USDA-ARS/Penn State MAnure PHosphorus EXtraction (MAPHEX) System

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Why MAPHEX ?

For Centuries, Manure was a Valuable Resource for Fertilizing Soils

But recently, Buildup of Phosphorus in soils has resulted in Increasing Regulation of Manure and Biosolids Application

MANURE SLURRY

MAPHEX Operation

80% of Total Solids

15% P in Solids

Ideal Uses for Solids

Composted and used for bedding

Sold to organic or mushroom farmers

MAPHEX Operation

10% of Total Solids

45% P in Solids

24X Press Solids
200X Raw Manure

Ideal Uses for Solids

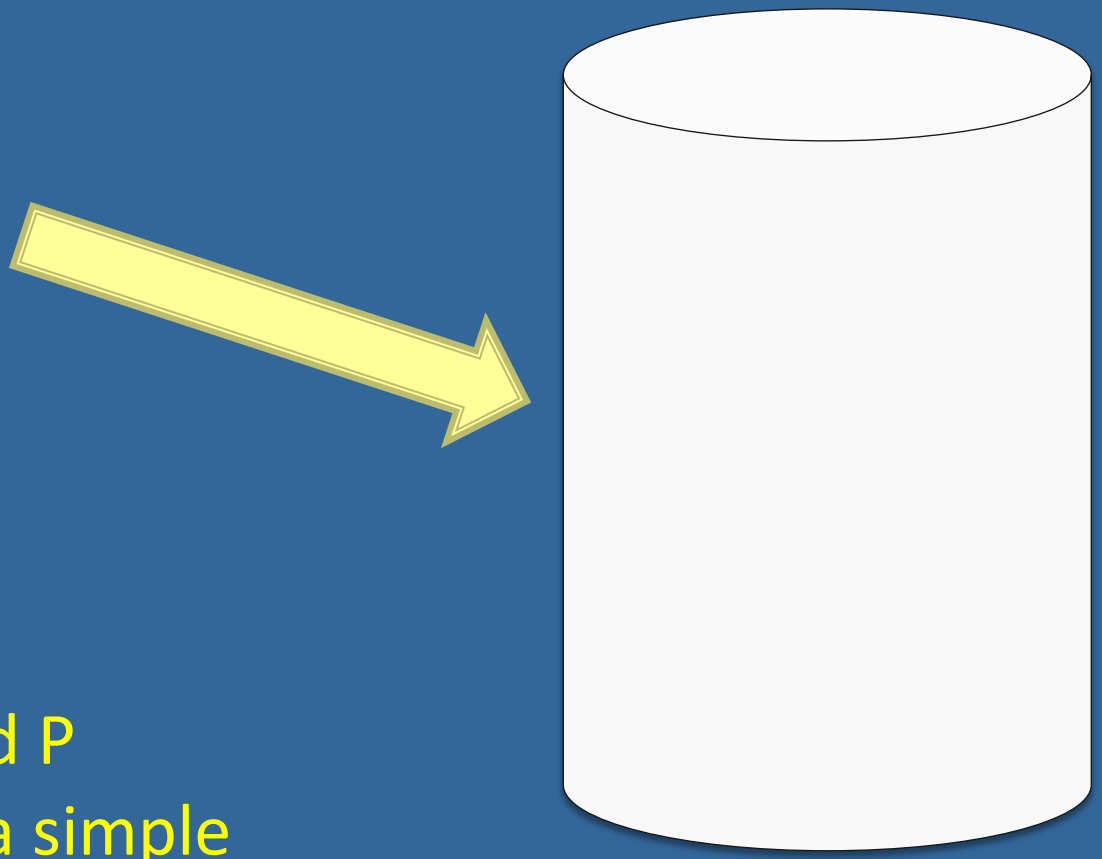
Highly compact form of P
Transported to places that need P
Sold to organic or mushroom farmers
Electric generation

MAPHEX Operation

Any One Of:

- Ferric Sulfate
- Ferric chloride
- Calcium Hydroxide
- Aluminum Sulfate
- Aluminum Chlorhydrate
- Geothite
- Mine Drainage Residual

Chemical Treatment



Converts dissolved P into a particle by a simple sorption process

MAPHEX Operation

10% of Total Solids

40% P in Solids

18X Press Solids
150X Raw Manure

Ideal Uses for AutoVac Solids

Highly compact form of P
Transported to places that need P
Sold to organic or mushroom farmers
Electric Generation
Best use is to recover filtrate material

MAPHEX Operation

<1% of Total Solids

Ideal for fertigatiion

<1% P in Liquid

>90% N in Liquid

What's in a Name ?

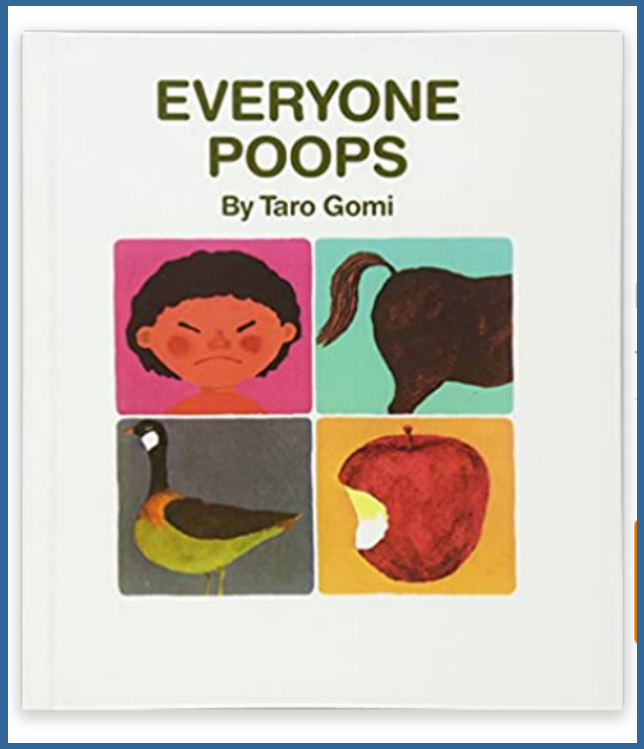
P Out Of Poo System ??

USDA/Penn State POOPS

USDA Patents POOPS

POOPS Conquers South Carolina Hurricane

POOPS is answer to Dairy Dilema



MAnure **PH**osphorus **EX**traction System

MAPHEX System

Performance
Dairy and Swine Manures

- Up to 96 – 99% P removal efficiency
- 99% solids removal efficiency
- All solids stackable (~ 70% moisture)

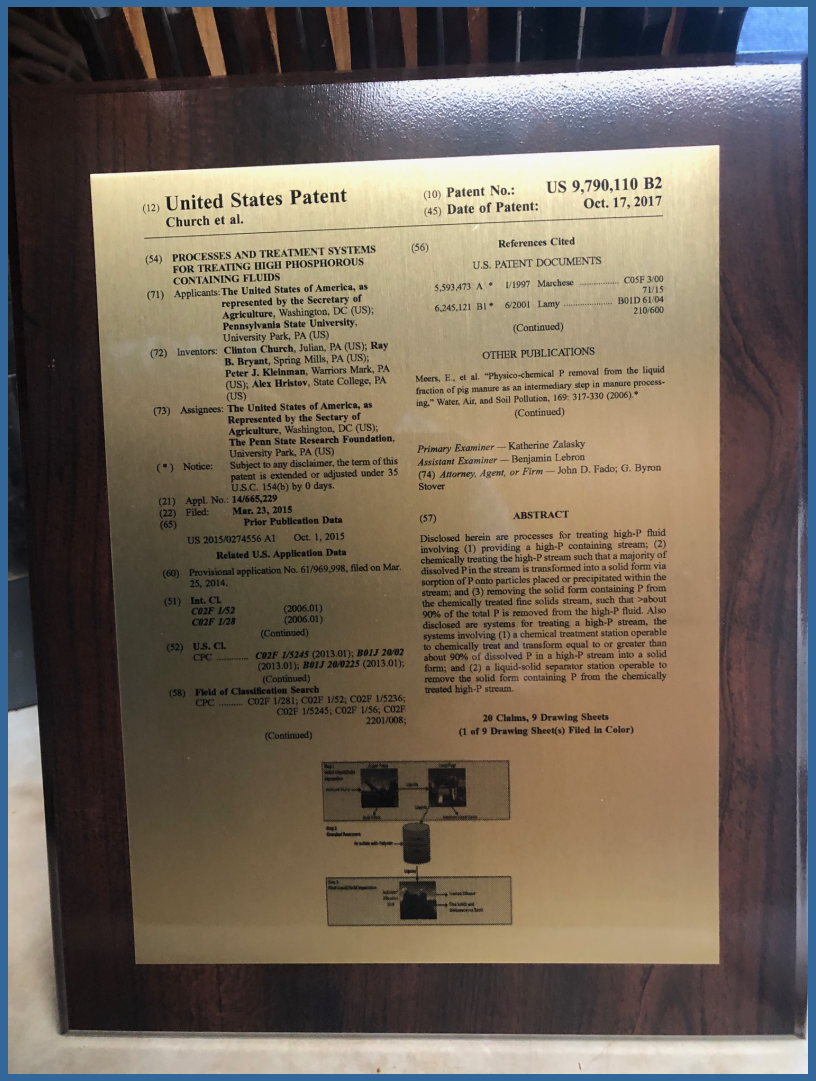
Performance
Dairy and Swine Manures

- Most N is retained (>90%)
- pH unchanged by process
- Ideal for fertigation of crops

Performance
Dairy and Swine Manures

- Beneficial uses of solids
  - Low P solids- bedding
  - High P solids- more economically transported or sold
  - Feedstock for energy generation

Manure Glory



(12) **United States Patent**
Church et al.

(10) **Patent No.: US 9,790,110 B2**
(45) **Date of Patent: Oct. 17, 2017**

(54) **PROCESSES AND TREATMENT SYSTEMS FOR TREATING HIGH PHOSPHOROUS CONTAINING FLUIDS**

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C02F 1/52 (2006.01)
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CPC ***C02F 1/5245*** (2013.01); ***B01J 20/02*** (2013.01); ***B01J 20/0225*** (2013.01);
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(58) **Field of Classification Search**
CPC C02F 1/281; C02F 1/52; C02F 1/5236; C02F 1/5245; C02F 1/56; C02F 2201/008;
(Continued)

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,593,473 A * 1/1997 Marchese C05F 3/00 71/15
6,245,121 B1 * 6/2001 Lamy B01D 61/04 210/600

(Continued)

OTHER PUBLICATIONS

Meers, E., et al. "Physico-chemical P removal from the liquid fraction of pig manure as an intermediary step in manure processing," Water, Air, and Soil Pollution, 169: 317-330 (2006).*

(Continued)

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(57) **ABSTRACT**

Disclosed herein are processes for treating high-P fluid involving (1) providing a high-P containing stream; (2) chemically treating the high-P stream such that a majority of dissolved P in the stream is transformed into a solid form via sorption of P onto particles placed or precipitated within the stream; and (3) removing the solid form containing P from the chemically treated fine solids stream, such that >about 90% of the total P is removed from the high-P fluid. Also disclosed are systems for treating a high-P stream, the systems involving (1) a chemical treatment station operable to chemically treat and transform equal to or greater than about 90% of dissolved P in a high-P stream into a solid form; and (2) a liquid-solid separator station operable to remove the solid form containing P from the chemically treated high-P stream.

20 Claims, 9 Drawing Sheets
(1 of 9 Drawing Sheet(s) Filed in Color)

Church, C. D., A. N. Hristov, R. B. Bryant, P. J. A. Kleinman, and S. K. Fishel.2016. A novel treatment system to remove phosphorus from liquid manure. Applied Engineering in Agriculture, 32: 103 – 112.

Church, C. D., A. Hristov, R. B. Bryant, and P. J. A. Kleinman. 2017. Processes and treatment systems for treating high phosphorus containing fluids. US Patent 9,790.110B2.

Church, C. D., A. N. Hristov, P. J. A. Kleinman, S. K. Fishel, M. R. Reiner, and R. B. Bryant. 2018. Versatility of the MAnure Phosphorus Extraction (MAPHEX) System in removing phosphorus, odor, microbes, and alkalinity from dairy manures: A four-farm case study. Applied Engineering in Agriculture.

Church, C. D., A. N. Hristov, P. J. A. Kleinman, S. K. Fishel, M. R. Reiner, and R. B. Bryant. Reduction of daily operating expenses for Animal Manure treatment system. Applied Engineering in Agriculture

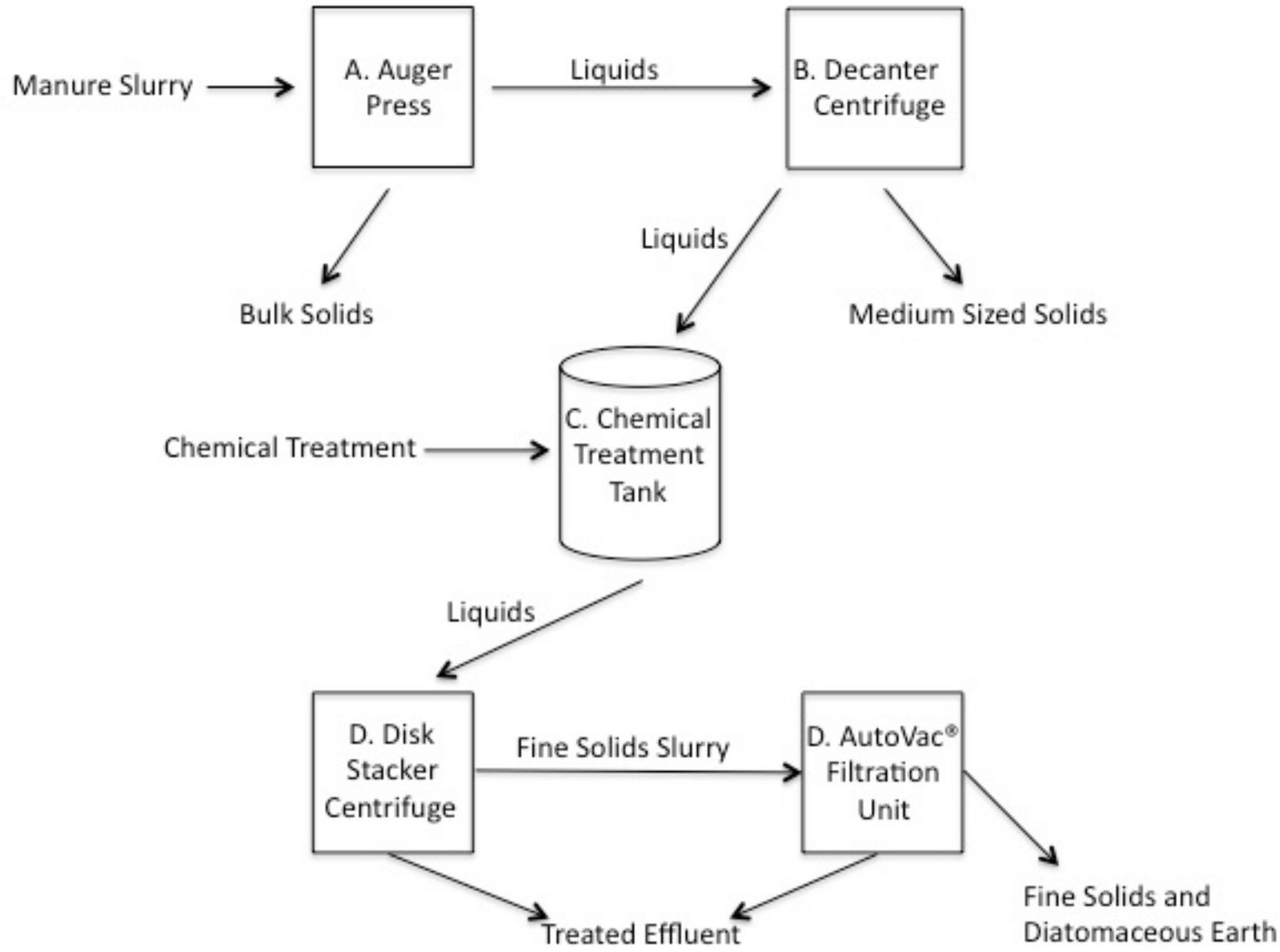
Church, C. D., A. Hristov, R. B. Bryant, and P. J. A. Kleinman. 2018. Methods for Rejuvenation and Recovery of Filtration Media. USDA Docket Number 129.17. U.S. Patent Application Serial No. 62/727,732 - DN. 77.16. (Provisional Patent)

Church, C. D., S. K. Fishel, M. R. Reiner, P. J. A. Kleinman, A. N. Hristov, and R. B. Bryant. Pilot scale investigation of phosphorus removal from swine manure by the MAnure PHosphorus Extraction (MAPHEX) System. Accepted in Applied Engineering in Agriculture.

Current Work:

1) Lowering Daily Operating Costs
   -a bit less than 2.5 cents per gallon for 95% P removal efficiency
   -a bit less than 1 cent per gallon for 75% P removal efficiency

   a) Re-using filter media
   b) Reconfiguring the System which allows a much greater flow rate


Manure Slurry
A. Auger Press
Liquids
B. Decanter Centrifuge
Bulk Solids
Liquids
Medium Sized Solids
Chemical Treatment
C. Chemical Treatment Tank
Liquids
D. Disk Stacker Centrifuge
Fine Solids Slurry
D. AutoVac® Filtration Unit
Treated Effluent
Fine Solids and Diatomaceous Earth

Current Work (cont.):

2) Implemented a Research-Scale System for Optimization testing (Mini MAPHEX)

3) Testing of Different manure sources (beef, poultry, etc.)

Current Work (cont.):

5) MAPHEX Lite
   - Consists of the first two MAPHEX steps
   - Should remove 50-60% of P
   - Capable of 100,000 gallons/day
   - Will have ‘whistles and bells’
- Demonstrate in PA and VT LTAR watersheds and beyond

USDA-ARS/Penn State MAnure PHosphorus EXtraction (MAPHEX) System

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