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From a PI's Perspective: How We Made a T2 Success

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Abstract – A team of scientists (Drs. Ariel A. Szogi, Matias B. Vanotti, and Patrick G. Hunt) from the Agricultural Research Service (ARS) - Coastal Plains, Soil, Water & Plant Research Center in Florence, S.C., invented a new treatment process, called "quick wash," to extract and recover phosphorus from poultry litter and animal manure solids.[1] This invention led us down the path to an award-winning technology transfer process.[2] As part of this process, a new and unexpected use for the technology emerged that was different from what we had imagined—to the extent that it helped build a new business model for our commercial partner. The purpose of this paper is to describe and illuminate, from the perspective of a principal investigator, what made the process successful and the lessons we learned along the way.

(Keywords: federal laboratory; Department of Agriculture; technology transfer; commercialization; licensing; marketing; technology; principal investigator; phosphorus; biosolids; business models)

The Inspiration Behind the Effort

Environmental problems, the potential scarcity of phosphorus resources, and the value of recovered phosphorus products were the drivers to developing "quick wash," a method to recover the

[1] Ariel A. Szogi, Matias B. Vanotti, and Patrick G. Hunt. "United States Patent: 8,673,046 - Process for removing and recovering phosphorus from animal waste," March 18, 2014. See http://www.ars.usda.gov/SP2UserFiles/Place/60820500/Manuscripts/2014/pat8673046.pdf.

[2] FLC Excellence in Technology Transfer Award, 2015. See https://www.federallabs.org/index.php?tray=award_detail&cid=FLCawrd902&tid=1FLtop207.

phosphorus in livestock manure that consists of the rapid removal and recovery of phosphorus in solid form.

Nutrient pollution, caused by too much nitrogen and phosphorus in the environment, is one of America's most widespread, costly and challenging environmental problems, impacting many sectors of the U.S. economy that depend on clean water. The repeated application of untreated manures on soil can cause excess phosphorus accumulation in soils, and its subsequent loss through soil runoff or leaching can result in the pollution of surface waters. For this reason, widespread phosphorus pollution of waterways can occur in regions with concentrated livestock production. As result of phosphorus pollution, algal blooms in drinking water sources can drastically increase treatment costs and generate shortages in water supplies.

Phosphorus, an essential element for life on Earth, is a finite resource since mined phosphates are the main source in the production of phosphorus fertilizers. The demand for mined phosphorus is escalating worldwide due to both increasing food demand and human population. Inevitably, the future demand for mined phosphorus will exceed its supply capacity. Globally, the remaining phosphorus is found in various waste streams. These waste streams include large quantities of effluents rich in phosphorus from municipal, industrial, and livestock production sources. Therefore, phosphorus in these waste streams, if economically recovered, can contribute to a sustainable management of phosphorus resources.

The quick wash process mitigates both of these problems because phosphorus is selectively extracted from solid manure or municipal biosolids prior to land application. In layman's terms, the process takes manure—be it from a chicken or a human—and "washes" it, separating out the phosphorus, but leaving most of the nitrogen behind. This means that both the nitrogen-rich manure and the extracted phosphorus can be more judiciously applied, resulting in more effective fertilizer with less harmful phosphorus runoff as well as surplus phosphorus that can be reused in markets that need it, thus mitigating the shortage. The quick wash process selectively recovers more than 80 percent of the phosphorus from solid waste while leaving most of the nitrogen in the washed solid residue. Consequently, the washed solid residue has a more balanced nutrient composition that is safe for land application and is better balanced to match the specific nutrient needs of crops. Also, fertilizer tests of the recovered phosphate obtained with the quick wash method demonstrated that it is a good plant fertilizer. The concentrated phosphorus material contains more than 90% of its phosphorus in plant

available form, which provides a recycled phosphorus source for use as a crop fertilizer on phosphorus-deficient croplands.

Our lab's role in finding a solution to these problems was crucial for more reasons than one. For our agency, it helps meet the objectives of addressing manure management problems that harm the environment and maximizing nutrient recovery.[3,4] For the private sector, we addressed a challenge deemed impossible—to develop a totally new technology capable of meeting multiple and strict environmental standards at a low cost.

Although many similar processes are not profitable, we quickly realized that this one would be profitable. Eventually, economic incentives such as government subsidies, environmental credits, and tipping fees have been considered as possible additional incentives for wide adoption and integration of this new method to reduce phosphorus pollution from animal production activities. Thus, phosphorus recovery in a concentrated, usable form would allow a more economical long-distance transfer of manure nutrients, while reducing agronomic nitrogen and phosphorus imbalances and the adverse effects of soil nutrient losses on the environment.

Lightning in a Bottle: Going Viral

To promote this technology, we made numerous presentations at professional scientific meetings, and two journal papers were published in peer-reviewed engineering journals.[5,6] However, the online ARS news releases were the most effective promotional technique, attracting worldwide attention.

An ARS News & Events story describing the quick wash process, entitled "Mining Manure for Phosphorus,"[7] was released online by the ARS Information Staff. The news release announced ARS's interest in finding business partners to move the product to market. We did not anticipate that when

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[3] USDA. National Program 214 AGRICULTURAL & INDUSTRIAL BYPRODUCTS ACCOMPLISHMENT REPORT 2009-2013. October 2013. http://www.ars.usda.gov/SP2UserFiles/Program/214/NP214AccomplishmentRpt2009-2013FINAL.pdf.

[4] Christina Woods. NP 214 Agricultural and Industrial Byproducts. Report, April 2012. http://www.ars.usda.gov/SP2UserFiles/Subsite/sciQualRev/NP214%20Panel%20Report.pdf.

[5] A.A. Szogi, M.B. Vanotti, and P.G. Hunt. "Phosphorus Recovery From Poultry Litter." American Society of Agricultural and Biological Engineers, Transactions of the ASABE Vol. 51(5): 1727-1734. See http://www.ars.usda.gov/SP2UserFiles/Place/60820000/Manuscripts/2008/Man785.pdf.

[6] Szogi, A.A., Vanotti, M.B., Hunt, P.G. 2015. "Phosphorus recovery from pig manure solids prior to land application." Journal of Environmental Management. 157:1-7. doi:10.1016/j.jenvman.2015.04.010.

[7] Ann Perry. "Mining Manure for Phosphorus." ARS news story. February 29, 2008. http://www.ars.usda.gov/is/pr/2008/080229.htm

published in 2008, this technology would become viral. Yet, as a result of this news release we received nine requests for information from entrepreneurs in North America, Europe, and Asia.

The ARS patent application and related information for the quick wash process were provided after signing confidentiality agreements with each interested party. The preparation of these confidentiality agreements was facilitated and overseen by our Technology Transfer Coordinator. (ARS has a Technology Transfer Coordinator at each Area Office; in this case, the Coordinator covered all ARS research units within the southeastern United States).

Within two years after the ARS news release, we had four meetings with individual U.S. entrepreneurs interested in our invention; however, the only one that followed up with additional consultations and meetings with the goal of licensing our invention was Renewable Nutrients, LLC (RN), a small business located in North Carolina.

This interaction led to material transfer agreements, licensing, verification of the technology by independent consultants, and current commercialization.

The Technology Transfer

Initially, a technical consultant working with RN contacted our Research Center at Florence. This consultant read about quick wash from the ARS online news article and called the Florence lab to request more technical information, which was provided upon the signing of a confidentiality agreement.

After this first contact, company representatives attended a meeting at the Florence laboratory, where the technology was showcased. Since RN representatives did not know about ARS technology transfer programs, Florence scientists consulted with the Technology Transfer Coordinator and referred the RN CEO to the Office of Technology Transfer (OTT) at ARS Headquarters in Beltsville, Maryland. Along with technical consultations with the ARS team and the OTT, a Material Transfer Agreement (MTA) was used to determine if wash litter and the recovered phosphorus could be granulated for commercialization. ARS licensing specialists provided instructions regarding how to apply for an exclusive USDA license for the pending patent of the quick wash process.

Upon obtaining the exclusive license, the first step was to advertise in the *Federal Register* the notice of intent to grant exclusive license of the USDA invention to RN. The exclusive license was later granted after 30 days from the date of this published notice since ARS-OTT did not receive any written

evidence and argument from other potential investors interested in licensing the invention. The exclusive license was granted five months later once negotiations with the OTT office in Beltsville were completed. In accordance with USDA-ARS policies and procedures, the exclusive license agreement between USDA-ARS and Renewable Nutrients, which was granted August 10, 2010, is confidential because of conflict-of-interest rules.

Finding a New Purpose for Quick Wash

The ARS team worked closely with RN to develop approaches for commercializing this new technology. Our role was to provide innovation, scientific knowledge, and improvement of the technology; RN's role was to design and develop commercial units of the technology. ARS's expectations were to effectively transfer the new technology after verification at pilot scale. RN's expectations were to reach the market with a reliable and proven technology to recover phosphorus that has competitive advantages for commercialization.

Originally we conceived of quick wash as a treatment to be used in the agricultural market with poultry litter, but our research has shown that the approach is equally effective with municipal biosolids (i.e., sewage). In addition to the agricultural market, RN realized the value of this technology for municipal disposal systems and changed its business plan to commercialize quick wash in the municipal wastewater treatment market. For this market, RN's business model now consists of sublicensing the technology to each municipal treatment plant. The technology is being marketed as Quick Wash™.

Bringing Quick Wash to Market

Jeff Dawson, CEO of Renewable Nutrients, worked to secure investors for commercialization. He interacted with local leaders to get the quick wash technology placed on a pilot scale in two municipal treatment plants.

Traditional technologies for phosphorus removal (specifically in the wastewater treatment sector) involve the addition of some form of binding agent to a facility's influent stream. Ferric chloride or aluminum sulfate, for example, are introduced and bind to phosphorus molecules, which then settle with solids material and ultimately depart the facility through its biosolids disposition program. This "chemical" removal of phosphorus can cost a facility anywhere from several thousand dollars to hundreds of thousands of dollars annually, depending upon the facility size and the amount of phosphorus that must be removed. Furthermore, this approach to phosphorus removal only serves

to embed this vital nutrient into the facility's biosolids output, and in many areas of the country the biosolids must be transported to disposal sites and landfilled due to land application restrictions for phosphorus.

In recent years, a few technologies have emerged to not just "remove" phosphorus from waste streams, but recover this nonrenewable resource. Quick Wash™, however, has surfaced as the only multi-stream and truly scalable phosphorus recovery methodology in the marketplace. While nearly all of the competitive options for phosphorus recovery concentrate on the liquid side streams of wastewater treatment facilities, Quick Wash™ can remove and recover phosphorus from a facility's side stream or solid stream with recovery rates exceeding 95%. In addition, the system can be effectively deployed in small treatment facilities as well as very large operations, whereas most other nutrient recovery platforms are limited (due to their requisite level of capital investment) to large facility applications.

The following chart provides a net present value (NPV) cost comparison over a 20-year period for various phosphorus removal or recovery options, including Quick Wash™. The NPV cost includes upfront capital expense, annual maintenance fees, labor, and chemical expenses for a typical 11-MGD wastewater treatment facility.

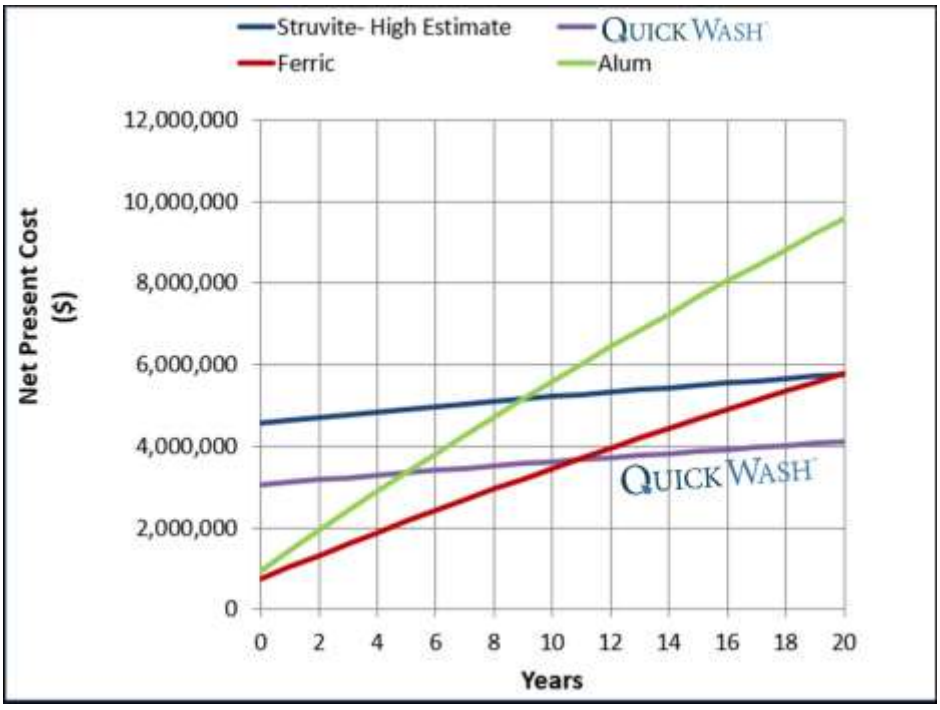

Figure 1. 20-Year NPV Cost Comparison of Phosphorous Removal/Recovery Options

The value proposition of Quick Wash™ is not simply limited to the removal and recovery of phosphorus. As already mentioned, Quick Wash™ can replace expensive chemical removal technologies. The system can also significantly reduce the amount of phosphorus in a plant's biosolids output, allowing for land application of the biosolids material and the elimination of transportation and landfill fees. Finally, facilities can sell the recovered phosphorus, a program that can serve as an incremental revenue stream, and participate in nutrient credit trading opportunities.

In the latter half of 2014, Renewable Nutrients designed and constructed a mobile pilot, at a cost of USD $500,000, for its Quick Wash™ phosphorus extraction and recovery system. The purpose of the mobile pilot was to demonstrate the Quick Wash™ technology and prove its performance in various scenarios and sizes of wastewater treatment facilities. The pilot was subsequently deployed in early 2015 at the Ephrata Wastewater Treatment Plant in Ephrata, Pennsylvania (a small 2-MGD facility).

Following Ephrata, the Renewable Nutrients team conducted eight additional pilot operations in the Mid-Atlantic, Southeast and Midwest areas, including:

- Westminster, Md.
- Raleigh, N.C.
- Chapel Hill, N.C.
- Greenville, N.C.
- Neoga, Ill. (a large swine production operation).

Currently, RN is marketing Quick Wash™ for the recovery of phosphorus from both animal and human waste through different techniques such as the company website and blog, and exhibiting at national technical conferences for water treatment professionals, such as the Mid-Atlantic Biosolids Association, the Water Environment Federation, and the American Water Works Association.

Our team at the Research Center has hit on a creative marketing technique: We worked with our IT staff to develop a bar code that participants can scan and immediately access a promotional video that RN produced about Quick Wash™.[8] The bar code was included in posters presented at scientific meetings by ARS Florence scientists. We thought it was a good idea to include a link to this video clip because our most recent technical presentations contain results of tests carried out at the request of the licensee. The ARS technology transfer policy permits its inventors, where practicable, to participate

[8] Video, "Renewable Nutrients Quick Wash™ Overview." March 19, 2015. https://youtu.be/VOq2mGh24js.

in the development of their inventions by providing technical assistance to licensees. We have been providing this assistance through monthly conference calls between scientists and RN personnel.

Figure 2. Bar Code Linking to RN Promotional Video

Looking Back: What We Learned

Trust is Key

Renewable Nutrients was the right partner because they trusted the science behind the quick wash project. A mutual trust developed between ARS and RN as a result of reviewing and confirming through technical advisors that the information included in the patent application was a sound scientific approach for phosphorus recovery from animal waste. When RN decided to change its business plan to commercialize Quick Wash™ in the municipal wastewater treatment market, it contacted the ARS Florence scientists to determine if the invention could be used for municipal waste treatment. Once again, we referred the CEO of RN to consult with the OTT office. This time, the ARS patent advisor who prepared the patent application confirmed to RN that the invention also covered use of the quick wash process for recovering phosphorus from municipal waste streams. At RN's request, our team provided technical assistance by performing laboratory tests to demonstrate the feasibility of recovering phosphorus from municipal sludge and biosolids. These lab tests showed that more than 80% of the phosphorus contained in municipal wastes can be recovered using the quick wash process. In addition, the process was tested by a third party—an environmental engineering consulting firm hired by RN—that satisfied RN's expectations of using the process to recover phosphorus from municipal sludge and biosolids. In addition, the consulting engineers developed a marketing program and a mobile pilot plant to test Quick Wash™ onsite at the municipal plant.

Patience Is a Virtue

The major challenge was to maintain the licensee's and scientists' interest in developing the technology during the long time before the technology reached commercialization. It took seven years from the

initial ARS news release to start commercialization of the technology. It took the first two of the seven years to license it. Since the technology was licensed while the patent was pending, plus RN's difficulty selling it in the animal waste treatment market, it took RN another four years to redirect its marketing strategy. It is important to mention that RN started to heavily invest in developing and marketing the technology for use in municipal waste treatment once the patent was officially issued in 2014. The commitment of the ARS scientists to provide technical assistance to RN was extremely important in helping RN shift its commercialization plan for the municipal market.

We Could Still Be More Agile

If we could do this tech transfer process over again, we would try to be better prepared to extend the focus of our invention beyond the research laboratory. This could have helped to transfer and commercialize the technology faster. A program for customer discovery and identification of real problems in the different sectors of the waste management industry could have helped ARS have a better idea of the business side of science while helping the licensee to discover an alternative market for the quick wash technology.

In 2015, the ARS started a program called ARS Innovation Corps (I-Corps @ ARS) to help scientists for faster transfer and commercialization of technology. The I-Corps @ ARS pilot consists of a set of activities and programs designed to help ARS scientists broaden the impact of their research by extending their focus beyond the laboratory to the end product of their work. I-Corps @ ARS is based on the NSF I-Corps™ and basically combines experience from established entrepreneurs with a curriculum on market opportunities and innovation.

If we had had this training years ago, we could have learned to be more "agile" with our tech transfer.

About the Authors

Ariel A. Szogi is Research Leader, Matias B. Vanotti is Research Soil Scientist, and Patrick G. Hunt (retired Research Leader) holds the title of collaborator at the Agricultural Research Service's Coastal Plain Soil, Water and Plant Conservation Research Center.

Notice

The authors would like to acknowledge Jeff Dawson, CEO of Renewable Nutrients, for providing information on the marketing aspects of Quick Wash™.