Pilot Plant Testing of a Process that uses Sewer Sludge to Produce an Organically-Enhanced Granular Fertilizer

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ABSTRACT

A full scale granulation plant pilot plant was utilized as a testing facility to confirm process chemical and physical operating parameters and final fertilizer composition for the production of an inorganic/organic (sewage sludge) granulated fertilizer. Conditioned dewatered sludge is used as a replacement for water as the pipe-cross reactor cooling agent. The test unit had a processing capacity of 300 kg/hr. Pipe-cross reactor raw materials included sulfuric acid, anhydrous ammonia, and conditioned dewatered sewage sludge. Granulator raw materials included anhydrous ammonia, aluminum sulfate, granulated ferric sulfate, and recycled product. Final fertilizer product met EPA Part 503 standards and fertilizer industry standards end point conditions of hardness, critical relative humidity and moisture including 17-19% nitrogen (N) with 7.5% organic matter, 4% total carbon, and 3% amino acids.

KEYWORDS: sewage sludge, fertilizer, pipe-cross reactor, granulation, nitrogen, organic matter, amino acids

INTRODUCTION

The Fertilizer Production Process utilizes historically proven standard commercial fertilizer manufacturing equipment developed by the Tennessee Valley Authority (TVA) which has been used throughout the fertilizer industry since the 1950's. This equipment involves a "Pipe-Cross Reactor" and a "Granulation System." In 1974, TVA invented the pipe-cross reactor wherein one or two acids were simultaneously ammoniated with the slurry discharging into a TVA-type rotary granulator. Use of the pipe-cross reactor (PCR) followed by granulation and drying was introduced by the Tennessee Valley Authority (TVA) to produce Nitrogen-Phosphorous-Potash-Sulfur (NPKS) mixtures. This became an established process used by numerous producers world-wide. Its use had established a new type of granulation for these mixtures: melt granulation. The PCR had inlet ports for anhydrous ammonia, various acids and water as a cooling agent. The salient feature was that the heat of the ammonia-acid reaction was confined to the pipe and was efficiently utilized there to vaporize a large fraction of the moisture and thereby reduce dryer fuel requirements.

This process uses anhydrous ammonia as the nitrogen source and phosphoric and sulfuric acids as the major source of phosphorous and sulfur. The pipe discharges the slurry onto a cascading bed of recycled solids in the granulator. This slurry serves as the binder for the formation of granules. The heat of reaction maintains a pipe temperature of 100 to 150° C. The granulation products have excellent quality; they are hard, remain free flowing in storage, and have good resistance to degradation. Substantial savings in fuel cost and less particulate loss from the plant were obtained.

Full scale granulation pilot plant testing was completed to confirm the use of the Modified TVA PCR [Figure 1] in a granulation process [Figure 2] that converted sewage sludge organics (proteins) through chemical and physical processes into a fertilizer with value–added high nitrogen (17 to 19%) content and organically enhanced with 7.5% organic matter, 4% total carbon, and 3% amino acids while sterilizing pathogens, eliminating odors (ORP > 350 mV) and completing the drying, screening and cooling process for a granular product that has reduced heavy metals and no spontaneous combustion/explosive problems experienced by traditional sludge dryers.

Figure 1: Modified Pipe Cross Reactor

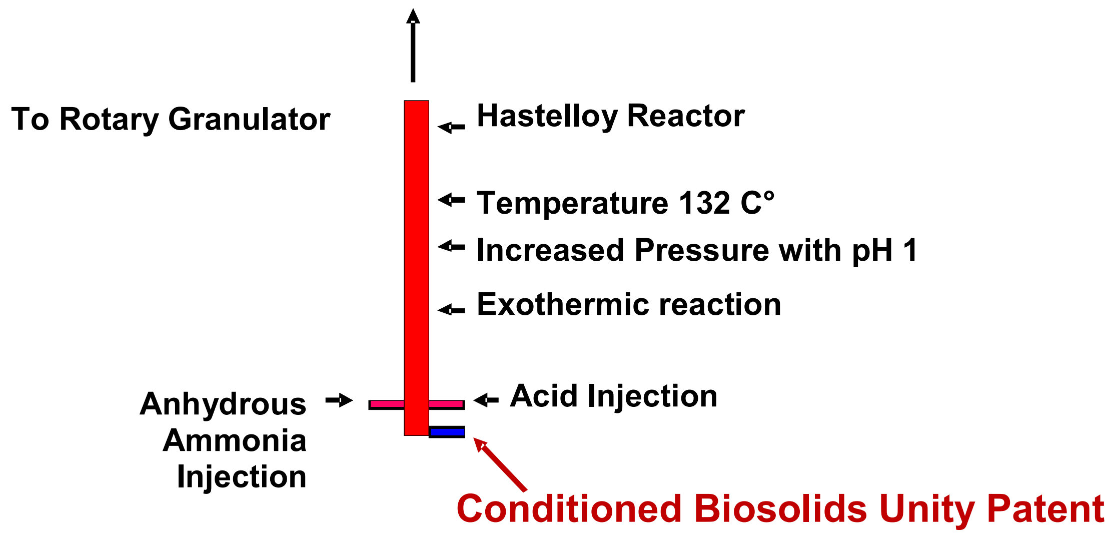
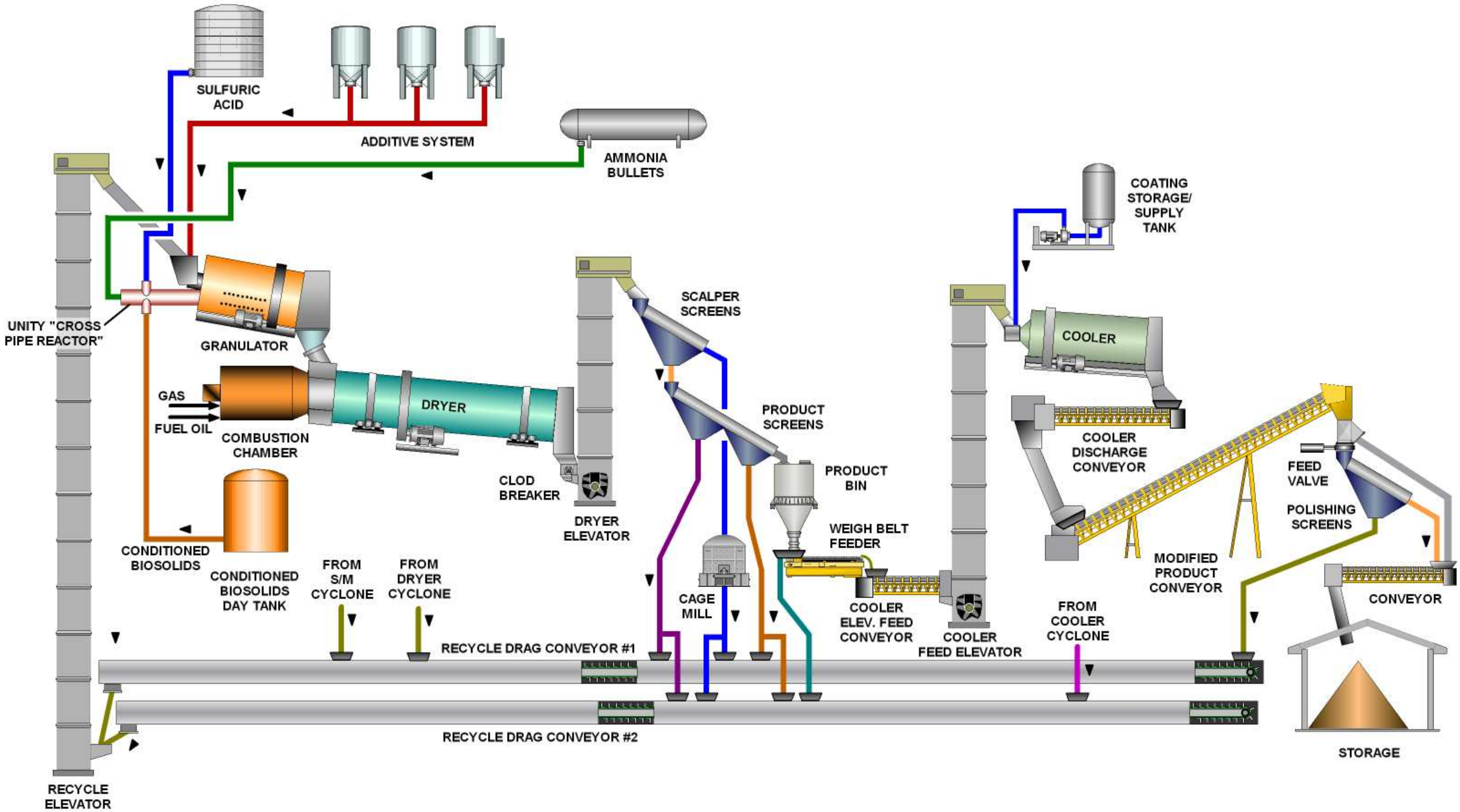


Figure: 2 Standard Fertilizer Technology



Production is carried out in two independent processes: the Sludge Conditioning Process and the Fertilizer Production Process. The Sludge Conditioning Process preconditioned dewatered wastewater sludge into 6,000 gallons of a homogenized pumpable fluid material (Conditioned Biosolids). Sewage sludge was dewatered to 15% solids with polymer on a belt filter press at a local municipal activated sludge plant and chemically conditioned to meet end point viscosity of less than 5,000 centipoise (cP) and Oxidation Reduction Potential (ORP) greater than 300 mV

The Fertilizer Production Process consists of feeding 93% sulfuric acid, anhydrous ammonia and sewage sludges (15% solids) at 215 to 275 kg/h through a PCR. The study of the data gathered during the pilot plant tests confirmed process operating and design parameters such as the mole ratios,, recycle ratios, dryer load requirements, combustion potential, equipment dust loadings, gas emissions needed for the design of a full scale 500 to 1500 tons per day production facility.

The pilot plant was operated four (4) days per week, 10 hours per day at production capacities that ranged between 100 and 200 kg/h. The test runs produced a total of 15 short tons of finished product.

The critical chemical reactions that produce the Fertilizer product take place in the pipe-cross reactor with operating temperatures up to 150°C at a pH of less than 1. At these operating conditions a number of important reactions occur that positively affect the quality and properties of the Fertilizer product, they are:

- Microbial sterility is achieved which exceed all time/ temperature requirements of the US EPA 40CFR Part 503 for Class A standards for Residuals management;
- Inorganic salts are formed from the reaction of mixing an acid with anhydrous ammonia;
- Hydrolysis of the Residuals organic macro-molecules (proteins) occurs with proteins converted to amino acids (3%).

The details of the Fertilizer Production Process involve:

1. Pumping Conditioned Biosolids to a pipe-cross reactor used for mixing a base (anhydrous ammonia), and acid (sulfuric acid) to form a slurry;
2. Flashing off the water contained in the slurry as steam,
3. Spraying of the slurry into the cascading bed of recycled particles in a drum granulator to form accreted (onion-like) granules
4. Drying, screening and cooling of the granules to achieve the finished fertilizer product.

When the pressurized slurry generated by the exothermic chemical reaction in the PCR is sprayed in the granulator 95% of the water flashes off and only about 5 % of additional combustion energy is required to complete the drying process. The final product is a hard fertilizer granule containing less than 2% moisture.

AGRONOMIC TESTS

Unity reports that their fertilizer has been tested in National and International green house and field trails and have shown the excellent results when compared with Urea on oranges, rice and Bermuda grass. More testing is planned for major soil types and different crops

RESULTS

The following is a summary of the pilot plant testing results:

- Sewage Sludge at 15% solids and 85% water after chemical conditioning was proven can be utilized as feed to the pipe-cross reactor.
- **Fertilizer:** The inorganic/organic fertilizer met end product requirements of 17-19% N, 1% P, and 19%S.
- **Product Moisture:** The inorganic/organic fertilizer was able to achieve industry standards for moisture of 1.5%, achieving moistures as low as 0.4%.
- **Granular Crushing Strength:** The inorganic/organic fertilizer was able to meet average crushing strength of 2.1 to 2.6 kg/granule which is considered good to desirable.
- **Product Combustibility:** The Fertilizer was classified as noncombustible as determined by lab combustibility tests. Dusts that are not combustible at an initial concentration of 500 g/m^3 are retested at 1000 g/m^3 and 2,000 g/m^3. The granulated Fertilizer dust was classified as noncombustible at concentrations of 500, 1,000 and 2000 g/m^3.
- **Sewage Sludge Sterilization:** PCR, granulator and dryer all exceed time/temperature requirements of EPA Part 503 regulations. Time/temperature and low pH conditions provide sludge sterilization.
- **Value-Added:** Granulated fertilizer has value-added micronutrients and amino acids (3%) from sludge protein.
- **Fertilizer Physical and Chemical Properties:** The Fertilizer meets or exceeds the Fertilizer Industry's "Physical Property Standards" which include the following criteria shown below in **Table 1 and 2**.

Table 1: Physical Properties of Unity and Other Fertilizers

Property	Unity Product	Granular Urea	MAP	DAP
%Critical RH (30 deg C)	80 - 85	70 - 75	70 - 75	65 - 75
Moisture Penetration, cm	0.5 - 1.0	15	1.0	2.0
Moisture Absorption, mg/cm^2 (30 deg C and 80% RH for 72 hours)	41 - 144	350	90	175
Abrasion Resistance, % Degradation	0.49 - 0.99	0.2 - 3.0	0.5 - 2.0	0.5 - 2.0
Granule Crushing Strength, kg/granule	2.0 - 2.6	1.5 - 3.5	2.0 - 3.0	3.0 - 5.0
Granule Integrity (1)	Excellent	Fair to Good	Fair to Good	Fair to Good
Bulk Density, loose, kg/m^3	825 - 875	720 - 820	900 - 1100	875 - 1100
Angle of Repose, degrees	35	34 - 37	30 - 35	30 - 35
Combustion Potential	0	NA	NA	NA
Oxidation Reduction Potential, mV	+350	NA	NA	NA
Chemical Compatibility (TSP, KCL)	Compatible	Limited (2)	Compatible	Compatible

(1) Qualitative observation based on strength of the top layer after exposure for 72 hours
(2) Limited compatibility with TSP compatible with KCL
Source of data for Urea, MAP and DAP Fertilizer Manual 1998

Table 2: Chemical Analyses of Inorganic/Organic Fertilizer (a)

Process Run	Nitrogen Total %N	Total P_20_5 %	Sulfur %S	Amino Acid %	Iron % Fe	Total Carbon %	Organic Matter %	Free Moisture % (b)
7-890	17.4	1.1	19.6	3.08	2.3	4.6	7.6	4.9
7-891	17.7	1.3	20.0	3.11	2.7	4.94	7.9	1.7
7-892	17.5	1.1	19.3	3.11	2.2	4.581	7.5	3.6
7-893	17.6	1.2	19.3	3.00	2.1	4.824	7.5	2.1
7.894	17.6	1.1	20.3	2.96	2.1	4.207	7.2	1.3
7-895	18.0	1.1	19.8	2.64	2.3	4.357	6.9	0.4
7-896	17.8	1.2	19.7	3.10	2.1	4.620	7.1	1.1
7-897	17.2	1.1	19.0	2.88	2.65	4.983	7.8	3.5
7-898	17.0	1.2	18.8	3.23	2.43	5.530	9.0	3.7
7-899	17.4	1.2	18.7	3.25	2.5	4.866	7.8	2.1
7-900	17.5	1.1	19.4	2.3	--------	--------	-------	0.6
7-901	18.0	1.02	19.9	2.91	2.21	4.608	6.9	2.2

(a) Chemical analyses performed using Association of Official Analytical Chemists AOAC methods
(b) Free moisture determined using vacuum oven desiccator method on an unground sample.

CONCLUSIONS

The commercial fertilizer market at 54 million dry tons per year is based on a synthetic type fertilizer. The sewage sludge market is estimated at 50 million wet tons per year at 15% solids. The incorporation of sewage sludge under pressure, high temperature and low pH conditions allows sewage sludge organics to be sterilized and converted to amino acids for incorporation into an inorganic/organic commercial fertilizer. This provides beneficial recycle of organics from cities and counties back to the farmer.

Dewatered sewage sludge (15% solids) can be successfully used by this process to produce a new inorganic/organic commercial fertilizer with important value-added amino acids and micronutrients. The process is operated under chemical and physical conditions that convert sewage sludge into proteins and amino acids.

FUTURE PLANS

Plans are in the works for a new Florida Fertilizer Facility. The following milestones have been completed.

- Purchase Agreement on a 364 Acre Site
- Granted Zoning Approval
- Successful Environmental Site Investigation
- Received approval from County Development Authority
- Approval from the County Commissioners
- Granted a Regional Residual Management Permit
- Obtained approval for the issue of $155 million in tax-free Industrial Revenue Bonds

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