Development Of a Slow-Release Fertilizer to Minimize the Nutrient Loss and Environmental Impacts Of Nitrogenous Fertilizers

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A FINAL YEAR PROJECT (FYP) REPORT SUBMITTED TO THE NATIONAL UNIVERSITY OF SCIENCES AND TECHNOLOGY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF BACHELOR OF ENGINEERING IN ENVIRONMENTAL ENGINEERING

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Approval Sheet

This is to certify that the contents and forms of thesis titled, as "Development of slow-release fertilizer to minimize the nutrient loss and environmental impacts of nitrogenous fertilizers" is the original work of author and has been carried out under my direct supervision. I also certify that the thesis has been prepared under my supervision according to the prescribed format and I endorse its evaluation for the award of Bachelor of Engineering in Environmental Engineering Degree through the official procedure of the Institute.

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Abstract

The agriculture sector of Pakistan accounts 18.9% to the GDP and the growth of this sector depends entirely on the application of urea fertilizer. Around 70% of urea is lost by volatilization, leaching, and runoff. The problem can be faced by the facilitation of a cost-efficient and biodegradable slow-release fertilizer. In this project, rice husk coated fertilizer is produced with biodegradable polyurethane as a binder. The pan coating machine was used to coat the urea granules. These coating fertilizer products are thus compliant with the European Union standard of 75% nutrient-release within 28 days of application. Moreover, volatilization of ammonia was diminished by 50%-60% of coated fertilizer with not only the mechanical strength tests for storing but also for transportation. The cost-benefit analysis showed a profit of PKR 18,671 per acre for the farmer and at the same time a 64% reduction in the nitrous oxide emissions into the atmosphere. In conclusion, coated fertilizers with various nutrient output patterns will be made as per the needs of different crops. The application of coated fertilizers in the field will also bring rewards in the form of profit to farmers and human and environmental health.

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In the name of Allah, the Most Gracious, the Most Merciful.

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Chapter 1

1 Introduction

1.1 Pakistan's Agricultural Dependence

Pakistan is an agricultural country, and its economy is heavily reliant on agriculture, employing a significant portion of the workforce and contributing substantially to 19% of the country's GDP. This sector acts as the backbone of the nation, providing food security and generating foreign income through exports. Despite its importance, agriculture faces challenges like water scarcity and a need for modernization. Urea (a nitrogen-containing fertilizer) is the most popular fertilizer in Pakistan, which is commonly used to bolster yield, promoting faster growth of crops. Pakistan's domestic production of urea lessens dependence on imports, ensuring a steady supply however, this reliance on urea, on the other hand, is rather worrisome, because improper use is the main cause of environmental problems including water pollution and greenhouse gas emissions.

1.2 Problems with Fertilizer Use

Using fertilizers comes with several problems that need to be addressed to utilize the potential of the fertilizer fully.

1.2.1 Eutrophication

Conventional fertilizers contain a high percentage of nitrogen and phosphorus. In cases where these nutrients are not efficiently absorbed by crops, they can leach into waterways. The extra nutrient runoff may cause eutrophication which is a process of overgrowth of algae leading to depletion of oxygen supply in water bodies and hence, affecting the aquatic environment (Akinnawo, 2023).

1.2.2 Nitrogen Leaching

The widespread use of urea fertilizer in Pakistan, although it is necessary for crop production, also has the environmental burden of nitrogen leaching. A large fraction of nitrogen fertilizer (40-45%) does not go into use by the plant, and this fertilizer undergoes changes in the soil and transforms into ammonium and nitrate. On the other hand, in case of the conversion proceeding too quickly or irrigation and rainfall being excessive, the nitrate form, highly soluble in water, will keep moving beyond the root zone and contaminating the groundwater. This leaching of surplus nitrogen is harmful. It can contaminate drinking water sources with nitrates that can result in a health risk and release ammonia gas into the air. Hence, careful management of application rates, timing, and consideration of alternative fertilizer sources are the three main steps to reduce nitrate leaching caused by the application of urea fertilizer (Riley, Ortiz-Monasterio and Matson, 2001).

1.2.3 Volatilization

The process through which urea fertilizer is hydrolyzed in the soil, catalyzed by the enzyme urease, results in the formation of ammonia (NH3) and carbon dioxide (CO2) is referred to as volatilization by urea. One ammonium is watered; this ammonia readily changes into its gaseous form, especially under conditions, such as high temperature, high soil pH, and moisture. This ammonia gas could subsequently disperse into the atmosphere, forming detrimental environmental effects including the depletion of nitrogen from the soil and penultimate contributing to air pollution and eutrophication due to freshwater bodies. Volatilization of urea is the main problem that should be solved when aiming to optimize the effectiveness of the fertilizer and reduce its impact on the environment. Many strategies can be introduced into the fertilizers to counteract the nitrogen loss via volatilization including the use of urease inhibitors and applying urea during cooler periods which in return, gives a secure plan for efficient use of nitrogen resources and consequently, reduces the impact of nitrogen pollution. The effects of nitrogen pollution are shown in Figure 1.1

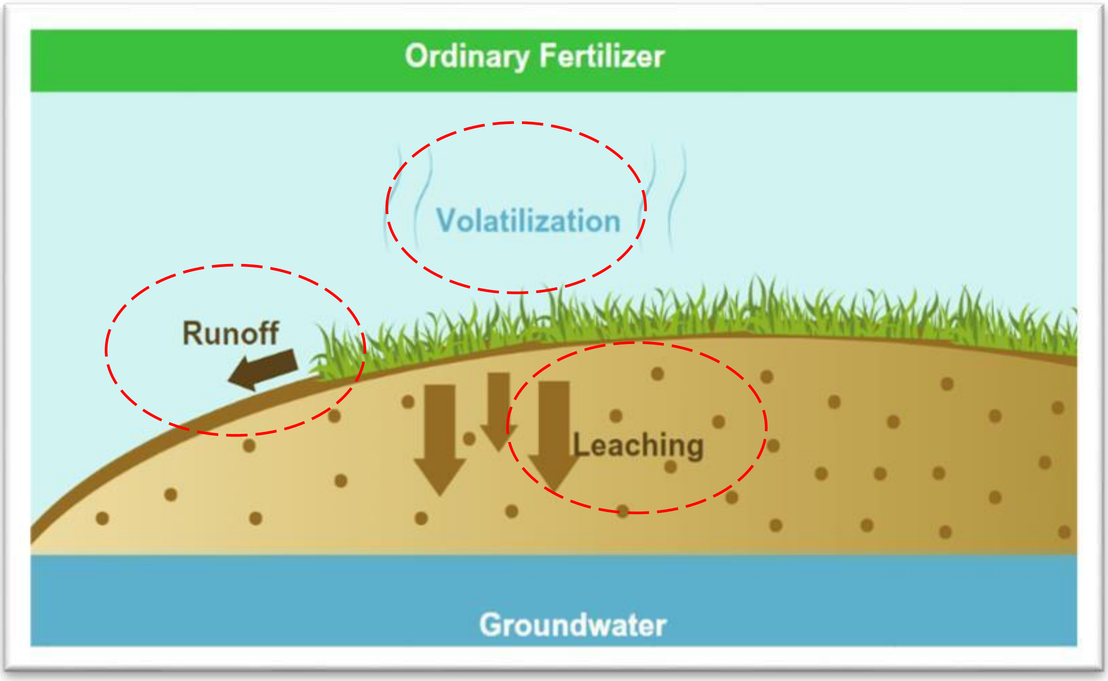

Figure 1.1: shows effects of using traditional fertilizers on environment

1.2.4 Nitrogen Utilization Efficiency of Urea

Urea, a widely used nitrogen fertilizer, faces a critical challenge: nitrogen utilization efficiency (NUE). However, the truth is that urea is used only up to 55-60% of the total applied nitrogen, which is not entirely absorbed and used by crops. Therefore, a very large portion, about half goes into the environment. This ineffectiveness has negative effects. Excess nitrogen can be washed away to the soil with the water, and pollute the water bodies, and

serve as a source of air pollution. Thus, the enhancement of urea nitrogen utilization ability becomes the key step of sustainable agriculture practices in Pakistan as well as elsewhere in the world (Swify *et al.*, 2024).

1.3 Slow-Release Fertilizer

Conventional fertilizers of the type-urea demonstrate problems of nutrient runoff and non-use efficiency, which could be addressed by using slow-release fertilizers. Slow-release fertilizers, unlike their fast-acting counterparts, release nutrients in a slow and gradual manner over a long period. The use of extended release enables many advantages for plant health and the environment. Among the main advantages of slow-release fertilizers is increased efficiency of nutrients in plants utilization. With a continual supply of nutrients readily available during their growth stage, plants can easily take what they need without the risk of being overloaded by a sudden increase, which is a common problem with the conventional fertilizers. Therefore, nutrients are not wasted, and there is a smaller amount of leaching to the adjacent soil and water system. Thus, application of slow-release fertilizers leads to better soil health. The slow release of nutrients fosters the development of useful soil microbes that are significant in nutrient cycling and soil health in general. With the development of the complex microbial communities, there is a higher likelihood of a long-term and stable environment for the growth and development of the plants.

The amount of nitrogen going to pollute waterways will be little with the use of slow-release fertilizers; from an environmental standpoint, they reduce the risk of water pollution due to nitrogen leaching. As previously said, the conventional fertilizers usually discharge a huge amount of nitrogen at once, which is more than what the plants need immediately. Excess nitrogen in soil – carried away by irrigation or rainfall – can contaminate underground waters as well as worsen eutrophication. Fast-acting fertilizers, instead of slow-release fertilizers, lead to the opposite outcome.

Slow-release fertilizers help to match the rate of nutrient release with plant demand, thus protecting freshwater bodies (Bashir *et al.*, 2013).

Another environmental advantage of slow-release fertilizers is the possibility of the reduction in greenhouse gas emissions. Creating synthetic fertilizers is a demanding process, especially however generating nitrogen-based fertilizers as if urea can be a source of greenhouse gases. Through less using all organic fertilizers and creating the atmosphere where there is no excess of nitrogen, slow-release fertilizers can help to form a more sustainable agricultural system with smaller carbon footprint.

Besides, it should be taken into account that slow-release fertilizers are not good for each plot. Different kind of formulations release nutrients at varying rates. Thus, the best product to be used should be determined based on factors like soil type, plant species, and climatic conditions. Choosing the best slow-release fertilizer and applying it according to the manufacturer's instructions are the key factors for the best possible outcome (Liu et al., 2021).

1.3.1 Types of Fertilizers:

Slow-release fertilizers are characterized as physical and chemical type.

Physical Fertilizers:

Physical fertilizers are released based on their size and diffusion through a semi-permeable membrane. The smaller the prill size, the faster the nutrient release. Matrix-based fertilizers are the most common type of physical slow-release fertilizer. They are made by incorporating nutrients into a water-soluble matrix such as organic polymers or biopolymers. As water moves through the matrix, nutrients dissolve and are released to plants, but they have high production cost whereas chemical fertilizers use chemical reactions to control nutrient release.

Example:

Hydrogel matrix fertilizers: These are fertilizers in which the nutrients are distributed in a hydrogel network which is a polymer network that can absorb the water surrounding the fertilizer granule. In this case, hydrogel absorbs the water and dissolves in the soil releasing the nutrients to the plant.

Chemical Fertilizers:

There are two main types of chemical slow-release fertilizers: chemically inhibited and chemically bonded.

Chemically Inhibited Fertilizers:

Chemically inhibited fertilizers contain a coating that prevents nutrients from dissolving in water. Microbial activity breaks down the coating over time, releasing nutrients to plants but their synthesis process is complex.

Example:

Dicyandiamide (DCD): It is nitrification inhibitor used in the field to slow the rate of change of ammonium to nitrate in the ground. This also helps reduce the risk of nitrate polluting the ground and let nitrogen and other nutrients to be supplied to the plants naturally.

Chemically Bonded Fertilizers:

Chemically bonded fertilizers contain nutrients that are chemically attached to another molecule. A plant or microbe must break the chemical bond to release the nutrient, but they have a limitation of being non-degradable.

Example:

Zeolite-based fertilizers: These are fertilizers with nutrients bound to a mineral of zeolite and this slowly releases to the soil as it disintegrates.

In our project, we are using a coated fertilizer which is a type of physical slow-release fertilizer. Coated fertilizers have a coating that controls the release of nutrients. The coating can be made from a variety of materials, including sulfur, polymers, or resins. The thickness and permeability of the coating determine how quickly nutrients are released. In our project, the urea granule will be coated with a binder that is biodegradable polyurethane and the coating is an agricultural residue that is rice husk. Both the binder and the coating will be layered uniformly over the urea granule as shown in the figure In our project, we are using a coated fertilizer which is a type of physical slow-release fertilizer. Coated fertilizers have a coating that controls the release of nutrients. The coating can be made from a variety of materials, including sulfur, polymers, or resins. The thickness and permeability of the coating determine how quickly nutrients are released. In our project, the urea granule will be coated with a binder that is biodegradable polyurethane and the coating is an agricultural residue that is rice husk. Both the binder and the coating will be layered uniformly over the urea granule as shown in the Figure 1.2:

Figure 1.2: Illustrates the structure of our slow-release fertilizer

Eventually, this hopeful conclusion states that slow-release fertilizers present an alternative for the conventional types of fertilizers. The continuous flow of all the nutrients is what makes them excellent provider of a steady food supply among the plants. This allows the plants to grow well, improves the soil health, and reduces environmental damage from nutrient runoff and greenhouse gas emissions. With the quest for more eco-friendly farming techniques, slow-release fertilizers are on the brink of being the key in food security and the protection of the environment.

Objectives

The specific objectives of this study are as follows:

- To coat granular urea with rice husk using polyurethane and its subsequent characterization.
- To optimize the coating composition to minimize polyurethane amount.
- To investigate the effect of coating formulation and thickness on nutrient release profile.

Innovation

A slow-release fertilizer was produced through non-energy intensive physical processes by using polyurethane in conjunction with rice husk, paraffin oil, and commercially available granular urea. The method is simple and scalable for industrial production, making it a promising candidate for large-scale fertilizer production. Rice husk, an agriculture residue; abundantly produced in Pakistan was used to coat the slow-release fertilizer. The prepared coating variants successfully suppressed ammonia volatilization of granular urea significantly, thereby reducing emissions of N2O, a potent greenhouse gas. The prepared coated fertilizer has the potential to increase crop yield, making it an environmentally sustainable and economically viable option for modern agriculture.

Scope

This study is designed to invent the fertilizer coated with a special substance and the comparison is aiming at microbial activity and volatilization of the coated and uncoated fertilizers. In contrast to other experiments that have been carried out on plants, this research is totally focused on the development and the comparative analysis of the fertilizers. The key aim here is an investigation on the performance of the coated fertilizer to minimize the effusion of nutrients and volatilization (which can lead to wastage of nutrients hence detrimental environmental impacts) and possibly a better alternative to traditional uncoated fertilizers. Whether conducted by comparing coated fertilizers with direct feeds to plants or by experimental characterization and cautious testing, this study is aimed to give insights into the efficiency of coated fertilizers as sustainable alternatives in agriculture practices, which will drive towards an efficient nutrient management strategy without experimenting live plants.

Chapter 2

2 Literature Review

Literature review forms a part of research as a solid base for future investigations and gathering relevant information to organize the research process with clear objectives hence the investigations proceed in the right way. It is an important part of the research since it provides a foundation for future research and helps to gather the relevant information to do the research correctly with a clear direction. The article collection of mine is comprised of a few of the subjects studied to be able to derive a sound analysis and obtain the information required in this research. It provides a common trend that highlights the recent studies done in the field of slow-release fertilizers by presenting the findings and implications, respectively, of the most significant ones.

2.1 Finding 1: Increased Nitrogen Utilization Efficiency with Neem Coated Urea

This research by (Zheng *et al.*, 2020) explored the use of Neem-coated Urea in wheat cropping. The results of their study demonstrated that this method of application was 30% more efficient in nitrogen utilization than the conventional use of urea. Neem-coated urea tends to leach and become volatile less compared to nitrogen-containing soil fertilizers, which are known to be lost from the soil. Such losses not only reduce the efficiency of the fertilizer but also aggravate the level of pollution in the environment.

2.2 Finding 2: Rice Husk Amendment Improves Soil Health and Crop Yield

(Runkle *et al.*, 2021) analyzed the possibility of using rice husk as a soil amendment for sustainable rice production. Their research concludes that rice husk as a material proved suitable for improving soil fertility and agroecology. The method of operation for rice husk amendment is that adding rice husk improves the soil porosity, drainage, and water-holding ability. These factors can all be a reason for the growth of plants (Runkle *et al.*, 2021).

2.3 Finding 3: Polyurethane-Coated Urea for Slow-Release Fertilizer

The research by (Li *et al.*, 2012) concentrated on creating a urea-based slow-release fertilizer that was coated with polyurethane. It is implied that polyurethane coating is a possible way to make urea fertilizer, which will be slowly released. Slow-release fertilizers can enhance nitrogen use efficiency by leaching nutrients continuously, thus reducing the danger of contamination and surrounding pollution.

2.4 Finding 4: Soil Column Leaching Test Methodology for Release Rates

In the study of (Cole *et al.*, 2016), they proposed a method to evaluate the release of chemicals of various classes from controlled-release fertilizers. The column leaching test is accomplished by suspending the soil and the water in the assembly; then, the fertilizer is poured into the soil column at the top and is followed by the water leaching process, and the concentration of nutrients in the leachate is monitored over time. Through this method of research, it becomes easy for scientists to determine the separation rate between various fertilizers and check if the chances of nutrient losses are present .

2.5 Finding 5: Pan Coating for Uniform Urea Granule Coating

(He *et al.*, 2023) focused on a pan coating machine that allows the application of a uniform coating to urea granules. The results of their experiment indicate that this technique is a good way of making coated urea fertilizers. A uniform coating plays a pivotal role in the uniform distribution of nutrients that are released at the same rate. Slow-releasing fertilizers with homogeneous coating can supply plants with more regular nutrition compared to fertilizers with heterogeneous coatings.

Chapter 3

3 Methodology

3.1 Materials

The following materials were used in the preparation of the slow-release fertilizer,

- Rice husk obtained from rice milling factory
- Polyurethane obtained from Sigma eldrich
- Paraffin Oil obtained from Sigma eldrich
- Urea granules obtained from Engro fertilizers

The following materials were used for testing of the slow-release fertilizer,

- TKN indicator obtained from Sigma eldrich
- 4 % w/w Boric acid solution obtained from Sigma eldrich
- Sodium hydroxide obtained from Sigma eldrich
- 0.02 N sulphuric acid solution obtained from Sigma eldrich
- De-ionized water obtained from Sigma eldrich
- Distilled water obtained from Sigma eldrich
- Sand
- 0.01 N Nitrate solution obtained from Sigma eldrich
- 3 drops Chloroform obtained from Sigma eldrich
- 0.02 N Hydrochloric acid solution

3.2 Fertilizer Preparation

The rice husk was dried under sunlight for 12 h and crushed using a mechanical grinder. The obtained rice husk powder was sieved using ASTM certified sieve sizes 16 and 40. In the second phase, 2.5 g of polyurethane (PU) was mixed with paraffin oil. Five grams of urea, PU-paraffin oil mixture, and 5g of sieve 16-passed rice husk were added to a pan coating machine and mixed for 5 minutes. Coated granules were dried in air for 24 h. A similar procedure was followed to prepare coated granules with different binder concentrations and sieve size 40. Table 3.1 shows various slow-release fertilizer compositions.

Table 3.1: shows SRF compositions

Sr no.	Polyurethane (grams)	Paraffin Oil	Rice husk (grams)	Urea (grams)
1.	2.5	Excess	5	5
2.	3	Excess	5	5
3.	3.5	Excess	5	5

3.3 Soil column leaching test

The methodology was adopted from a similar approach by (Cole *et al.*, 2016).The experimental assembly consisted of 4 pipes each measuring 30 cm in length and 5 cm in diameter. Each pipe was vertically mounted into a Buchner funnel of 80 mm pore size. The assembly was supported by a tri-iron stand. The pipe was filled with sand up to 28 cm in length, followed by 5 g of fertilizer followed by 1 cm of sand layer. 50 mL de-ionized water was added to each pipe three times weekly. The leachate was collected in a 500 mL beaker, and weekly taken for TKN and nitrate testing. The experiment continued for 28 days at normal conditions. The setup was as follows in Figure 3.1

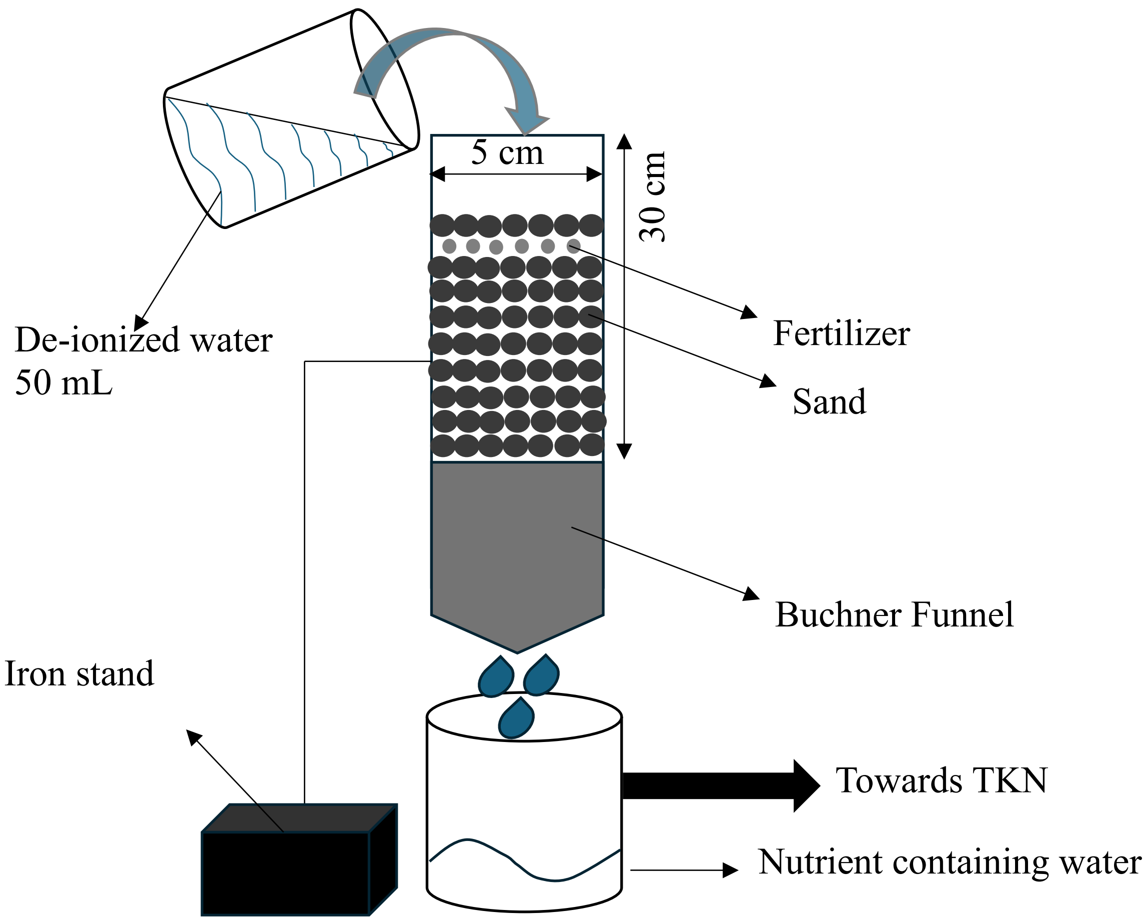

Figure 3.1: Illustrates the soil column leaching test methodology

3.4 Drop test

The methodology was adopted from a similar approach by (ASTM, 2002).In this experiment 5 g of each fertilizer was carefully measured and placed in separate plastic jars. These jars were subjected to six falls from varying heights of 9, 15, 24, and 60 inches, with each fall targeting a different face of the plastic jar. The results were indicated by determining the percent weight change after completion of six falls from a particular height for each fertilizer. The setup was as follows in Figure 3.2

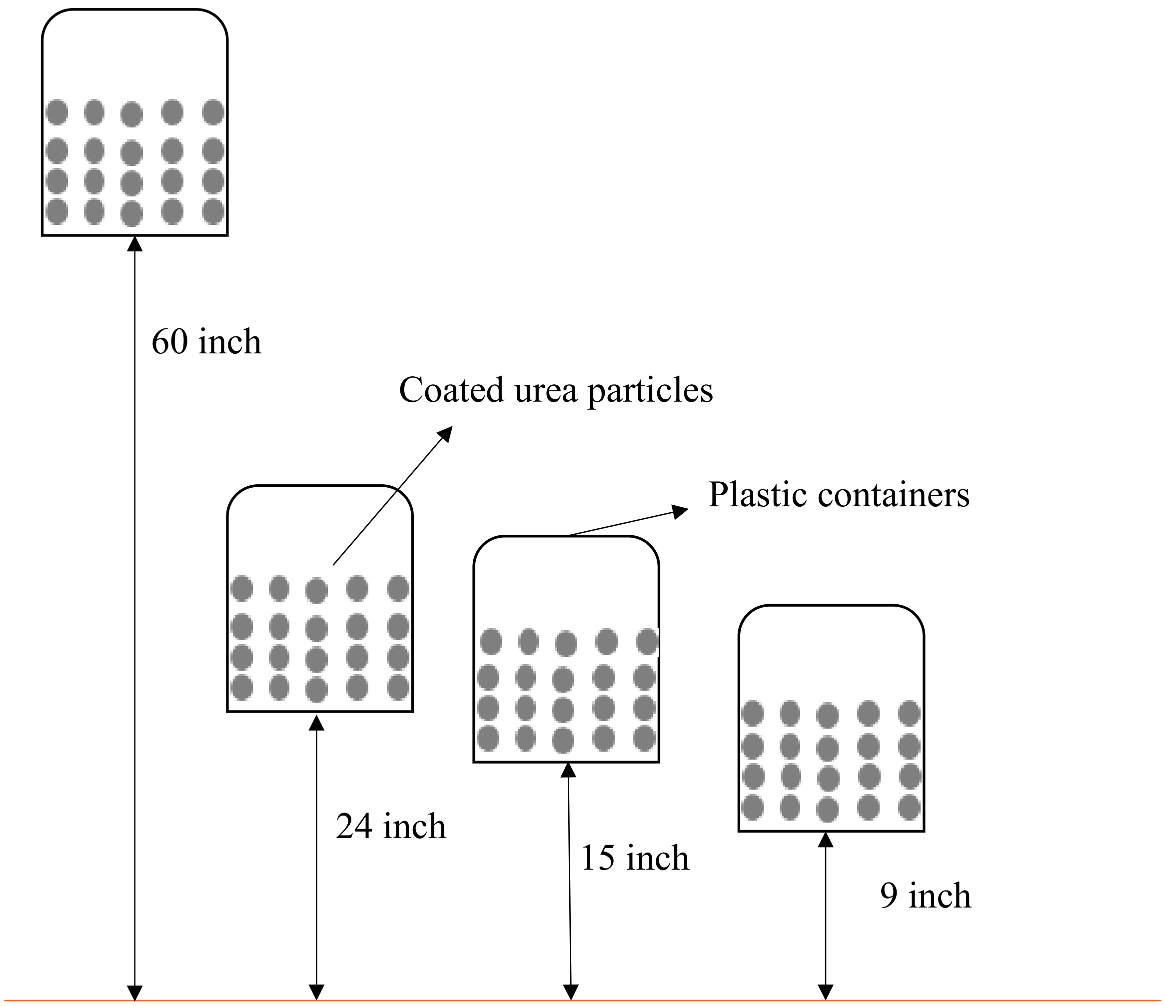

Figure 3.2: Describes the drop test methodology

3.5 Ammonia Volatilization

The methodology was adopted from a similar approach by (A. Rahman *et al.*, 2018).The setup consisted of four assemblies, each comprising a 500 mL conical flask (exchange chamber) fitted with inlet-outlet facilities, a 250 mL conical flask (trap chamber) also fitted with similar facilities, and an air pump capable of providing air flow-rate of 3.5 liters per minute. The exchange chamber contained 300 g of sand, 5 g fertilizer, and distilled water up to the 500 ml mark. The exchange chamber was connected to the trap chamber, which contained 75 ml of boric acid solution (4 percent w/w). The ammonia volatilized from the fertilizer was trapped in the boric acid solution, which was subsequently titrated against 0.02 N sulfuric acid to determine the amount of ammonia volatilized. The mixed-indicator for TKN was used, and the endpoint was indicated by a color change from blue to purple. The experiment continued for 28 days. The setup was as follows in Figure 3.3.

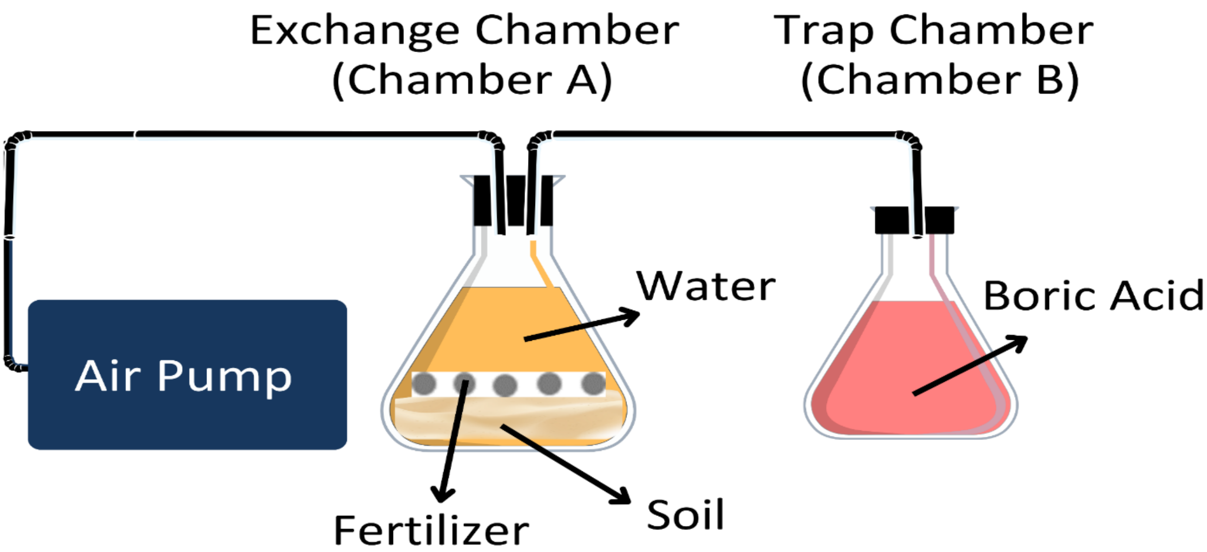

Figure 3.3: shows the ammonia volatilization test methodology

3.6 Visual analysis

The prepared coated fertilizer samples were visually inspected under visible light by an observer at a distance of 20 cm from the samples. The objective of the visual inspection was to detect any visible cracks on the surface of the coated fertilizers. It was carried out both before and after the drying process to evaluate the integrity of the coatings under different conditions.

<u>**Chapter 4**</u>

4 Results & Discussion

4.1 Visual Analysis

The weighted PU urea-coated granules that we analyzed visually showed notable differences as visible in Figure 4.1. The non-uniform coating of the 2.5g granules suggested possible adhesion problems. On the other hand, post-drying fissures were seen in the 3.5g granules, suggesting potential structural flaws. However, the 3g coated grains showed a uniform covering, indicating that the encapsulation was effective. These results highlight the major implications of our study and highlight the effectiveness of polyurethane and rice husk covering in reducing ammonia volatilization and delaying the rate at which nutrients seep out. This study might have ramifications for sustainable agriculture practices and the environment, making it not just a step but a huge leap in the development of slow-release fertilizers (Li *et al.*, 2012).

2.5 g PU coated urea | 3 g PU coated urea | 3.5 g PU coated urea

Figure 4.1: shows the prepared variants of PU coated fertilizers

4.2 Drop Test

In Table 4.1 (Mesh size 16): When assessing rice husk-coated urea granules, consideration should be given to the kind of rice husk powder and mechanical strength at PU concentrations of 2.5g, 3g, and 3.5g.

Firstly, samples coated with rice husk powder that had been sieved through a mesh size of 16 shown greater adhesive capabilities than those coated with powder that had been coarser. The larger mesh size 16 particles allowed for better interlocking between the urea granules and rice husk powder particles, adding to the coating's stability.

Second, while evaluating mechanical strength, a 3g PU coating yielded the greatest results. A balance between adhesion and mechanical strength was established by this concentration, which resulted in minimal weight loss during the drop test and showed increased durability against mechanical stress.

Table 4.1: shows results of drop test of sieve 16 passed rice husk coated SRF

Sieve 16 passed rice husk	**9 inch fall %Weight Change**	**15 inch fall % Weight Change**	**24 inch fall % Weight Change**	**60 inch fall % Weight Change**
Uncoated urea particles	1.74%	2.54%	3.02%	4.2%
2.5 g PU coated urea particles	0.35%	0.10%	1.05%	4.17%
3.0 g PU coated urea particles	0.33%	0.35%	0.35%	3.83%
3.5 g PU coated urea particles	0.35%	0.24%	0.22%	3.65%

In Table 4.2 (Mesh size 40): In contrast, while assessing rice husk-coated urea granules using mesh size 40, the impact of PU concentration and kind of rice husk powder on adhesive properties and mechanical strength is investigated. Samples coated with 40 mesh-sized-mesh rice husk powder exhibited incoherent properties compared to coarser rice husk powder. The finer particles did not properly stick to the urea granules, reducing mechanical strength and compromising coating integrity.

The results for sieve 40 showed that even at this concentration, the mechanical strength of the samples coated with coarser rice husk powder was still superior. However, the greatest results for PU concentration were achieved with 3g of PU coated for sieve 16 (Runkle *et al.*, 2021).

Table 4.2: shows drop test results of sieve 40 passed rice husk coated SRF

Sieve 40 passed rice husk	**9 inch fall** **%Weight Change**	**15 inch fall** **%Weight Change**	**24 inch fall** **%Weight Change**	**60 inch fall** **%Weight Change**
Uncoated urea particles	1.74%	2.54%	3.02%	4.2%
2.5 g PU coated urea particles	1.33%	13.40%	14.20%	17.35%
3.0 g PU coated urea particles	0.66%	12.5%	14.69%	17%
3.5 g PU coated urea particles	2.01%	11.30%	15.4%	18%

4.3 Nutrient Release Profile

Our research on slow-release fertilizers was conducted with strict adherence to regulations, ensuring both environmental sustainability and agricultural performance. A fundamental guideline provided by the European Union concerns the nutrient release profile, which stipulates that the release rate must not exceed 75% over 28 days. We conducted a 4-week soil column leaching test to verify compliance with this standard, focusing on polyurethane (PU) coated fertilizers. Our investigation revealed significant differences in the nutrient release kinetics among various PU-coated fertilizer formulations. Notably, formulations with 3g and 3.5g of PU covering consistently met the regulatory requirement showing release rates of 47% and 68% after 28 days, maintaining their release rates within allowable bounds throughout the evaluation as displayed in Figure 4.2. In contrast, the formulation with a 2.5g PU coating did not adhere to the recommended release profile releasing 86% of its content within 28 days, further emphasizing the importance of our adherence to regulations and the credibility and reliability of our research.

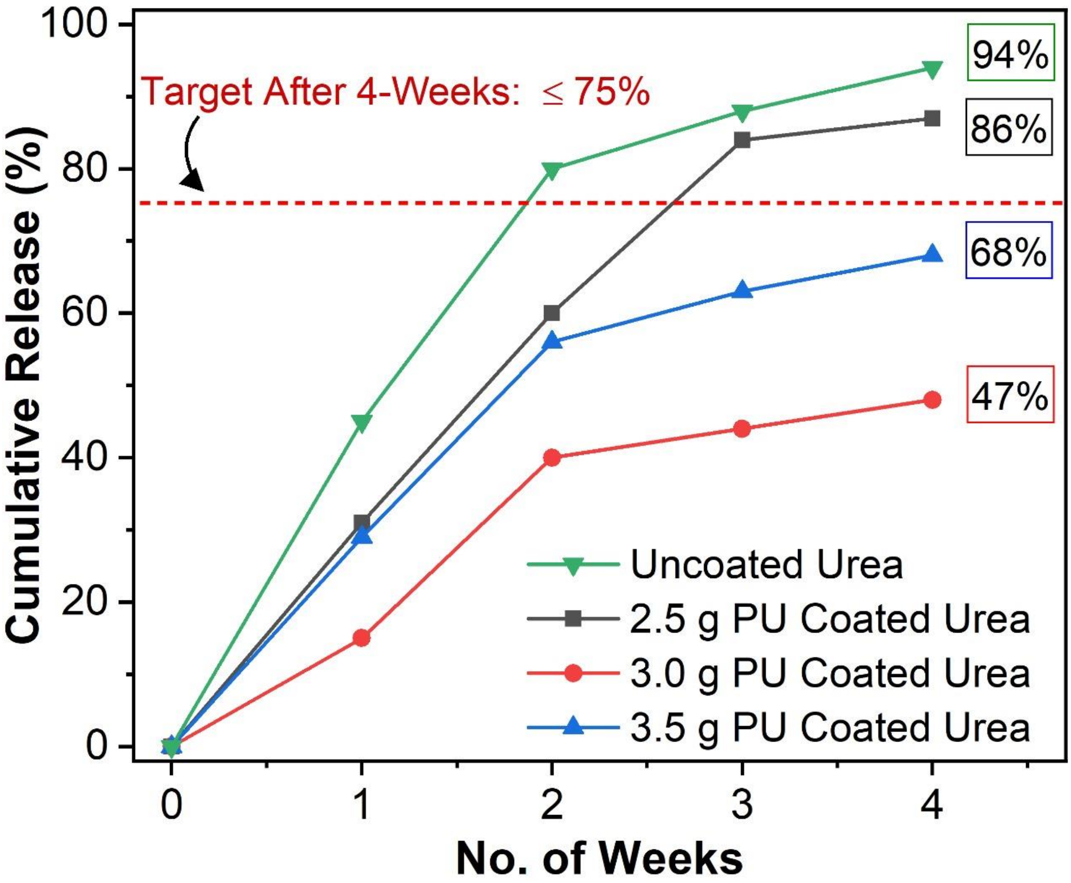

Figure 4.2: shows the nutrient release profile of s.r.f. variants and uncoated urea

4.4 Volatilization Test

The experiment aimed to compare the effectiveness of polyurethane (PU) coated fertilizers in reducing ammonia volatilization rates to that of traditional fertilizers. Specifically, we focused on studying the volatilization kinetics of PU-coated urea formulations versus traditional urea. Our results demonstrate that PU-coated fertilizers significantly reduce ammonia volatilization. The data revealed that PU-coated formulations were less volatile than traditional urea. Notably, the volatilization rate of the 3g PU-coated fertilizer was the lowest at 924 mg/L, compared to the much higher rate of 2061 mg/L for ordinary urea as shown in Figure 4.3.

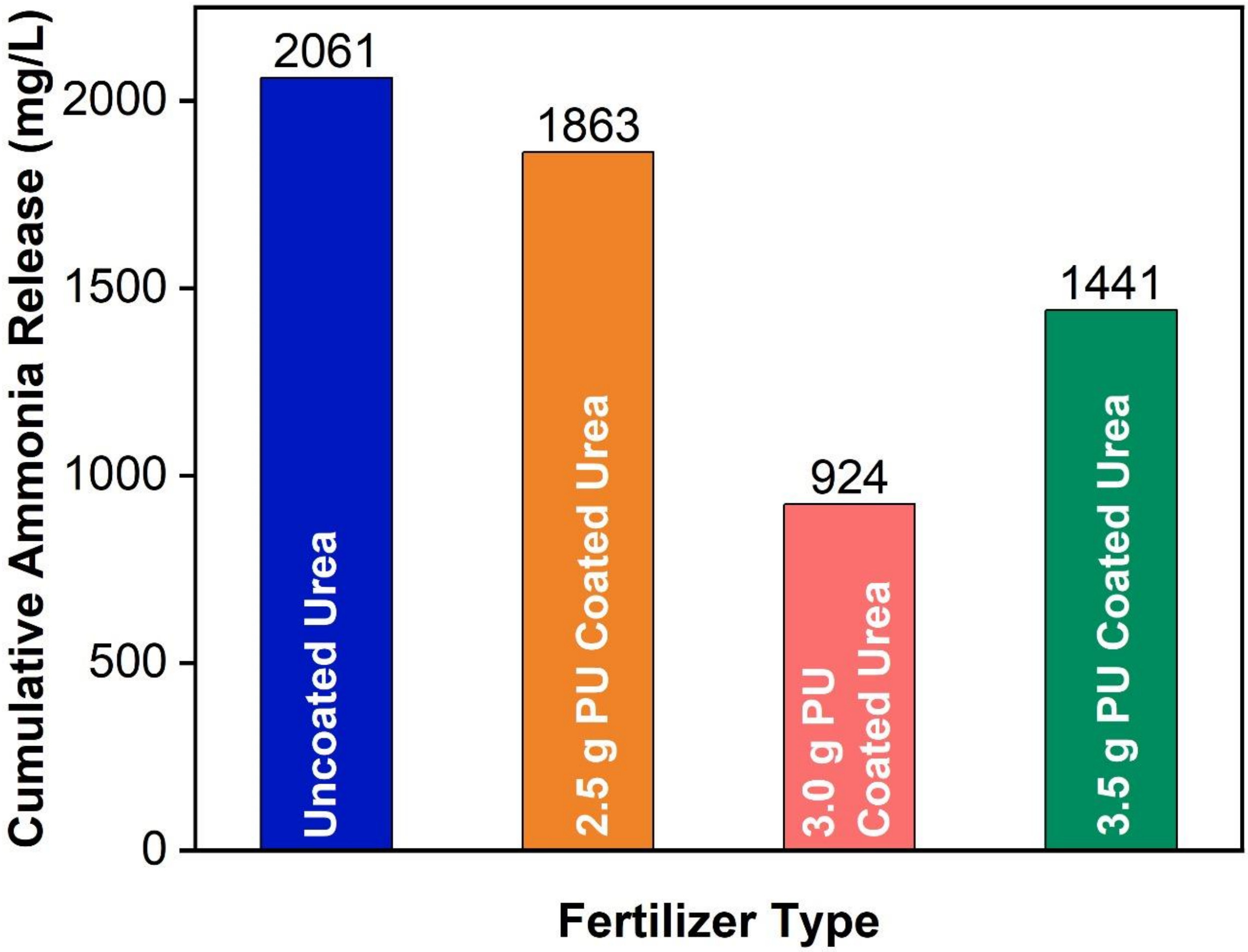

Figure 4.3: shows the ammonia release of variants of s.r.f. and uncoated urea

Further investigation revealed differences in the volatilization rates among the various PU-coated urea formulations. The volatility of the 2.5g PU-coated urea formulation was greater than that of the 3g formulation, while the 3.5g formulation displayed lower volatility. This indicates that the thickness of the coating affects the dynamics of volatilization.

5 Cost Benefit Analysis

The cost of preparation of the slow release fertilizer is displayed in Table 5.1

Table 5.1: shows the cost benefit analysis of preparation of the s.r.f.

Sr no.	Product	Amount required per 1 kg of coated fertilizer	Cost (Market Retail Prices)	Cost of Product
1.	**Uncoated Urea**	800 g	PKR 112.5 / kg	PKR 90
2.	**Rice Husk**	175 g	PKR 52 / kg	PKR 9.1
3.	**Polyurethane**	25 g	PKR 414.25 / kg	PKR 10.36
4.	**Electricity**	0.36775 kW	PKR 33.83 / kWh	PKR 12.4
5.	**Total**	1000 g	-	PKR 121.86

Assuming 150 kg urea is applied to 1 acre of land then,

For Urea:

One 50 kg bag of urea = **PKR 4900**

3 bags of urea will cost the farmer = **PKR 14700.**

Yield = **896 kg rice** ∵ (1kg rice = PKR 130)

N_2O Emissions = 150 × 0.46 × 0.896 × 0.4233 = **26.17 kg**

CO_2 equivalent = 6.9 metric tons.

Where,

- 0.46 is the percentage of Nitrogen available in urea
- 0.896 is the ammonia volatilization factor
- 0.4233 is the ammonia to N_2O conversion factor

For Slow-Release Fertilizer:

One 50 kg bag of PU slow-release fertilizer = **PKR 6093**

3 bags of PU fertilizer will cost the farmer = **PKR 18279.**

Yield = **985.6 kg rice** ∵ (1kg rice = PKR 130)

N_2O Emissions = 150 × 0.8 × 0.46 × 0.4017 × 0.4233 = **9.39 kg**

CO_2 equivalent = 2.5 metric tons

Where,

- 0.8 is amount of urea present in our slow-release fertilizer
- 0.46 is the percentage of Nitrogen available in urea
- 0.896 is the ammonia volatilization factor
- 0.4233 is the ammonia to N_2O conversion factor

The difference in **fertilizer cost =** 14700-18279 **= PKR -3579**

The difference in **rice yield =** 985.6-896 **= 89.6 kg**

Worth of Crop = PKR 11,648

Revenue = PKR 8069/acre.

The rice crop yield is expected to increase by **9.1%** by simple application of slow-release fertilizer as per literature (Zheng *et al.*, 2020)

So, by simple application of P.U. coated fertilizer, the farmer has a per acre increase in deep placement of slow-release fertilizer may produce even better yield as per literature.

Chapter 6

6 Conclusion

The slow-release characteristics of granular urea were enhanced through a coating method using polyurethane and rice husk. The aim was to reduce the adverse environmental effects caused by ammonia volatilization and quick nutrient leaching. The process demonstrated that urea granules could be successfully encapsulated, and the amount of polyurethane used directly impacted the mechanical strength of the coated fertilizer. The coating effectively protected the urea granules, resulting in a significant up to 55% decrease in ammonia volatilization, aligning with EU regulations for slow-release fertilizers and representing a significant step forward in reducing nitrogen loss. Additionally, the encapsulation procedure reduced environmental effects while enhancing nutrient use by causing a regulated release of nutrients into the soil. The slow-release characteristics of the fertilizer were further improved by using rice husk in the coating composition. Due to its porous structure and high silica content, rice husk has better moisture retention and more prolonged kinetics of nutrient release, leading to improved crop yield and reduced water usage. This underscores the potential for using agricultural by-products in fertilizer technology, offering a promising avenue to support sustainable farming practices.

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