil. The pollution of water by chemical fertilisers may result in a large amount of water being unsuitable for drinking. Another interesting impact of chemical fertilisers on the atmosphere is nitrogen dioxide pollution which leads to global warming. Under the redox alternating state, the nitrate in soil is easily reduced to nitrogen dioxide.

Literature Review

In ‘N2O and NO emissions from soils after the application of different chemical fertilizers’ (28 October 1999), an experiment was conducted in Japan with three different nitrogen chemical fertilisers to measure the N2O and NO emissions. The three different types of soils used were controlled-release urea, a mixture of ammonium sulfate and urea with nitrification inhibitor, and a mixture of ammonium sulfate and urea with no nitrification inhibitor. 20 g N m?2 of nitrogen was applied to the soil and the total emission of nitrogen oxide from controlled-release urea, a mixture of ammonium sulfate and urea with nitrification inhibitor, and a mixture of ammonium sulfate and urea with no nitrification inhibitor were 1.90, 12.7, and 16.4 mg N m?2, respectively (Hou et al., 2000). The total amount of nitrogen monoxide emitted from controlled-release urea, a mixture of ammonium sulfate and urea with nitrification inhibitor, and a mixture of ammonium sulfate and urea with no nitrification inhibitor were 231, 152, and 238 mg N m?2, respectively. Thus confirming the higher the nitrogen content in fertilisers, the higher nitrous oxide emission can be released.

In the ‘Investigation of Effect of Chemical Fertilizers on Environment’(Savci, S. 2012), threatening problems associated with the use of chemical fertilisers are revealed. The release of nitrous content from chemical fertilisers are harmful to both the environment and living organisms. Not only does it leach into waterways, soil and atmosphere resulting in issues such as eutrophication moreover it leads to serious health damages. Long term exposure to nitrogen monoxide can decrease lung functionality and also increases the risk of respiratory problems.

In this study, the investigation of aqua pollution showed that 2-10% of the nitrogenous content in fertilisers is not absorbed by plants but is rather left to interact with surface or groundwater. Thus, in the Antalya region of Kumluca, more than 50% of the well water in agricultural land has a measured nitrate content higher than the government limit of 45 mg/L. This potentially leads to

eutrophication, and adverse health effects such as nitrate poisoning in animals and humans, especially in infants. In infants younger than four months of age, ingested nitrates are more readily reduced to nitrites due to a higher gastric pH. This nitrite is cable of oxidising the Fe2+ in haemoglobin to Fe3+ resulting in a different compound called methemoglobin, which is incapable of binding with oxygen thus can lead to hypoxemia.

Soil degradation and the deterioration of soil fertility have also been observed over time due to the nitrogen content in fertilisers actively forming acids decreasing the soil pH. The heavy metals from fertiliser accumulate in plants and the food chain acting as contributors to the infertility and toxicity of the land. Atmospheric pollution is also a result of increasing atmospheric nitrogen oxide emission (by 0.1% per annum), but it can also be due to the evaporation of ammonia as ammonia-containing fertilisers are applied to soils with urea.

Analysis of Solutions

The use of nitrogen-based fertilisers in crop production is a common practice as it increases crop yield and economic return (Halvorson et al., 2014). It has been shown that only up to 51% of applied nitrogen (N) is taken up by plants, leaving approximately half of all available N to either be attenuated by organic soil matter or lost to the environment in the form of nitrous oxide (N2O) emissions, nitrate ground leaching, and N and phosphorus (P) runoff leading to aquatic eutrophication (Chien et al., 2009). This type of pollution generally occurs when soil N levels are greater than what the plants are able to absorb or during seasonal changes when there are little to no crops present to make use of the N present in soil (Chien et al., 2009).

One method used to mitigate these issues is the use of enhanced-efficiency fertilisers (EEF), defined as products which minimise potential nutrient loss to the environment and promote plant uptake. Enhanced-efficiency N fertilisers (EENF) aim to manipulate the release and interaction of N with both the soil and plant (Halvorson et al., 2014). One way this is achieved is by coating products in order to make them either semi-permeable to water or completely water insoluble (Chien et al., 2009). This category of EENF is referred to as water-soluble coated urea and includes two main products: polymer-coated urea (PCU) and sulfur-coated urea (SCU) (Chien et al., 2009). In general, these products are constituted of solid urea coated in various polymers which form a semipermeable membrane. Resins or thermoplastic materials form the layers of PCU which facilitate the diffusion of soil water into the granule and diffusion of N back out (Halvorson et al., 2014).

However, although designed to release contents over a pre-established time frame, the rate and duration of release in PCUs is significantly dependent on soil moisture and temperature (Halvorson et al., 2014). This drawback has led multiple studies to conclude that several applications of urea, if properly timed, can in fact produce a higher crop yield than one application of PCU (Chien et al., 2009). The release mechanism for SCU differs slightly and depends more on the thickness of the coating, which is comprised of a layer of sulfur, wax and conditioner (Chien et al., 2009). This product was rejected by many farmers due to the fact that the S coating added approximately 20% more weight, which reduced the N content to below 40% (Chien et al., 2009). It is therefore more economically feasible for farmers to purchase uncoated ure—which also has a higher N content of 46%—than to incur the transport and coating costs associated with SCU (Chien et al., 2009).

Another solution to the issue of nutrient (specifically nitrogen) pollution is the use of nitrification inhibitors. The root cause of nitrogen leaching is ineffective use or overuse of nitrogen fertilisers. In particular, fertilisers should be applied when crops need the nutrients most; however, such small, regular doses are not always practical for farmers. Hence, nitrification inhibitors are intended to reduce the rate at which bacteria convert ammonium nitrogen (NH4-N) into nitrate (NO3), such that nitrate is produced in the soil at the same rate as the crops are using it (Agro Services International, 2002). The reason why nitrification inhibitors are not suitable for widespread application, explored by the Japanese experiment described above in the literature review, is that their effect is significantly reduced by high rainfall, high temperature, and microbial activity. Their efficacy is particularly limited in most Australian soils. Additionally, these chemicals may have currently-unknown interactions and negative impacts on the complex pathways of the nitrogen cycle (University of Melbourne, 2018).

Finally, one substance which is attracting increasing research attention is biochar, a type of carbon typically used as a soil amendment to increase soil fertility, raise agricultural productivity, and increase soil nutrient capacity (Zhang et al., 2013). However, the ability of biochar alone to adsorb phosphate or nitrate, two primary contributors to pollution and eutrophication from fertilisers, is currently low. (Adsorption is the adhesion of particles—atoms, ions or molecules—to a surface.) This has directed research into the possibility of combining biochar and layered double hydroxides (LDHs) —chemicals that contain cation pairs which attract anions like phosphate and nitrate. It was found that such composites increase the efficiency of LDH in removing phosphate from solutions and soil samples, due to the increased surface area provided by the porous biochar (Brookshire, 2017). One limitation of this solution is that the long-term effects of biochar on soil are still under investigation, with some studies indicating that high surface area biochar decreases the efficacy of pesticides and herbicides in protecting crops from pests (Graber, 2011). According to Graber, biochar with a low specific surface area (SSA) should be used to balance negative impacts on the efficacy of herbicides with the function of absorbing excess nutrients from soils.

A study led by Zhang (2013) found that combining magnesium and aluminium with biochar to form a biochar/MgAl-LDH composite was most effective in adsorbing phosphorus in an aqueous solution. This sample had a maximum uptake capacity of 410 milligrams of phosphate per gram of composite. By this, Zhang concluded that biochar/LDH composites could be applied to the treatment of wastewater containing excess phosphate. A more recent publication by Ogonek (2016) expands upon this by suggesting that if an appropriate desorption technique was developed, PO43- -laden biochar (biochar that had adsorbed phosphate) could act as a slow-release fertiliser. This would reduce the need for commercial agricultural fertilisers that are currently relied upon to meet food crop demand, thereby reducing the run-off of phosphate into aquatic ecosystems.