THE

MANURE GRANULATION

HANDBOOK

FROM THE FEECO

MATERIAL PROCESSING SERIES

FEECO INTERNATIONAL

TOMORROW'S PROCESSES, **TODAY.**

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Introduction

FEECO International was founded in 1951 as an engineering and equipment manufacturer. We quickly became known as the material experts, able to solve all sorts of material processing and handling problems, and now serve nearly every industry, from energy and agriculture, to mining and minerals, as well as waste transformation, and everything in between.

As sustainability continues to become a global focus, more than ever, advanced technologies are needed in creating beneficial reuse opportunities for increasing amounts of waste. Concurrently, the transformation of organic wastes is being looked at as the next generation in alleviating many of the issues created by the human impact on Earth.

FEECO has become the premier name in providing feasibility testing, process and product design, and custom processing equipment for organic waste materials. From idea, to complete process solutions and custom processing equipment, we offer unparalleled capabilities in transforming organic wastes into value-added, marketable products.

Many of the world's top companies have come to rely on FEECO for the best in custom process equipment and solutions. These companies include:

For further information on our custom processing equipment and systems, or our many other capabilities, contact a FEECO expert today.

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Intro to

MANURE

INTRODUCTION

Manure has been used for centuries as a way to give nutrients and organic matter back to soil, while providing an outlet for farmers to effectively manage their on-farm waste.

However, as our understanding of the world around us grows, experts are beginning to discern the long-term effects of nutrient runoff and buildup in our soils. This issue has become a key discussion in sustainability lately, as large, concentrated livestock operations replace smaller farms, and efficiently managing massive amounts of manure becomes a growing challenge.

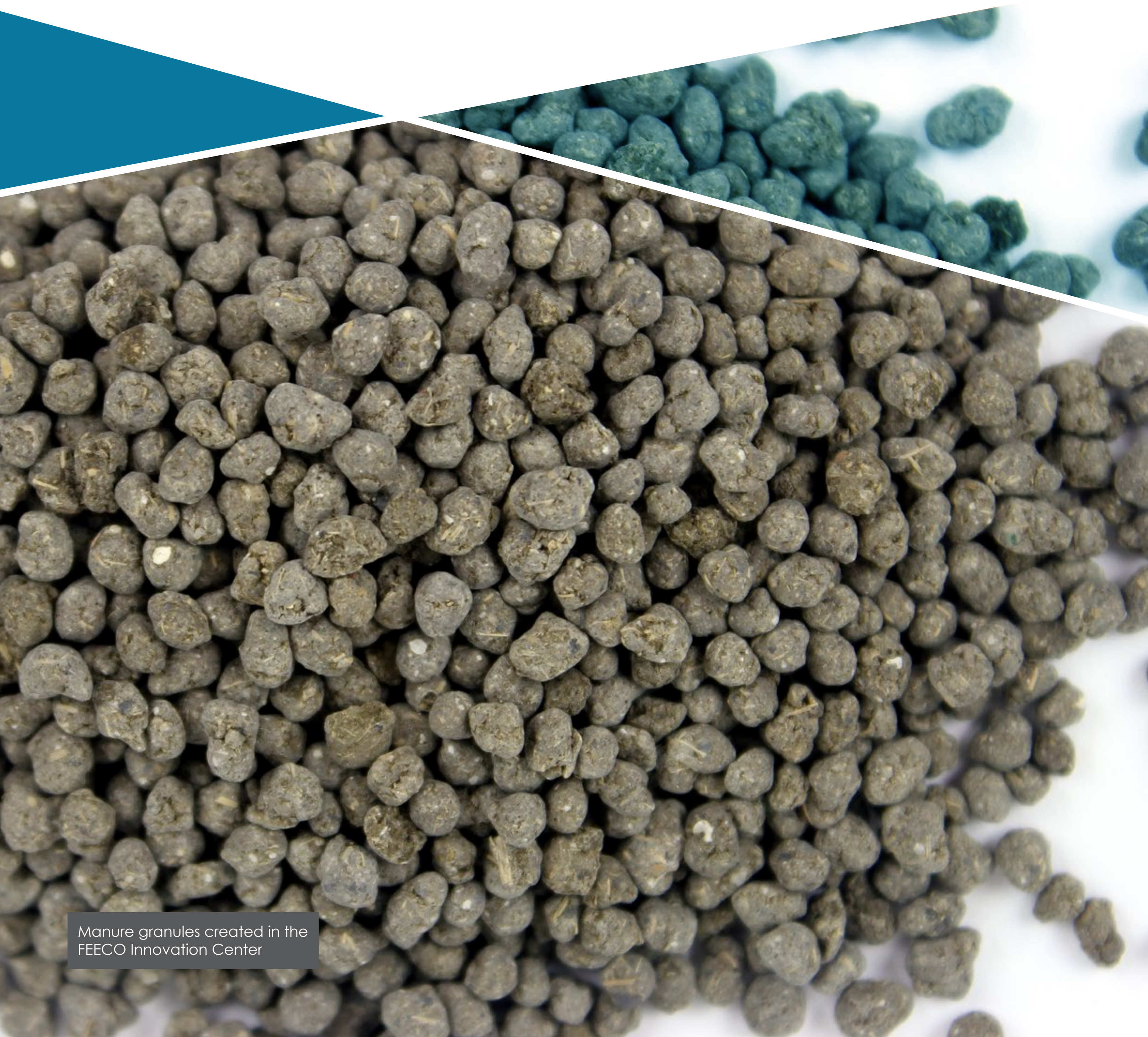
Many are starting to recognize that the solution to these issues likely lies in the problem itself; although manure does pose challenges in its raw state, this "waste" contains an abundance of nutrients and organic matter.

As such, a rising need for technologies in transforming manure and other organic wastes into fertilizer products can be explained as a culmination of numerous contributing factors. Among them:

- Non-renewable chemical fertilizer prices are volatile.
- Competition for land resources is increasing, resulting in less land to accommodate the increasing amounts of manure from larger herds.
- Manure is a renewable resource, unlike mined nutrient resources (i.e., Phosphorus, Potassium, etc.), which risk eventual depletion.
- Soils have become depleted of necessary nutrients and organic matter from the continued focus on macronutrients.

Much opportunity exists around nutrient recovery through the granulation of organic wastes, particularly manures, into premium fertilizer and soil amendment products. This handbook serves to examine the opportunities and benefits to this approach.

GRANULATION AS A SOLUTION



Manure granules created in the FEECO Innovation Center

The granulation of manure offers widespread opportunity in alleviating challenges faced by both farmers and the general global population. The most pertinent challenges are listed here, along with the corresponding solutions that granulation can offer.

PROBLEM: MOUNTING WASTES & COSTLY TRANSPORT

Manure presents significant challenges in waste disposal and handling for large-scale farms. An increasing population has put mounting pressure on the agriculture and livestock industries to provide more food from smaller plots of land. Herd sizes continue to grow, while prohibitively high land costs and surrounding land development sometimes prevents farmers from having an adequate amount of land for the amount of waste they produce. And with the average dairy cow generating 122 pounds of manure per day (over 22 tons per year), and the average hog generating 11.1 pounds per day (1.9 tons per year),[1] farmers face a growing problem of where to go with all that manure. Additionally, the high cost associated with hauling manure discourages transporting it long distances, often limiting transportation to just a few miles from the farm.

Unfortunately, it's not just a matter of finding scarce field space to store the manure. Crops only take in the amount of nutrients they need; the rest is either discarded in the form of runoff, or stored in soil reserves, which can also later leave the soil as runoff. Over-application of manure can leach a high concentration of both nutrients and pathogens into the surrounding groundwater, especially if there is a drainage ditch, pond, stream, or wetland nearby. Steep terrain and certain soil types can also increase this likelihood. Furthermore, oversaturated land does not allow the farmer to reap the full nutrient value from what he spreads. And while modern nutrient management programs aim to mitigate over-application, farmers still face a challenge of how to manage their increasing amounts of manure.

SOLUTION: TRANSPORTABLE PRODUCTS THROUGH GRANULATION

The transformation of manure into a dry, granular fertilizer product offers a solution to the waste management woes presented by manure.

Unlike raw manure, where storage reserves can be used up relatively quickly, dry granules are storable and can be used as needed.

Dry granules are easy to store and handle, requiring less storage space and also eliminating the offensive odor commonly associated with manure.

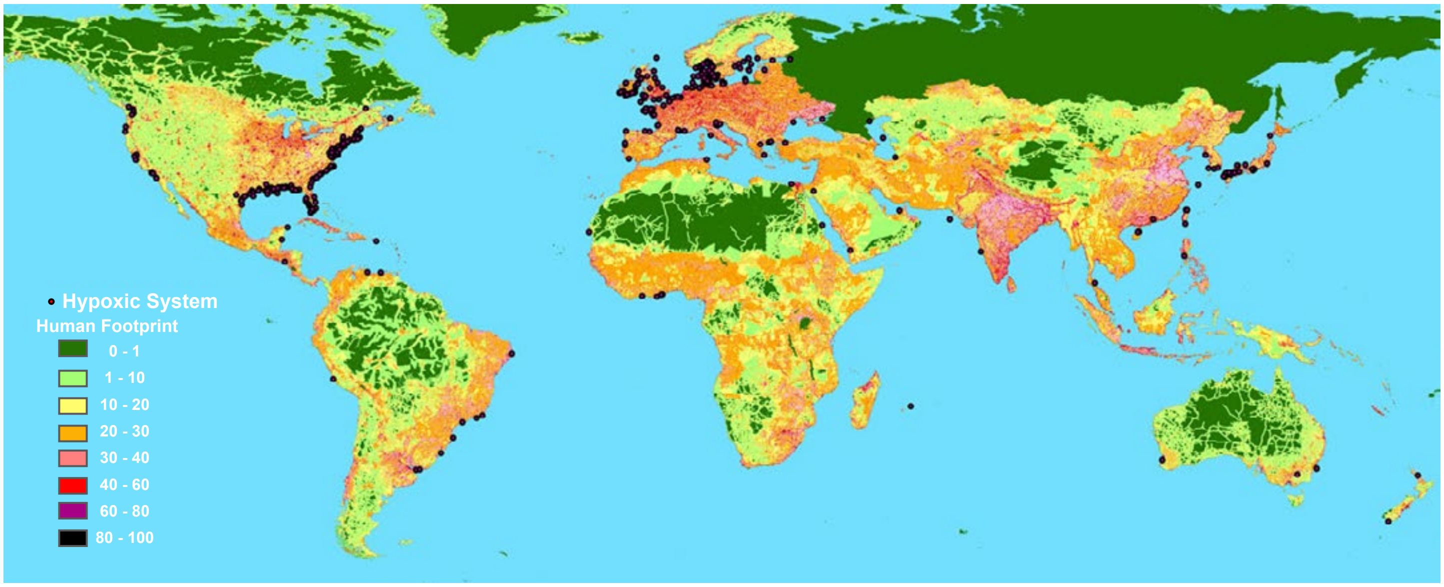
Transportation costs are reduced significantly, increasing the distance farmers can haul their manure for land application.

The granulation of manure alleviates the pressure on farms to manage their "waste," instead turning it into a problem-solving, money-saving opportunity.

PROBLEM: GLOBAL NUTRIENT RUNOFF

Nutrient runoff has proven to have big impacts on surrounding ecology. In fact, runoff has been attributed as a critical pollution source to dead zones around the world.

1. Barker, J.C., Hodges, S.C., Walls, F.R. "Livestock Manure Production Rates and Nutrient Content." *2002 North Carolina Agricultural Chemicals Manual*: 1. Archive of Agri-Environmental Programs in Ontario. Web. May 2016.



A map of dead zones and associated human footprint around the world. Source: *Scientific American*.

A dead zone is a hypoxic (low oxygen) area found in large bodies of water such as oceans and lakes. The depleted oxygen levels in a dead zone render the area uninhabitable for most marine life.

Dead zones are reversible, but restoration is typically expensive. A better solution to this growing problem is to keep nutrients from entering waterways in the first place.

Because a large portion of nutrients and pathogens enter the water through the erosion of soil and the leaching of manure through the soil, proper fertilizing techniques are crucial to preventing and reducing the movement of nutrients and other pollutants into ground or surface water.

This issue is in the spotlight in Wisconsin, where Concentrated Animal Feeding Operations, or CAFOs, and other dairy farms have largely been blamed for water quality issues in Kewaunee County, preventing some residents from being able to drink their well water. Kewaunee County has the most concentrated number of cows per acre in all of Wisconsin.[2]

SOLUTION: IMPROVED NUTRIENT MANAGEMENT THROUGH GRANULATION

The granulation of manure is a key factor in the effort to reduce runoff from the agriculture sector. While there are many factors that contribute to nutrient runoff from agriculture (distance to waterways, fractured bedrocks, type of soil, field slope, etc.), the spreading of raw manure, or even composted manure can increase the likelihood that runoff will occur.

This is because manure is typically in the form of a moisture-laden slurry. This additional moisture not only causes application to be less precise, but it can also cause nutrients to drain from soil more quickly than they would otherwise. Conversely, dry granules do not add additional moisture to soil, reducing the opportunity for runoff to occur.

2. Schuessler, Ryan. "Something's in the Water in Kewaunee County, Wisconsin." *Aljazeera America*. 13 Nov. 2015. Web. Feb.-Mar. 2016.

The potential for runoff is also decreased because a granular product makes following a nutrient management program much easier. This is particularly evident in the growing field of precision agriculture.

Precision agriculture, or 'precision farming,' is the practice of using modern technology and agronomic principles to provide site-specific field management based on the identification and analysis of in-field variability. The driving force behind precision agriculture is the basic principle that variability naturally occurs within fields. Therefore, applying the proper inputs (such as granular fertilizers) in the right place, at the right time, in the appropriate amounts, will achieve optimal yield for the entire field while reducing the risk of runoff.

While Variable Rate Technology (VRT) provides the site-specific field information, granular fertilizer provides the precise formulation and product handling that is required when delivering individualized fertilizer solutions to different areas within a field. The consistent formulations and enhanced product handling capabilities of granular fertilizers are fundamental to the practice of precision agriculture; without these benefits, site-specific applications would not be possible, forcing farmers to continue with a one-size-fits-all approach to their nutrient management.

Studies are currently underway to explore the benefits of connecting manure processing with precision agriculture practices. The University of Wisconsin-Madison's Accelerated Renewable Energy Consortium (ARE) has been utilizing FEECO to research the economic feasibility and scalability of processing manure into a variety of bio-based products.

PROBLEM: DEPLETED SOILS

A growing problem is being seen across the globe: crop nutrient value is in severe decline, and soils are losing their ability to produce the nutrient-rich produce we need to stay healthy. In short, after generations of taking more from our soil than what we've been putting in, we've stripped it of the necessary components to foster a healthy, productive soil environment.

Nutrient deficiency, or poor soil fertility, is part of the larger problem of soil degradation. In addition to poor soil fertility, soil degradation encompasses a number of other issues, including a lack of organic matter, poor soil structure, erosion, reduced or non-existant microorganisms, and more. Perhaps the most severe threat to nutrient deficiency specifically has been the continued use of improper farming techniques.

Over time, the continued harvest and replanting of crops removes the nutrients required for healthy soil and plant growth. Nutrients would normally replenish themselves naturally over time, but are unable to because of the persistent planting of crops, a practice which breaks the natural nutrient cycle, and ultimately strips the soil of the valuable nutrients it needs. And while traditional fertilizing techniques have focused on putting in the key macronutrients needed for plant growth (Nitrogen, Phosphorus, and Potassium), they do not restore any other nutrients, nor do they restore the organic matter necessary for a thriving soil environment.

In a comment regarding his latest paper on the topic, Ronald Amundson, Professor of Environmental Science, Policy and Management at the University of California, Berkeley stated, "Ever since humans developed agriculture, we've been transforming the planet and throwing the soil's nutrient cycle out of balance. Because the changes happen slowly, often taking two to three generations to be noticed, people are not cognizant of the geological transformation taking place."[3]

CONSEQUENCES OF POOR SOIL HEALTH

Soil health is a key component in sustaining world food security and the overall health of the world's population—both human and animal. Scientists are now finding that the continued focus on macronutrients throughout agriculture's history has stripped soils of the micronutrients and organic matter required for a productive soil environment, potentially limiting both crop yield and nutritional makeup.[4]

Crops have been bred to grow bigger, stronger, and produce more, with nutrition all but going by the

3. Yang, Sarah. "Human Security at Risk as Depletion of Soil Accelerates, Scientists Warn." *Berkeley News*. 7 May 2015. Web.
4. Dell, Bernard, Richard W. Bell, and Longbin Huang. "Importance of Micronutrients in Sustaining Crop Nutrition." *Murdoch University Research Repository*. Proc. of IFA Agriculture Conference, Kunming, China. N.p., 2006. Web. July 2016.

wayside. This is not only a concern for the health of the Earth's inhabitants in terms of nutrition, but it also has a major effect on the world's soils in general. Consider this alarming statement from the Nutrition Security Institute:

"The depletion of soil nutrients and soil microorganisms contributes to soil erosion and the loss of arable topsoil. The Earth is losing arable topsoil at a rate of 75 to 100 GT. per year. If soil loss continues at present rates, it is estimated that there is only another 48 years of topsoil left.[5]

Adding to concern, experts are estimating that by 2050, the Earth will be home to upwards of 9 billion people. According to the FAO,[6] this will require a 70% increase in food production, a tremendous feat, considering we'll have to do this on the same amount of land we have today, or less, given the likelihood of additional development.

SOLUTION: ORGANIC MATTER

While a blanket solution is not likely, many speculate that the beneficial reuse of organic matter from sources such as manure will be a key component in restoring soils around the globe. Organic matter is a critical component in maintaining and revitalizing soil health, and is the foundation of many biological processes that improve soil fertility and overall structure.

This valuable material fosters a thriving and productive soil environment through a number of benefits, including:

- Improved resistance to erosion
- Enhanced soil structure
- Greater ability to retain water
- Better nutrient holding ability
- Improved nutrient uptake by plants

Organic matter restores natural nutrients and microorganisms to the soil, fostering a healthier, more productive soil that can produce the nutrient-rich food we need to maintain and improve food security around the world.

The recovery of nutrients and organic matter from manure can be used to complete the once-disrupted natural nutrient cycle, creating a closed-loop system where nutrients used to grow our food are put back into the soil where they belong.

The granulation of manure offers significant opportunity to solve many of the issues faced today by farmers and the world in general. This includes eliminating the challenges associated with managing manure through land application, nutrient runoff, and the world's nutrient-deficient soils. Additionally, optimal soil environments will provide higher yields and more nutritious crops, helping to get the world back on track for the amount of food we'll need to produce to feed our growing population.

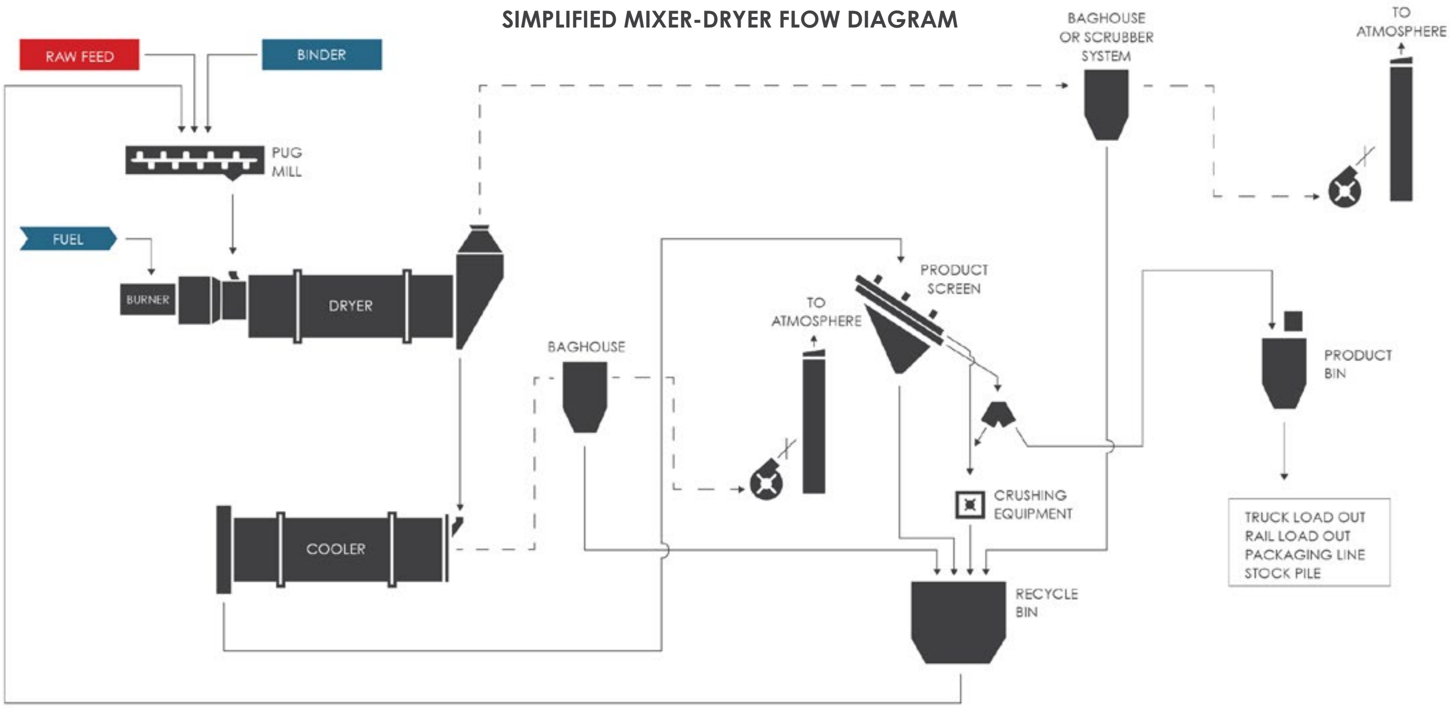
Furthermore, manure is a renewable resource. While we would likely still need to rely on inorganic minerals in order to maintain global food security, the addition of manure-based fertilizer products would take the pressure off some of these finite mineral resources.

5. Marler, John B., and Jeanne R. Wallin. "Human Health, the Nutritional Quality of Harvested Food and Sustainable Farming Systems." *Nutrition Security Institute.* Web. Feb.-Mar. 2016.
6. *High Level Expert Forum - How to Feed the World in 2050.* N.p.: FAO, Oct. 2009. PDF.

SYSTEMS

TYPES OF SYSTEMS | PRECONDITIONING | EQUIPMENT OVERVIEW

Manure granulation facility by FEECO International



TYPES OF MANURE GRANULATION SYSTEMS

There are four generalized and accepted approaches for the granulation of organic waste and manure streams: Mixer-Dryer Granulation, Disc Pelletizing, Drum Granulation, and Extrusion. Each method offers its own advantages and disadvantages, with the deciding factor typically coming down to which system will work with the material to produce the desired results best. In some cases, multiple systems may be suitable, in which case, the choice is typically one of economics.

THE MIXER-DRYER APPROACH

The diagram on this page shows a simplified manure granulation system with a mixer-dryer setup.

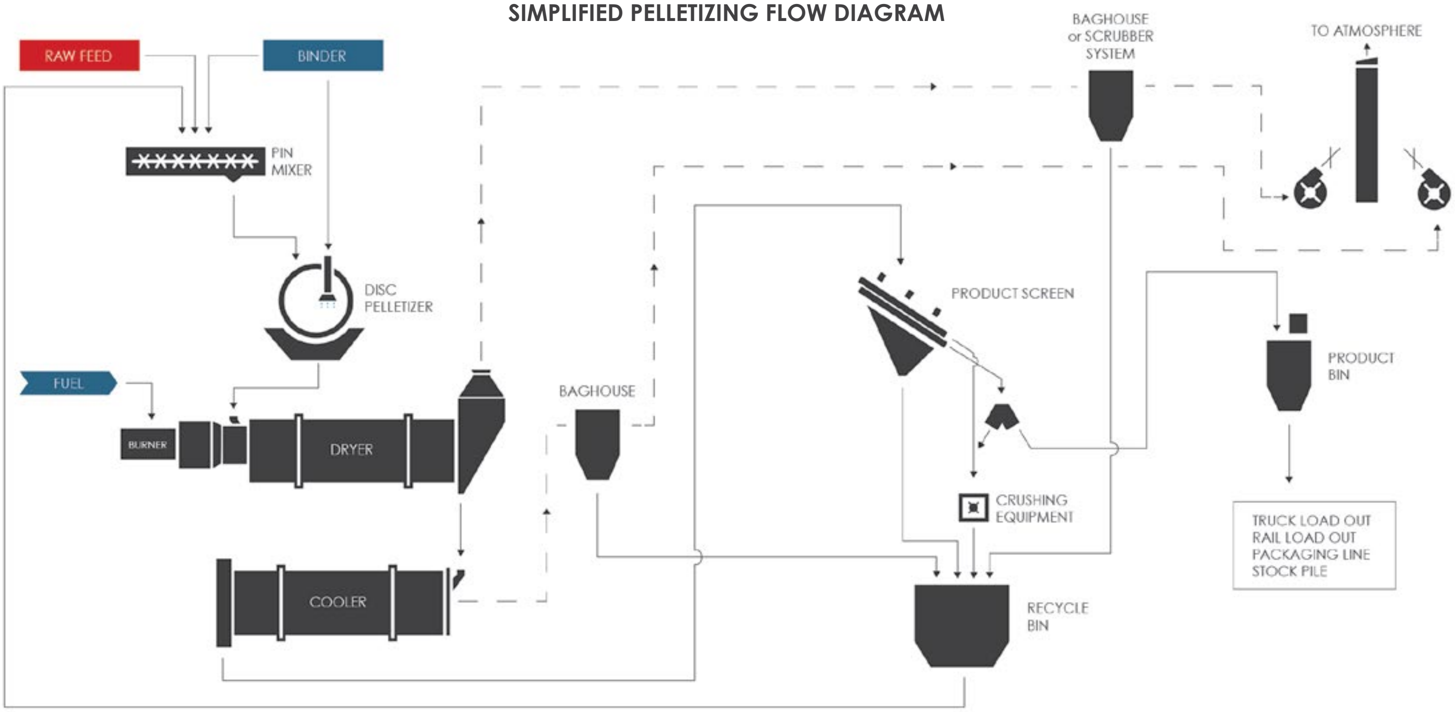
In this approach, pre-treated manure enters the system at the mixer. Mixer selection is based on the feedstock analysis and is most often a pin mixer or pug mill. Typically, a pin mixer is used for more dry, finely divided feed, such as chicken litter or compost. A pug mill is generally used when the feedstock is a sludge or paste, or dewatered liquid manure.

The mixer homogeneously combines the feedstock and binder, along with any additional inputs. While still in the mixer, the material begins to agglomerate, forming rounded pellets. The pellets are then discharged from the mixer, and carried via conveyor to the dryer (typically a rotary or fluid bed dryer) to be dried into their final form.

Upon drying, the material is then commonly cooled, which improves storability and helps to prevent caking.

The mixer-to-dryer approach is advantageous because it is a simple, closed system. Odor is

SIMPLIFIED PELLETIZING FLOW DIAGRAM



minimized, and control is easy. Things like speed, pin/paddle arrangement, and more, can all be adjusted to vary the size of the pellets.

Though there are many advantages to this method, there are also a few disadvantages. Oftentimes, a tight moisture window in the pin mixer can limit control. Pin mixers also require a finely divided, powdery feedstock, meaning the addition of pre-processing equipment such as pre-grinders or de-lumpers may be a necessity when working with a pin mixer.

THE DISC PELLETIZER APPROACH

The next approach, called pelletizing, is similar to the first approach, but includes the addition of a disc pelletizer to the process, after the mixer, and before the dryer. Adding a disc pelletizer to the process increases the throughput of the overall process and also adds an element of fine-tuning and control over the end product. In general, adding a disc pelletizer to the process improves overall efficiency and the quality of the end product.

Not only does a pelletizer create more on-size product, but the product is considered to be a premium product; pellets produced via pelletizing are a little more dense and more spherical, compared to those produced solely in a mixer. Pelletizers are also flexible with the addition of binders.

The diagram above shows a simplified manure granulation system with a disc pelletizer.

Again, material is combined and agglomeration begins in the mixer, where “seed pellets” are formed. Material then exits the mixer and is fed to the disc pelletizer, where the seed pellets are rounded and grown to the desired size through a layering effect.

Once they have reached the desired size, the pellets exit the disc pelletizer and are fed to the dryer and then the rotary cooler.

The disadvantage to adding a disc pelletizer to the process is that it then becomes an "open" system, requiring more housekeeping due to fugitive dust. An open system can also be much more odorous than a closed one.

THE GRANULATION DRUM APPROACH

Some situations may call for the use of a granulation drum. This approach is identical in process flow to the pelletizer setup, with only the granulation drum replacing the disc pelletizer.

The use of a granulation drum is desirable because it offers higher capacities and also allows for a closed system. Granulation drums are typically used when a premium product is not required, or when working with materials that are dusty.

THE EXTRUSION APPROACH

The last approach is the extrusion method, whereby a dry pellet mill and crumbler are utilized. Unlike the first three methods, which are considered tumble growth (non-pressure agglomeration or wet granulation), extrusion is a pressure agglomeration technique.

Extrusion utilizes pressure to force fine materials through a mold, melding them together into a pellet.

Extrusion is ideal for smaller operations that do not have the volume to support the capacities required by a non-pressure granulation system. The extrusion system is simple and requires a lower capital investment compared to the other methods. However, the cylindrical granules produced by the extrusion process are considered a lower-grade product than the round pellets produced by the tumble-growth methods. This is because round granules offer significantly less dust and attrition, and are more customizable. *Note: FEECO does not offer equipment or process solutions for extrusion.*

OPTIONS IN PRECONDITIONING

Preconditioning feedstock is a critical part of the process of transforming raw manure into a dry, granular product.

WHY PRECONDITIONING IS NECESSARY

When working with raw manure, many characteristics make it unsuitable for use as a feedstock in the granulation process. The preconditioning process varies greatly from one material to the next, with many options available, and often a combination of methods being desirable. The method(s) chosen depends on the characteristics listed here and what is required to transform the raw material into a workable feedstock. More specifically, preconditioning serves to get a material to the particle size distribution, moisture content, and material composition that will allow the desired end product to be created. In general, pre-conditioning focuses on:

PARTICLE SIZE DISTRIBUTION

In order to granulate a material, large particles will need to be removed or ground. A particle size distribution (PSD) for organic feedstock of around 60 mesh is ideal.

MOISTURE CONTENT

The right moisture content is also critical to the success of granulation. The ideal feedstock for poultry manure is under 20%, or dry enough so that the material can go through grinding. Ideal moisture content for hog and dairy manure is around 60% to 80% so the material is in a cake form, instead of a slurry.

MATERIAL COMPOSITION

The composition of the manure will also need to be addressed during the preconditioning stage. The material should be examined to determine if it contains coarse fibers or bedding, which might dilute nutrient content and inhibit granulation. The material should also be analyzed to determine if it contains natural binding agents that will aid in the granulation process, or if an alternative binder will be required.

Aside from the general guidelines above, wet and dry feedstocks often require different methods of preconditioning, due to their differences in moisture content, consistency, and makeup.

PRECONDITIONING WET FEEDSTOCK

Wet feedstock is most commonly dairy or hog manure. Listed below are some of the common pre-conditioning methods used with wet feedstock.

SAND REMOVAL

In dairy applications where sand is used as a bedding, sand removal is necessary. Not only is sand highly abrasive, which can degrade equipment over time, but it also reduces the effectiveness of granulation and would be undesirable in an end product.

Manure prior to solid/liquid separation process

The nutrient-rich cake produced from preconditioning, ready for granulation

Additionally, sand can fill up digesters if not removed before the anaerobic digestion stage. Sand removal is carried out using a sand separation system—a combination of steps that washes the material and runs it through an inclined screw, hydrocyclone, or sand lane to separate the manure from the sand.

ANAEROBIC DIGESTION

Anaerobic digestion is the breakdown of manure through biological processes that occur in the absence of oxygen. This process helps to homogenize and stabilize the manure in order to prepare it for solid/liquid separation and nutrient capture. The resulting material is a slurry, reduced in odor and pathogens, and ready for separation. In addition to the slurry produced, this process also produces biogas, which can be converted into a usable fuel source to make electricity, be used on-farm, or sold to energy producers.

COARSE FIBER REMOVAL

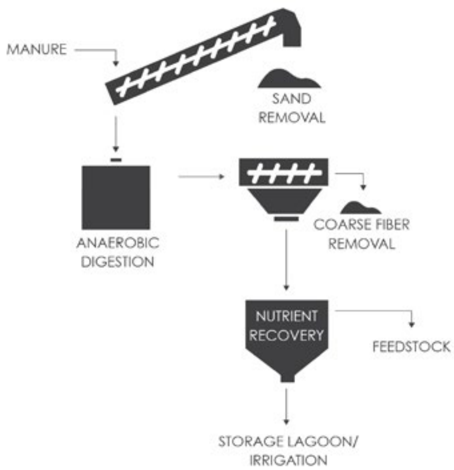
The removal of coarse fibers is also commonly seen with dairy manure. This step is necessary to remove particles such as bedding or straw that would impede granulation or create a weak pellet product.

SOLID/LIQUID SEPARATION

When moisture can be freely pressed out, solid/liquid separation (with nutrient capture) is required. This step yields a concentrated cake material, ideal for use in a fertilizer product because of its rich nutrient content.

A variety of options in methods and equipment exist for this purpose, with techniques combining mechanical, gravity, and even chemical action. A common preconditioning process for a "wet" feedstock is illustrated at right: raw manure first goes through sand removal, then anaerobic digestion, coarse fiber removal, and finally, solid/liquid separation with nutrient capture in order to recover nutrients and prepare the feedstock for granulation.

COMMON WET FEED PRECONDITIONING



PRECONDITIONING DRY FEEDSTOCK

Dry feedstock is generally a poultry manure, poultry litter, compost, or similar type of material. Listed below are some of the common preconditioning methods used for a dry feedstock.

DRYING

Pre-drying is sometimes necessary if the moisture content of the material is too high. When a grinding step is necessary, material with a moisture content that is too high (generally thought to be > 20%) would clog the grinding system. Drying can be carried out using a variety of equipment, or through the practice of back mixing, in which dried product is thoroughly mixed with wet feedstock to bring down the moisture content.

GRINDING

Large particles cannot be present in the feedstock, because they would inhibit effective granulation. For this reason, grinding is necessary when the material contains large particles, or has a particle size distribution that is too large. Grinding is commonly carried out using a hammer mill.

COMPOSTING

Since most anaerobic digestion requires a pumpable slurry, it is not likely an option with dry materials. Similar to anaerobic digestion, however, composting can be used to homogenize the feedstock for granulation and break down the material through the action of micro-organisms.

Chicken litter pellets created on a FEECO disc pelletizer

While composting can be used for both wet and dry feedstocks, it is typically only seen with dry feedstock, because wet feedstock is often too wet to be efficiently composted. Wet feedstock would likely require a lot of bulking agents in order to bring the moisture content down, which would in turn, dilute the nutrient content.

The diagram below illustrates a common preconditioning process for a "dry" feedstock, where the manure first goes through composting and then grinding before granulation begins.

COMMON DRY FEED PRECONDITIONING

Preconditioning is a necessary step to transform a raw manure or organic waste product into a suitable feedstock for creating a premium fertilizer product. Many preconditioning methods are available, with a combination of techniques often being desirable.

EQUIPMENT OVERVIEW

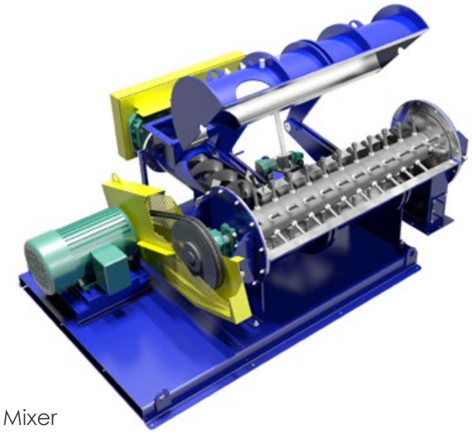
The following equipment is commonly used in manure granulation and can all be engineered and manufactured by FEECO.

PIN MIXERS

[Pin mixers] are a type of industrial mixer utilized throughout a number of industries to process a wide variety of materials. In the agriculture industry, they are ideal for processing finely divided solids such as chicken litter. They can be used as a stand-alone agglomeration device, or as the preconditioning step in a disc pelletizing setup.

HOW PIN MIXERS WORK

Pin mixers are comprised of a rotating cylinder



FEECO Pin Mixer

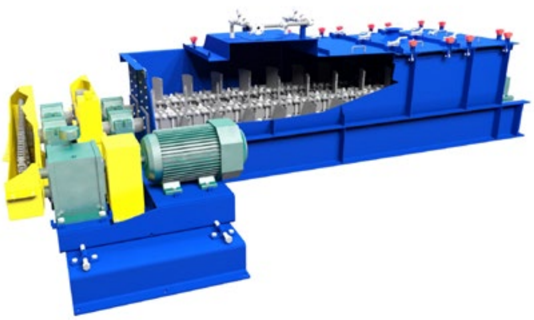
affixed with rods (or "pins"), inside a stationary shell casing. They utilize an intense spinning action to form agglomerates. This motion also densifies the material. Pin mixers are ideal for mixing solid and liquid feeds.

FEECO PIN MIXERS AT A GLANCE

SIZE	15" - 50" (380 - 1,270mm)
CAPACITY	500 lb/hr - 70 TPH
CUSTOMIZABLE?	Yes

PUG MILLS (PADDLE MIXERS)

Pug mills, also commonly called pugmill or paddle mixers, are another type of industrial mixer frequently used in the manure granulation process. Similar to pin mixers, they can be used as a stand-alone agglomeration device in the mixer-dryer setup, or as the pre-conditioning step in the disc pelletizer configuration.



FEECO Pug Mill/Paddle Mixer

HOW PUG MILLS WORK

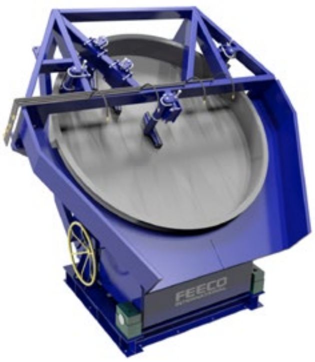
Pug mills utilize a gentle, kneading and folding-over motion to thoroughly mix feedstock materials. Because of this motion, pug mills are ideal for combining solid and liquid feeds in heavy-duty processing applications where the feedstock is more of a sludge or slurry.

FEECO PUG MILLS AT A GLANCE

SIZE	22" - 78" (560 - 1,981mm)
CAPACITY	2 TPH - 250 TPH
CUSTOMIZABLE?	Yes

DISC PELLETIZERS

Disc pelletizers are a non-pressure (tumble growth) agglomeration device used for pelletizing.



FEECO Disc Pelletizer

HOW DISC PELLETIZERS WORK

Disc pelletizers work by tumbling material on a rotating disc in the presence of a binder. This causes the fines or seed pellets to become tacky and pick up additional fines as they tumble, in a process known as coalescence. This allows the pellets to "grow" to the desired size, at which point they exit the pelletizer, and are carried via conveyor to a dryer. This is a continuous process, as feedstock and binder are continuously fed onto the pelletizer.

FEECO DISC PELLETIZERS AT A GLANCE

SIZE	6 - 25' (1.8 - 7.5m)
CAPACITY	1 TPH - 100 TPH
CUSTOMIZABLE?	Yes

ROTARY DRYERS

Rotary dryers are an industrial drying system prized for their high capacities, heavy-duty build, and reliability. Rotary dryers are a forgiving piece of equipment, known to take what is given and produce a quality, uniform product, despite variance in feedstock.

FEECO Rotary Dryer

HOW ROTARY DRYERS WORK

Rotary dryers work by tumbling pellets in a rotating drum as a drying air moves through the drum. Flights, or material lifters, pick up the material and drop it through the air stream as the drum rotates in order to maximize heat transfer efficiency. The tumbling action imparted by a drum offers the added benefit of "polishing" the pellets—further rounding them as they dry.

FEECO ROTARY DRYERS AT A GLANCE

DIAMETER	3' - 15' (1 - 4.6m)
CAPACITY	1 TPH - 200 TPH+ (1 MTPH - 181 MTPH)
CUSTOMIZABLE?	Yes

ROTARY COOLERS

Product discharges from the dryer, in general, at around 180°F, and therefore must be cooled before it can be stored or bagged. Cooling also helps to prevent caking issues during storage. For this, a rotary cooler is employed.

FEECO Rotary Cooler

HOW ROTARY COOLERS WORK

Rotary coolers work very similarly to rotary dryers; material is tumbled in a rotating drum, while flights pick up the material and cascade it through the air stream. Instead of heated air, chilled or ambient air is used.

FEECO ROTARY COOLERS AT A GLANCE

DIAMETER	3' - 15' (1 - 4.6m)
CAPACITY	1 TPH - 200 TPH+ (1 MTPH - 181 MTPH)
CUSTOMIZABLE?	Yes

HAMMER MILLS

Hammer mills are used for grinding down over-size pellets so they can be reintroduced into the process as recycle.

HOW HAMMER MILLS WORK

Hammer mills use a spinning shaft affixed with hammers and/or chains to break down over-size product.

FEECO Hammer Mill

GRANULATION DRUMS

Granulation drums are the centerpiece of most fertilizer operations. Granulation drums are incredibly versatile and can therefore be used to process a wide array of materials. They are used frequently throughout the agriculture industry to create a variety of fertilizer products, particularly when a chemical reaction is involved.

FEECO Granulation Drum

HOW GRANULATION DRUMS WORK

Granulation drums work by tumbling material in a rotating drum. When a reaction precedes the granulation drum, the tumbling action in the drum rounds the material into granules as it cools and solidifies. Tumbler flights can be added to increase material agitation.

Flexible and corrosion-resistant drum liners can be implemented to reduce or eliminate material buildup on drum walls and decrease the potential for damage due to a corrosive material.

FEECO GRANULATION DRUMS AT A GLANCE

SIZE	Drum diameters from 36" - 15' (1 - 4.6m)
CAPACITY	500 lb/hr - 3500+ TPH
CUSTOMIZABLE?	Yes

MATERIAL HANDLING EQUIPMENT

Material handling equipment is used frequently throughout manure granulation. Depending on the facility, a variety of material handling equipment may be utilized. This might include bucket elevators, conveyor systems, and belt trippers and plows.

Material handling systems are extremely customizable to suit the exact needs of a facility. Special care will need to be taken in selecting the appropriate equipment for the cake-handling portion of the process, as cake is sticky and difficult to manage.

FEECO Bucket Elevators in an on-farm manure granulation plant

BUCKET ELEVATORS

Bucket elevators transfer material vertically and are often chosen because they are ideal for high-capacity handling applications. Bucket elevators are highly customizable.


FEECO Troughed Belt Conveyor carry granulated manure

BELT CONVEYORS

Belt conveyors are also commonly employed in manure granulation facilities. Belt conveyors allow material to be carried horizontally and are commonly used to transport material from one process stop to the next, or from one building to another. They are also extremely customizable, with common modifications including the addition of loading skirtboards, belt cleaning systems, and more.

A variety of additional conveyor types exist to further optimize handling, with two of the most popular being:

Reversing Shuttle Conveyors: A belt conveyor that is mounted to a rail or track system, in order to allow for more than one discharge point and conveying in both directions.

Steep Incline Conveyors: Steep incline conveyors carry material vertically, or at an angle that is too steep for horizontal transport.

BELT TRIPPERS & PLOWS

Belt trippers and plows allow for increased flexibility of a material handling system. Trippers travel along the length of the conveyor and can discharge material at any point along the travel range, creating a continuous, long storage pile of material, as compared to a single pile of material discharged from the end of a conveyor. Trippers essentially "trip" material off the conveyor at either fixed or movable points, while belt plows are fixed, but allow for discharge from the conveyor on one or both sides.

BELT FEEDERS

Belt feeders ensure controlled feed rate from a bin or hopper onto a conveyor or other piece of process equipment. They are highly versatile and can be used in a variety of applications.

CONSIDERATIONS

Manure granules produced in the FEECO Innovation Center

CONSIDERATIONS IN MANURE GRANULATION

The granulation of manure or other organic waste into a fertilizer product is a complex process. In addition to developing a pre-treatment and granulation process around the unique source of manure to produce the desired end product, there are many additional considerations that will need to be examined during the development stages. While not an exhaustive list, the list provided here offers some of the most predominant factors to consider.

RETURN ON INVESTMENT

Return on investment is often the first consideration examined when looking to develop a manure granulation operation. In general, the payback period becomes shorter as the quantity of manure processed increases. This is because the larger the amount of feedstock, the more product that can be produced to either subsidize on-farm fertilizer costs, or to serve as an additional source of revenue to recuperate the initial investment. Furthermore, the labor costs will likely be the same whether the operation is producing 1 TPH or 10 TPH and the incremental capital costs are lower at the larger size plants. For example, to double the production capacity of a plant, the capital cost will typically go up by around 40-50%, allowing the process to produce twice the amount of saleable product for about 1.5 times the capital.

EMISSIONS

While all manure granulation operations produce emissions and will require some form of exhaust gas treatment, the unique source of manure, combined with local and state regulations will determine how much exhaust gas treatment will be required. A typical treatment system will consist of a cyclone or baghouse for particulate capture. When pollutants are present in the off gas, additional treatment may be required. This is often handled by adding a wet scrubber and/or thermal oxidizer. Biofilters offer an alternative option. If a scrubbing system is required, the resulting liquid waste will also need to be disposed of in accordance with regulations.

SPATIAL NEEDS & STORAGE CONSIDERATIONS

There are many things to consider in terms of spatial needs and storage for the operation. A manure granulation plant and the necessary supporting systems require a sizeable facility. If the operation will be on-farm, modifications will need to be made to accommodate the new operation.

A typical granulation layout alone might require a space 100' x 100' x 50' tall, not including receiving or product storage/bagging, which may require a significantly larger space than the granulation facility itself. If the feedstock source is nearby and no other minerals will be added, this area is relatively small. However, it can quickly grow to accommodate a more expansive receiving operation, or the addition of additives to the feedstock.

Space will also need to be made for the pre-treatment (nutrient separation, pre-drying, crushing, etc.) part of the process as well. While this does vary, in general, this part of the process usually requires about half the space that the granulation portion requires.

Designating an area for some cake storage is beneficial as well, because it can act as a buffer in the event that something goes down.

Although highly simplified, the illustration below offers an example of site layout for an on-farm granulation facility.

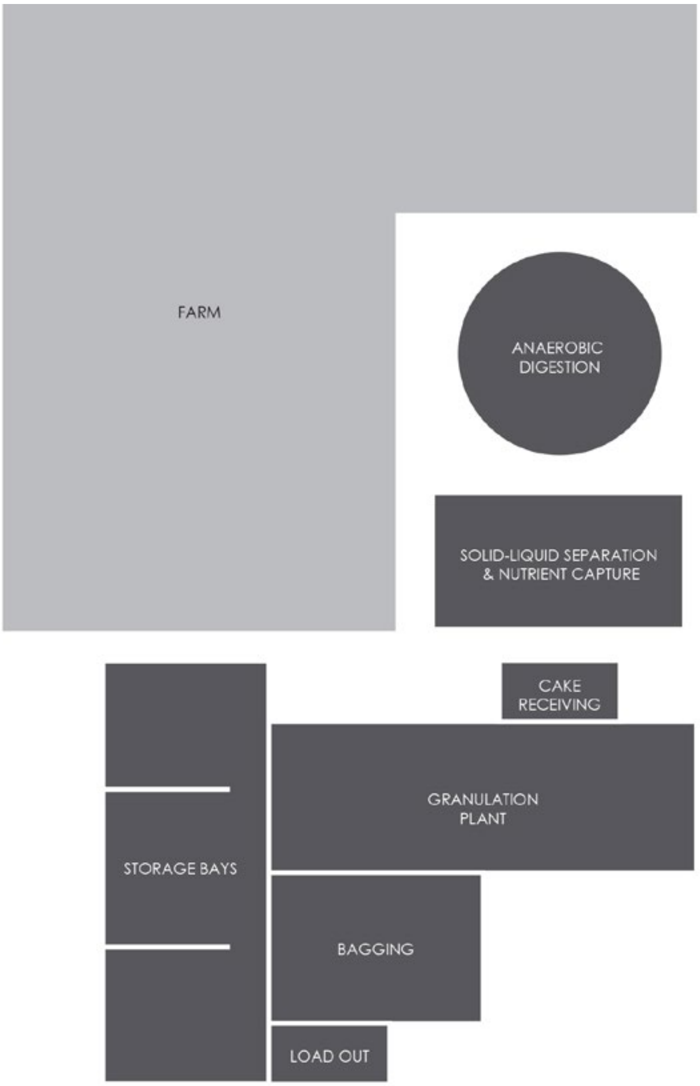


Diagram: A typical layout for on-farm granulation and supporting facilities

FUEL SOURCE

The fuel source should also be considered. Most often, natural gas is used, because it is readily available and cost effective. However, other options are available as well. Propane, fuel oil, and diesel offer alternative traditional fuel options, while biogas and waste heat from other on-farm operations offer supplemental fuel options when available. For example, many manure granulation operations are placed after an anaerobic digestion stage used to pre-treat manure. The biogas produced in anaerobic digestion can then be captured and used as the primary fuel source, or as a supplementary fuel source.

Similarly, the source of electricity should also be considered. If a reliable source of electricity is not available, alternatives and options such as large-scale generators will need to be considered.

PRODUCT OFFTAKE

Product offtake, or how the end product will be handled after granulation, will also need to be considered. Will the product be stored in silos, open bins, or super sacs? How will the product leave the facility; will a loadout system be required? Will the product be taken away in bulk by truck or rail, or will a packaging facility be required? Many options exist depending on the needs of the system.

ADDITIONAL CONSIDERATIONS

SYSTEM ENGINEERING

System engineering encompasses a number of items that will affect the overall success of a project. This will include layout drawings, Process & Instrument Diagrams (P&ID's), commissioning and start-up assistance, as well as overall project management. All of these items will need to be layed out at the onset of the project to provide clear direction.

MATERIAL HANDLING

Material handling is another important consideration in the design of a granulation facility. Material handling equipment ties the whole process together, moving material from one area to the next in seamless fluidity. As mentioned, a variety of material handling equipment is available, all customizable.

While the development of a manure granulation system is a complex task with a variety of factors that must be taken into consideration, working with a company that is highly experienced in the field will help to guide you through the process and all that it entails.

AUTOMATION

An automation control system such as a Programmable Logic Controller (PLC) should also be considered.

A process control system offers a number of benefits. Depending on the system, operators are likely to be able to view various data points, even adjusting them in real-time, all from a single screen. This is incredibly valuable for process optimization, as well as troubleshooting.

FEECO has partnered with Rockwell Automation to provide advanced automation systems to our customers. A system from FEECO not only brings process transparency to a process through the visualization of key performance indicators (KPIs), but it also allows for in-depth data collection, trending, and reporting. Additionally, remote support for troubleshooting by a FEECO process engineer is also available.

TESTING: THE CORNERSTONE TO A SUCCESSFUL OPERATION

With the transformation of manure into premium fertilizer products becoming increasingly popular, expansive research and development is being done around the processing of such waste materials. However, the processing of manure into a granular product is not a well-established industry. And with significant variation between manure types and even amongst the same type of manure, thorough testing is the foundation to a successful manure granulation process. What follows is an overview on testing in the FEECO Innovation Center.

WHY TESTING IS IMPORTANT

When working with organics, testing is critical to the development of the process itself, as well as the overall success of the process and end product.

In addition to variation in the type of manure, many on-farm practices can affect the make-up of the manure. The type of feed the animals consume, the type of separation system used, handling practices, farm location, and even barn type can all change the consistency and make-up of the manure, creating an unending matrix of manure outcome possibilities and making testing an absolute necessity.

HOW TESTING WORKS

As with any testing, the manure sample must be as representative as possible, to ensure the testing process simulates on-farm conditions.

The first objective is to determine if a preconditioning step is needed. The material may require a pre-conditioning stage to optimize the material feedstock for granulation. Again, this focuses on obtaining a good particle size distribution, moisture content, and material composition for granulation.

All of these things will change how the material will respond to granulation, and consequently, how the process will need to be designed in order to produce the desired results. It may be obvious from the start whether a material will require pre-processing, or this conclusion may be reached through the testing process itself.

With so much variation in material, it is sometimes unclear which method (mixer-dryer, drum granulation, or pelletizing) will best suit the material and be able to produce the desired end product results.

The consistency of the material most often dictates which mixer will be the most suitable starting point, with pin mixers favoring more dry, finely divided solids such as chicken litter, and pug mills more suited to cakes such as separated dairy manure. If this method produces the desired results, process engineers can move on to fine-tuning the process and testing it as a continuous process loop.

If the end product requires more refinement, however, or if the process is struggling to produce on-size product, process engineers will likely try another approach, either utilizing a different mixer, or adding a disc pelletizer to the process.

While the pelletizing approach is similar to the first method, it offers an added layer of control; the addition of a disc pelletizer allows process engineers to more closely control and fine-tune the size and other characteristics of the end product.

PRODUCT CUSTOMIZATION

Most often, producers are looking to target a specific set of particle characteristics, which could include any combination of the following:

- Bulk Density
- Crush Strength
- Solubility
- Attrition
- Compression
- Particle Size Distribution
- Flowability
- Moisture Content
- Physical/Surface Quality
- Green/Wet Strength

Testing centers around the creation of these desired specifications. Throughout testing, process engineers work with a number of variables in order to produce these results. Depending on the setup, variables might include:

- Material Feed Rate
- Amount of Recycle
- Binder Feed Rate

- Type of Binder
- Mixer Speed
- Type of Mixer
- Mixer Pin/Paddle Arrangement
- Disc Speed
- Disc Angle
- Dryer Temperature
- Dryer Air Flow
- Dryer Flight Design and/or Pattern

While the product created can be 100% manure-based, the granulation process can also accommodate the addition of other value-adding materials. Additional macro or micronutrients can be added to improve overall quality or create a fortified nutrient blend customized to a desired application.

THE PHASES OF TESTING

The organics testing process in the FEECO Innovation Center generally happens in four phases:

FEASIBILITY/PROOF OF CONCEPT

Process engineers run batch-scale tests to determine if the specific source of manure will agglomerate. Small sample sizes can be produced for use in lab or grow room trials to determine if the product will perform as needed.

PROOF OF PRODUCT

In this more in-depth batch testing phase, more time is spent determining if the specific manure sample can be made to exact specifications. Additional formulations and binders can also be tested.

PROOF OF PROCESS

Building off of step two, this phase utilizes a continuous setup to determine if the process is viable on a continuous scale, and what process variables will need to be for continuous production of the specific manure sample.

PROCESS/PRODUCT OPTIMIZATION

This phase works on fine-tuning the end product, as well as the continuous process itself, providing a recipe for process scale-up. Samples produced can be used in field trials.

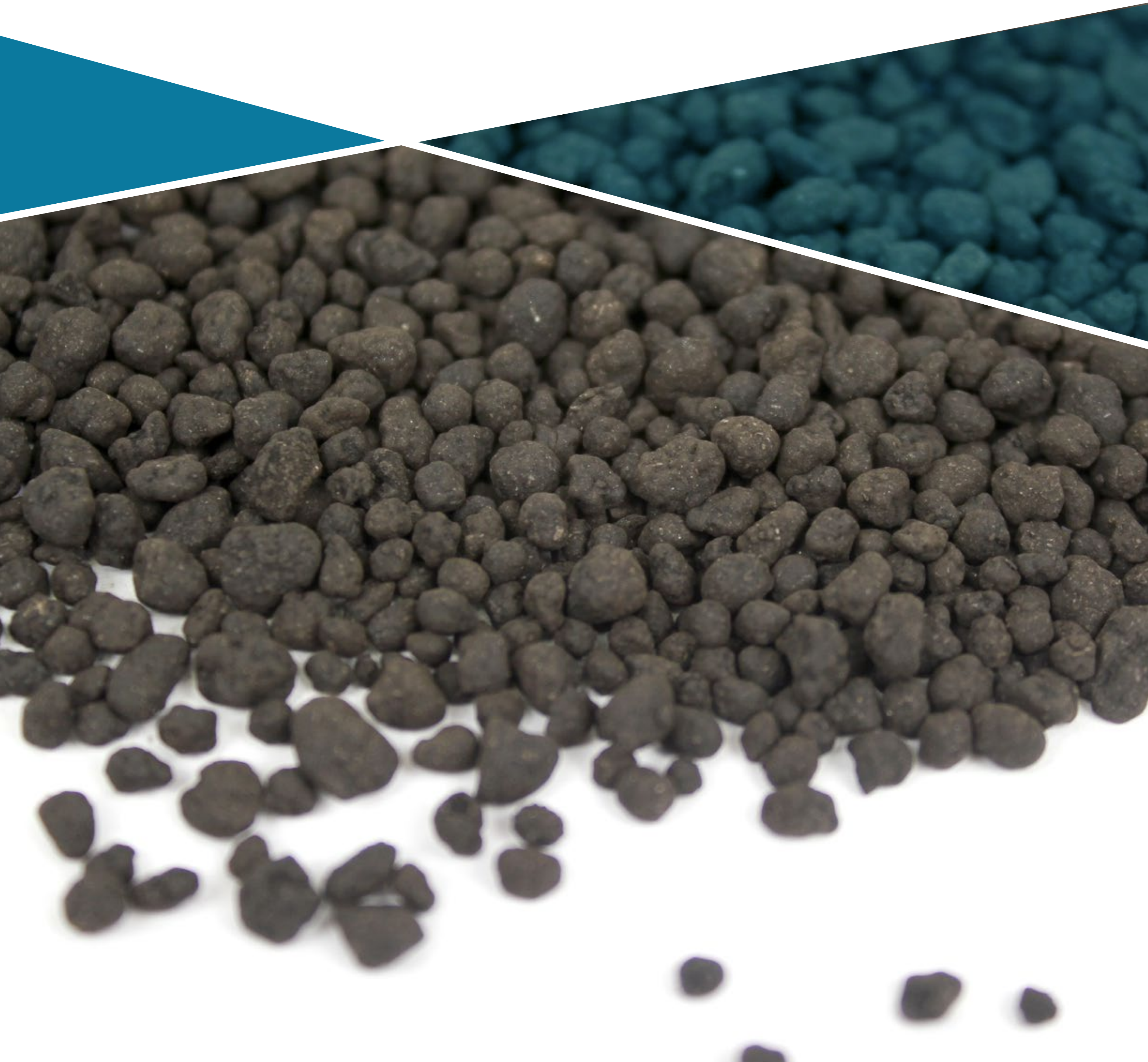
AUTOMATION

Throughout testing, FEECO process engineers utilize our state-of-the-art automation system from Rockwell Automation to gather, trend, and report on data, even adjusting process variables in real time.

While FEECO offers control systems as part of a system purchase, the capabilities afforded through automation in the Innovation Center are especially valuable during the testing phases, providing customers with complete process transparency through data visualization. This provides for unparalleled data analysis during the process development stages.

OUTLOOK

THE FUTURE OF FARMING | BEDDING RECOVERY



THE FUTURE OF FARMING: **AN INTEGRATED APPROACH TO MANURE MANAGEMENT**

As large farms become the future of agriculture, the need for sustainable solutions in managing manure is becoming an ever-increasing focus.

However, while large farms are learning to deal with the amount of manure they produce, significant opportunity lies in processing manure to produce products that can be used on-farm, reducing costs and offering improved sustainability.

The following will look at the opportunity that exists for large farms to take a more integrated approach to manure management.

While farmers have long known about the benefits that manure can offer to soil, new technologies are making utilizing manure to its fullest potential even more possible, and not just for soil nutrient management.

With one all-encompassing process, the complete utilization of manure can create four products, reducing on-farm costs, providing additional sources of revenue, and creating a sustainable, closed-loop system of self-sufficiency. An overview of this process is provided here.

STEP 1: ANAEROBIC DIGESTION

PRODUCT YIELDED: BIOGAS

Anaerobic digestion is the first step in transforming manure into a fertilizer or bedding product.

Anaerobic digestion is a natural process that uses microbial activity to break down organic materials in the absence of oxygen. Two materials result from this process:

Biogas: A methane gas that can be converted into electricity to be used on-farm, sold back to the energy grid, or cleaned up and sold as Renewable Natural Gas (RNG).

Slurry: The homogenized slurry remaining is rich in nutrients and organic matter, but offers reduced pathogens and odor. This is the base material for creating fertilizer and/or bedding products.

STEP 2: SOLID/LIQUID SEPARATION

POTENTIAL PRODUCTS YIELDED: TEA WATER, RECYCLED MANURE SOLIDS, NUTRIENT-RICH CAKE

Once manure has gone through anaerobic digestion, the remaining slurry must go through a solid/liquid separation process before it can move on to subsequent processing for use as a fertilizer or bedding. This can be carried out using a number of different methods. Some of the more advanced systems available typically yield three materials, depending on the process used: a nutrient-rich cake, tea water, and coarse fibers/recycled manure solids.

Nutrient-Rich Cake: The nutrient-rich cake is a concentrated, cake-like material made up of organic matter and nutrients. This is the base of any subsequent fertilizer products.

Tea Water: Tea water is the remaining liquid portion

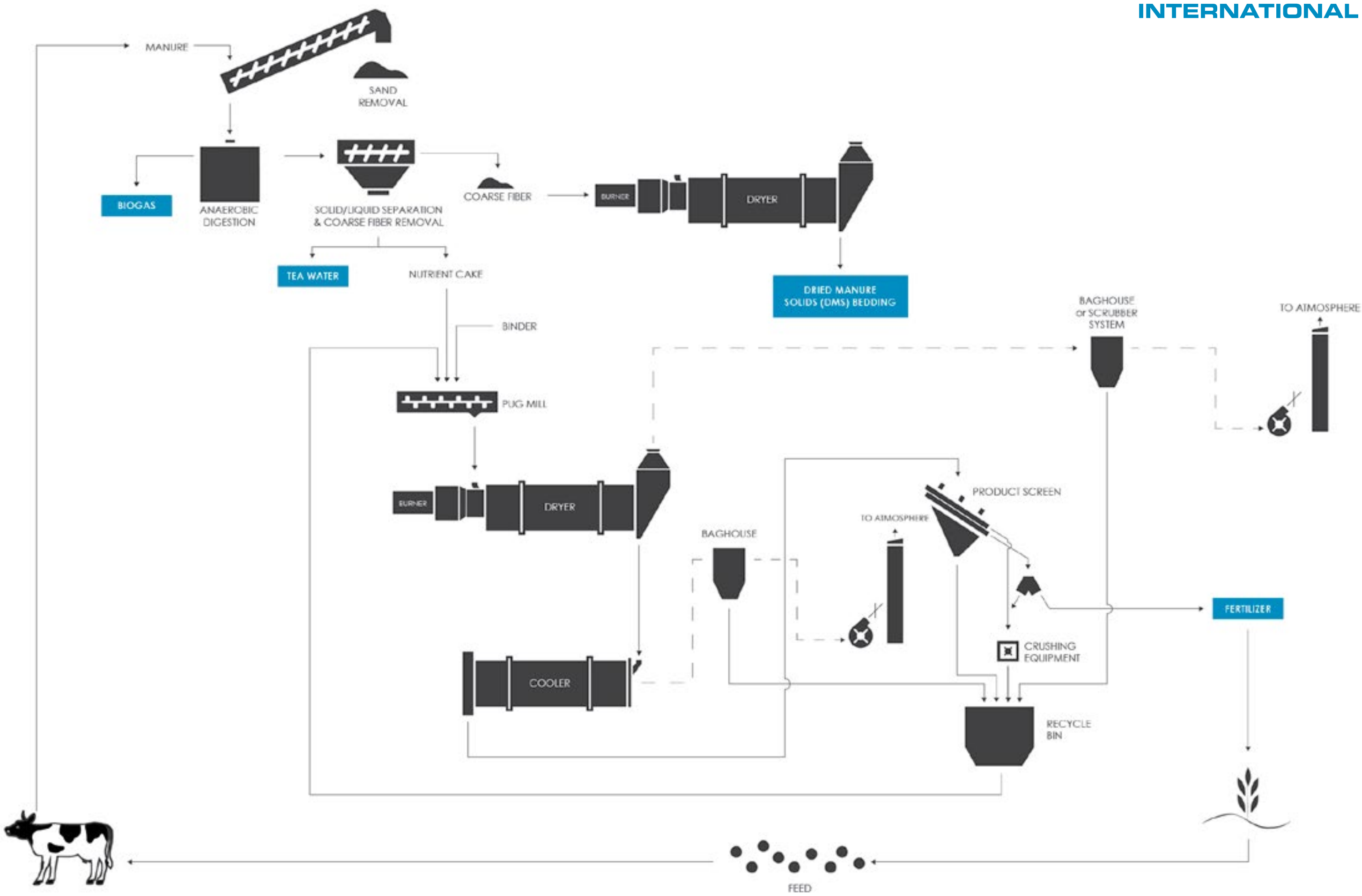


Diagram: The diagram above illustrates the process of creating the four products explained here, creating a closed-loop system of self-sufficiency for farmers.

that has been separated from the solids. This non-potable water has been stripped of much of the nutrients and is acceptable for use in irrigation, or other non-potable uses. It's worth noting that additional processing to make this into potable water is available.

Coarse Fibers: Coarse fibers are the large fibers that have been separated out because they are unfit for granulation. And while they can't be utilized in a fertilizer product, they are a suitable option for livestock bedding.

STEP 3: GRANULATION

PRODUCT YIELDED: A PREMIUM FERTILIZER PRODUCT

The nutrient-rich cake recovered from the solid/liquid separation process can now be processed into a fertilizer through the process of granulation. Material preparation and the actual granulation process may differ depending on the characteristics of the unique sample at hand.

The nutrient-rich cake is fed into a pug mill (paddle mixer) where it is combined with dried recycle. Here, the action of the mixer, combined with a binding agent, agglomerates the material into round granules. The granules exit the pug mill and are fed into a dryer where they are dried to their final moisture content. Granules are then cooled in a rotary cooler. A screen following the cooler separates over- and under-size product from on-size product. On-size product moves on to storage, packaging, transportation, or use as a fertilizer on-farm, while over-size is crushed down, combined with the under-size, and fed back into the process as recycle.

The granulation process is highly customizable; minerals and other additives can be included in the process to produce custom formulations and fertilizer blends. Granules produced by this process are considered a premium product.

STEP 4: COARSE FIBER/RECYCLED MANURE SOLIDS DRYING

PRODUCT YIELDED: DRIED MANURE SOLIDS BEDDING

The coarse fibers left over from the solid/liquid separation process, also considered recycled manure solids, can now be used as a bedding material. Use of recycled manure solids (RMS) for bedding is growing in popularity as traditional sources of bedding become increasingly costly and difficult to obtain.

Because the recycled manure solids have gone through anaerobic digestion, they are reduced in odor and pathogen content. However, some farms are finding that they can improve the quality of their milk by further improving the quality of their RMS bedding. For this reason, many farms are looking to dry their recycled manure solids into dried manure solids (DMS).

While this can be done by composting material, a controlled drying approach may be more suitable. FEECO offers a controlled drying method that allows the moisture and pathogen content to be brought down to sufficient levels, without over-drying material to the point that it becomes dusty. This also avoids the risk of fostering bacterial growth that can be associated with a less controlled approach, such as composting.

As the importance of sustainability in agriculture continues to become a global focus, an integrated approach to manure management will likely play a key role. The opportunity to use manure to its fullest potential alleviates many of the economic and environmental challenges farmers are faced with.

FEECO has been serving the fertilizer and agriculture industry since 1951. We offer process design, custom equipment, and parts and service for both organic and inorganic applications, as well as specialty fertilizers and bedding recovery. From material testing, to bedding dryers, and even complete granulation systems, FEECO's capabilities are unmatched.

FEECO INTERNATIONAL

ADDITIONAL RESOURCES

For further information or reading on manure, we have provided some additional resources below. Please note that the inclusion of any resource or company is not an endorsement and the views of that resource do not reflect those of FEECO International.

ASSOCIATIONS & PUBLICATIONS

4R Nutrient Stewardship
www.nutrientstewardship.org/4rs

United States Department of Agriculture's Natural Resources Conservation Service:
Animal Waste Management
www.nrcs.usda.gov

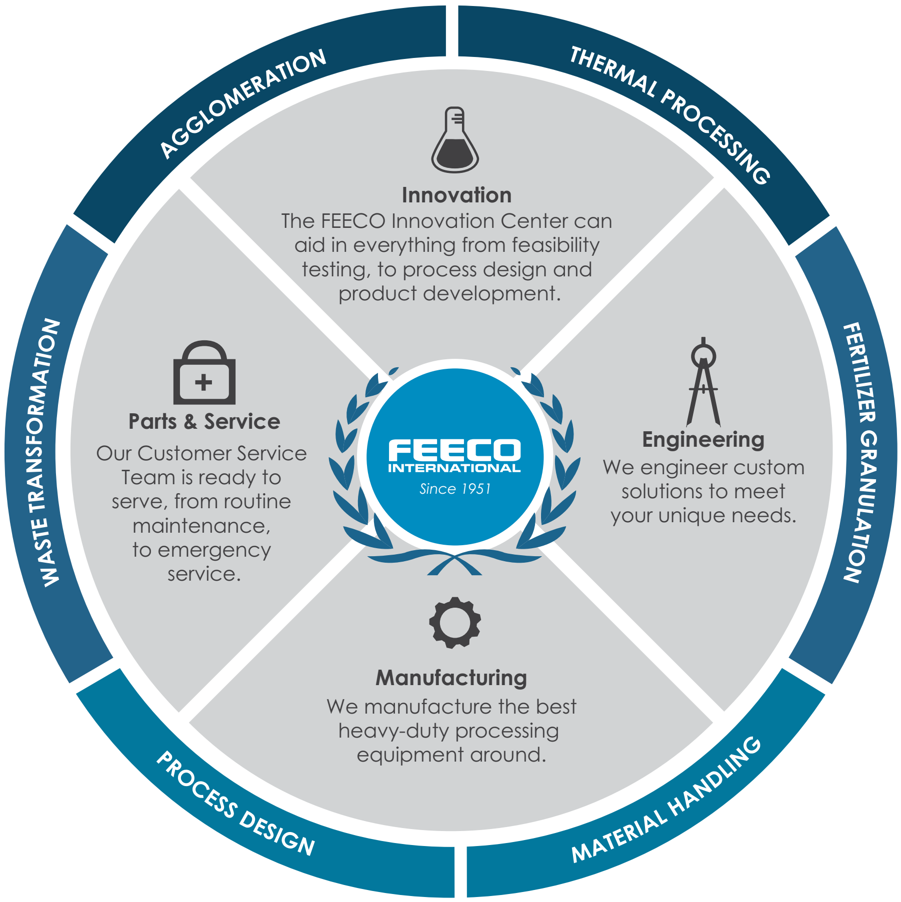
BOOKS

Animal Manure Recycling: Treatment and Management
by Sven G. Sommer, Morten L. Christensen, Thomas Schmidt, Lars Stoumann Jensen
ISBN-13: 978-1-118-48853-9

ABOUT FEECO

FEECO International, Inc. was founded in 1951 as an engineering and equipment manufacturer. We are recognized globally as an expert in industry-leading process design, engineering capabilities (including everything from process development and sample generation, to feasibility studies and detailed plant engineering), custom equipment manufacturing, and parts and service. We serve a range of industries, including fertilizer and agriculture, mining and minerals, power/utility, paper, chemical processing, forest products, and more. As the leading manufacturer of processing and handling equipment in North America, no company in the world can move or enhance a concept from process development to production like FEECO International, Inc.

The choice to work with FEECO means a well-rounded commitment to quality. From initial feasibility testing, to engineering, manufacturing, and parts and service, we bring our passion for quality into everything we do.



For more information on processing manure, material testing, or custom equipment, contact FEECO International today!

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FEECO.com/contact