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Testing the quality of polymer-coated urea

Key facts

- PCU is a slow-release nitrogen (N) fertilizer product in which each urea prill is individually coated with polymer (plastic).
- PCU benefits are realized when environmental conditions cause substantial N loss.
- Damage to the polymer coating can change the release pattern of N during the growing season, decreasing the effectiveness of PCU as a controlled-release fertilizer.
- Blending PCU with sharply angled fertilizer products can damage PCU during mixing.
- The purity of PCU can be compromised when handling, mixing, and applying the product.
- It is important to know you are receiving relatively undamaged PCU and that your fertilizer application method is not damaging the product.

Polymer-coated urea (PCU) is a nitrogen (N) fertilizer product in which each urea prill is individually coated with polymer (plastic). Considered a slow-release fertilizer, PCU is defined by the Association of American Plant Food Control Officials as a fertilizer that contains plant nutrients in a form that extends its availability significantly longer than a reference fertilizer (in this case urea) (Slater 2014).

The way PCU works is that urea dissolves inside the coating and slowly diffuses into the soil over time. The mechanism for the nitrogen release from PCU includes three phases: the lag phase, the constant release phase, and the release decay phase (Shaviv et al. 2003). During the **lag phase**, water is absorbed inside the coating through the pores of the polymer. Little, if any, N is released into the soil during this phase. During the **constant release phase**, the water dissolves the urea and the dissolved nitrogen diffuses through the polymer into the soil. While urea in PCU readily dissolves in water, the nitrogen release from PCU is controlled by the rate urea diffuses through the polymer coating. Diffusion is a process where the N moves from an area of high N concentration (inside the polymer coating) to an area of low N concentration (the soil environment). Nitrogen release increases as temperature increases because an increase in temperature causes the coating to expand, making the pores in the plastic bigger; N release decreases as temperatures get cooler. During the third phase, **release decay**, the release rate of N through the polymer coating slows after the urea is completely dissolved within the polymer.

Once outside the polymer, the unprotected urea rapidly dissolves with water and then converts (via the soil enzyme urease) to the ammonia or ammonium form. Through the microbial process of nitrification, ammonium is then converted to nitrate. While both nitrate and ammonium are plant available forms of N, they are subject to environmental losses, especially when plants are small. The advantage of PCU over unprotected urea is that it prevents large amounts of nitrate from existing in the soil early in the growing season, reducing the likelihood that it could be leached, denitrified, or volatilized. Use of PCU will have the most benefit (and is perhaps the most widely used) on sandy soils where nitrate leaching can be problematic. Applying PCU on sandy soils can lead to increases in N use efficiency, decreases in groundwater nitrate, and a decreased need for supplemental N later in the growing season (Bero et al. 2013; Maharjan et al. 2016; Wilson et al. 2010). PCU can also be beneficial on wet or poorly drained soils where denitrification losses (conversion of nitrate to nitrous oxide [N_2O] or N_2 gas) can be substantial (e.g., Halvorson et al. 2011; Noellsch et al. 2009). In addition PCU can reduce N loss through ammonia volatilization compared to non-coated urea when surface applied (e.g., Connell et al. 2011) compared to non-coated urea.

PCU is more expensive than urea fertilizer although the price difference will vary from year to year. In recent years, the cost has been 30 to 50% greater on a per ton basis compared to urea. This can translate to $0.15 to $0.30 more per pound of N (relative to urea), but has been observed to be $0.50 more per pound of N. Thus, the advantage of using PCU over urea may not be economical every year. The benefits of PCU are only realized when there are environmental conditions that cause substantial N loss. Deciding to use PCU means you are accepting an additional cost every year to mitigate the risk that can occur in any one year.

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PCU is marketed under several trade names including, in alphabetical order, CoteN™ (Haifa Chemical Ltd.), DurationCR® (Koch Agronomic Services, LLC), ESN® Smart Nitrogen (Agrium Inc.), and Polyon® (Koch Agronomic Services, LLC), although new products may be available on the market at any time. Each product's polymer is company specific and proprietary, and different PCU products will have different release rates of N based on the molecular characteristics and thickness of the polymer. The thickness of the coating reduces the N concentration of the fertilizer product. For example, urea is 46% N by weight while ESN® is 44% N and Polyon® is 43% N. Some of these products are marketed for agricultural crops and some for horticultural crops, turf, or ornamentals. For the purposes of this publication, mention of specific products does not indicate endorsement.

Evaluating PCU quality

Damage to the PCU polymer coating can result in faster nitrogen release rates and decrease its effectiveness as a controlled-release fertilizer. Once the polymer is cracked, water can easily enter and the release of N can be similar to uncoated urea. Damage can occur as a result of handling practices, blending or mixing the PCU with other fertilizers, or the application method (e.g., Agrium's ESN, Use and Handling Frequently Asked Questions, smartnitrogen.com). The most severe damage has been seen during the handling of PCU, especially when transferring in equipment with scaly deposits (Beres et al. 2012). For example, transporting with a steel auger will cause more damage compared to a belt conveyer (Beres et al. 2012). Asking for the PCU to be the last component mixed can reduce the time in contact with other fertilizers and reduce damage as well. Changing the method in which the fertilizer is applied can also reduce damage. For example, using airboom spreaders to apply PCU tends to increase polymer damage. However, as long as the PCU is not damaged prior to loading into the airboom truck, the amount of damage with the airboom spreader is usually less than 15% of the prills (Rosen unpublished). Spinner spreaders or drop spreaders will result in less damage than airboom spreaders. The best practice is to minimize mixing PCU with other fertilizers and avoid any unnecessary handling prior to application.

Damage to the polymer coating can change the release pattern of N during the growing season. Research conducted at the Sand Plain Research Farm in Becker, MN, showed that PCU damaged via applicator released 60% of its N after 8 days, while undamaged PCU only released 12% (Bierman et al. 2015).

FIGURE 1. Undamaged PCU (left) and damaged PCU (right). There is no difference in appearance to the naked eye.



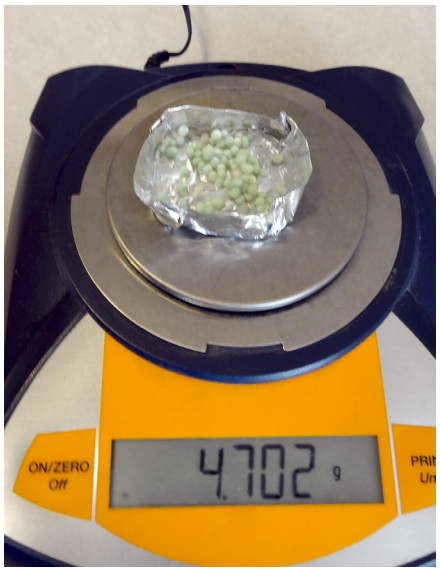


FIGURE 2. Weighing PCU and aluminum foil drying tin on a digital scale.

Since N fertilizer with a polymer coating costs more, it is important to know you are receiving relatively undamaged PCU and that your fertilizer application method is not damaging the product. A simple test, explained here, can be conducted to test the damage to the PCU. It is recommended that fertilizer dealers and cooperatives test PCU at different points in the handling process and before and after mixing, and that farms and crop consultants test the PCU after mixing or after land application.

Knowing if PCU is damaged and may release over a shorter period of time is important when interpreting plant tissue N levels during the growing season. If plant tissue N is low later in the growing season, it is important to know if more N will be supplied by the PCU when deciding if extra N is needed. In addition, damaged PCU can lead to larger than expected plant tissue N content earlier in the growing season.

Any damage that occurs to a prill of PCU is not visible to the naked eye (figure 1) and the only way to assess the quality is to quantify its release. The PCU N release test described here is a 24-hour water test that can be conducted with minimal effort.

The 24-hour water test

The test to determine if the PCU is damaged is simple but requires some supplies. The method outlined here is a modified version originally reported by Bierman et al. in 2015. The test requires at least 1 ounce (28 grams) of the PCU, an accurate scale, at least three containers able to hold 3 ounces of water, a few miscellaneous supplies, and a place to dry the fertilizer. The scale needs to be accurate enough to measure ounces to two decimal places (i.e., down to 0.01 oz) or to a tenth of a gram (i.e., down to 0.1 g), and be able to weigh the PCU and the container at the same time (figure 2). Several common household items can be used for the container that will hold the water and fertilizer including coffee cups, mason jars, plastic cups or drink containers, or yogurt containers. In this example, we used plastic centrifuge tubes with flat bottoms (figure 4).

Materials and supplies

- 1 oz (28 g) of PCU
- Containers that are 3 oz (90 mL) or larger
- Small wire strainer (to collect the fertilizer)
- Aluminum foil constructed into a drying tin (at least 1.5 inches long, 1.5 inches wide, and ½ inch tall) (figure 2)
- Scale that measures down to 0.01 oz or 0.1 g
- Drying space or low temperature oven

To begin, the PCU fertilizer samples need to be dried in order to get rid of excess moisture; a warm dry place with plenty of air circulation is good, but a low temperature (105°F) drying oven is even better. It is ideal if a sample of undamaged PCU is also tested, but if one is unavailable, the values reported here can be used for comparison.

Each PCU sample should be tested in triplicate, meaning you have three samples for each PCU sample, so label the containers accordingly. Here we test two PCU fertilizers (unblended and blended) and the samples are labeled: Unblended-1, Unblended-2, Unblended-3, Blended-1, Blended-2, and Blended-3. Using at least three replications per sample is the best way to account for variation given that we are only using a small sample compared to the amount applied to the field. The unblended PCU used in this example is ESN®, obtained directly from the manufacturer (Agrium, Inc.), and can be considered undamaged. The blended fertilizer is also ESN® and was collected after being blended with ammonium sulfate and potassium chloride by a fertilizer dealer. The fertilizer was collected directly from the bulk truck as it was falling out of the auger and into a spreader. The blended PCU was evaluated alone, meaning the ammonium sulfate was removed (figure 3). This was a specialty blend requested by a farmer.

Test procedure

Repeat the following procedure three times for each product you wish to test.

STEP 1. Place a drying tin on the scale and record weight. Do not use the tare option on the scale.

STEP 2. Add about 0.30 dry oz (plus or minus 0.05 oz) or 8 g (plus or minus 1.4 g) of PCU to the drying tin and record the exact weight (figure 2).

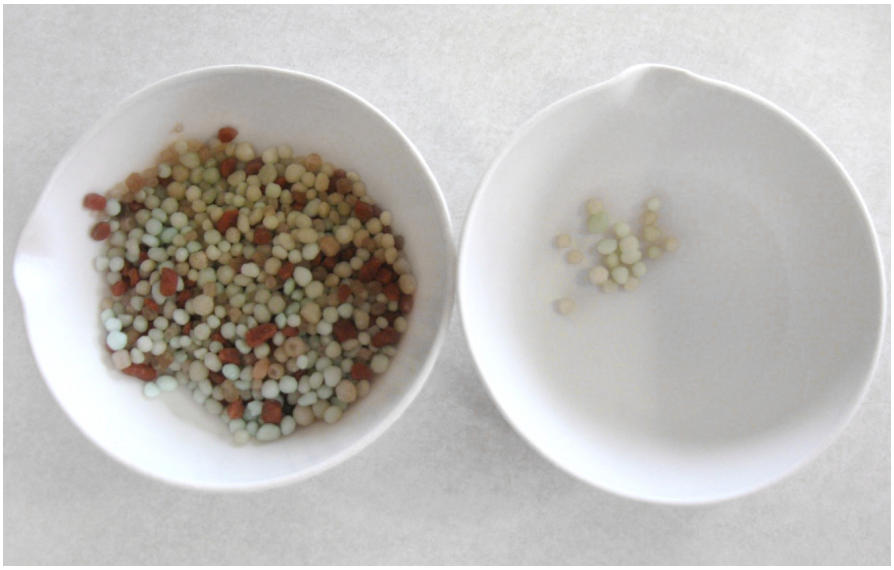
STEP 3. Add the dry PCU to a labeled container (container A in figure 4).

STEP 4. Add 3 fluid oz (about 90 mL) of water to the labeled container and stir (container B in figure 4). Distilled water is preferred, but tap water is acceptable. This part of the test should be conducted at room temperature. Nitrogen release will increase under warmer temperatures.

STEP 5. Wait 24 hours.

STEP 6. Weigh drying tin and record weight. It is preferable to use the same drying tin for the same sample pre- and post- water test as the value here and in step 1 will be the same.

FIGURE 3. PCU blended with ammonium sulfate and potash (left) and PCU separated from test material (right).



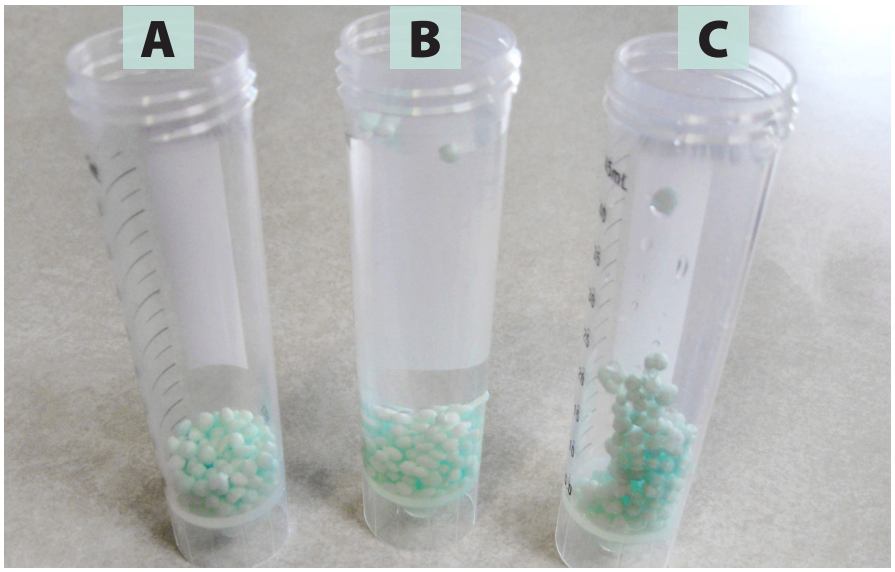


FIGURE 4. Ten grams of PCU: pre-water test (A), during water test (B), and drained following 24 hours (C).

STEP 7. Pour off the water and collect the PCU prills in a wire strainer (container C in figure 4). It is important to not lose any PCU prills in the process. If you do, you need to repeat the study with fresh PCU. Transfer all PCU prills to the drying tin from step 6.

STEP 8. Put the drying tin and the PCU in a warm, dry environment with good air circulation; the goal here is to dry down the fertilizer as quickly as possible to prevent further N loss. Drying in a drying oven at 105°F for 12–24 hours is ideal.

STEP 9. Periodically check on the PCU and stir to ensure even drying.

STEP 10. When the PCU appears dry, take the containers out to cool. Record the weight of the PCU and foil weighing dish combined. Put the PCU and foil weighing dish back in the dryer for at least 1 hour and reweigh. If the weights are within 2% of each other, the PCU is dry. Otherwise, put it back in the dryer for at least 4 hours and repeat the measurement process until two consecutive weights are within 2% of each other.

Table 1 provides example calculations. In this scenario, the sample Blended-2 did not meet the criteria of being within 2%, so it should remain in the drying oven longer (for the purposes of this scenario, we will assume that the second dry weight of Blended-2 is the final dry weight). Use the last weight for the next calculation.

STEP 11. Calculate the mass loss per sample using the three weights measured: (1) drying tin, (2) drying tin + PCU pre-water test, and (3) drying tin + PCU post-water test. Table 2 provides example calculations. The mass loss can then be converted to percent loss and averaged across samples. The final result is the average percent loss of each tested product.

Results and interpretations

- Unblended (and relatively pure) PCU lost about 6% of its mass during the 24-hour water test. This is consistent with other findings. There is always a minor percentage of the product that can be lost immediately, so expected minimum purity is 94%.
- Blended PCU lost 22% of its mass in 24 hours, indicating that blending with sharply angled fertilizer products can damage PCU during mixing. For purposes of this study, we attempted to find the most aggressive handling of the PCU. This handling process is not likely a standard practice and it was conducted upon farmer request.
- It is clear that the purity of PCU can be compromised when handling, mixing, and applying the product. The 24-hour water test described here is a simple and effective approach that can be conducted by the fertilizer dealer, a crop consultant, or the farmer to evaluate the damage to the product at each stage in the handling and application of the product.

Measurements and calculations

1. Measured weights from the **Blended-1** sample in **table 2**.
   - Weight of drying tin (empty): 35.8 g
     The same tin was used pre- and post-water test.
   - Pre-water test weight of PCU and drying tin: 45.9 g
   - Post-water test weight of PCU and drying tin (after drying and weighing twice): 43.1 g
2. Initial weight of PCU:
   45.9 g – 35.8 g = 10.1 g
3. Final weight of PCU:
   43.1 g – 35.8 g = 7.3 g
4. Percent mass loss:
   [(10.1 – 7.3) ÷ 10.1] x 100 = 27.7%

TABLE 1. Example measurements and calculations for determining if PCU samples are dry.*

SAMPLE	Grams				
	Empty dish A	Drying weight #1 (1:00 pm) B	Drying weight #2 (2:00 pm) C	% Difference (B-C) ÷ (B-A) x 100	Less than 2% different
Blended-1	35.8	43.1	43.1	0.0	Yes
Blended-2	36.1	45.3	44.6	7.6	No
Blended-3	38.8	47.1	47.1	0.0	Yes
Unblended-1	35.9	45.3	45.1	2.1	Yes
Unblended-2	35.2	44.9	44.8	1.0	Yes
Unblended-3	35.1	44.6	44.6	0.0	Yes

*We recommend taking two consecutive weights at least one hour apart. If the weights are within 2% of each other, the sample can be considered dry. If not within 2%, leave PCU in oven for four more hours and reweigh.

TABLE 2. Example data calculations to determine percent (%) mass loss of PCU from water immersion test.

SAMPLE	Pre-water test			Post-water test				
	Grams							
	Empty dish A	PCU + dish B	Initial PCU (I) B-A	Empty dish C	PCU + dish D	Final PCU (F) D-C	Mass loss I-F	% Loss (I-F) ÷ I x 100
Blended-1	35.8	45.9	10.1	35.8	43.1	7.3	2.8	27.6
Blended-2	36.1	46.7	10.6	36.1	44.6	8.5	2.1	19.7
Blended-3	38.8	48.8	10.0	38.8	47.1	8.3	1.7	17.1
							Average loss	21.5
Unblended-1	35.9	46.0	10.1	35.9	45.2	9.3	0.9	7.8
Unblended-2	35.2	46.3	10.1	35.2	44.8	9.6	0.5	5.0
Unblended-3	35.1	46.1	10.1	35.1	44.7	9.6	0.5	5.2
							Average loss	6.0

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