Environment and Natural Resources Trust Fund

Research Addendum for Peer Review

Project Manager Name: Lawrence M. Zanko, NRRI
Key Project Team Members: Tim Hagen and Marsha Patelke, NRRI

Project Manager Email address: lzanko@nrri.umn.edu

Project Title: Waste Water Phosphorous Filtration Using Recycled By-Products

Project number: LCCMR ID:038-B

1. **Abstract** - The goals of this study are to evaluate the use of different forms and quantities of iron with several different filter media and to construct a waste water treatment filter that will benefit Minnesota by reducing the amount of phosphorous discharged. Minnesota Rule 7053.0255 requires a 1.0 mg/L for all new or expanded dischargers. Those that are shown to affect a lake are to receive the fullest practicable limit. In the past this was interpreted to mean a 0.3 mg/L total phosphorus (TP) limit. New phosphorus limit guidance, in consideration of Federal Regulations, instructs that all facilities that have the reasonable potential to cause or contribute to an excursion in state standards receive a water quality based effluent limit (WQBEL). In many cases these limits will be <0.1 mg/L TP. A limit of 0.1 mg/L TP reinforces the importance of developing a treatment system that increases the effective surface area of interaction/potential for adsorption. The study will compare its effluent TP levels with the more restrictive test target. In an effort to create an improved filtration media or method for municipal waste water as well as septic systems, materials evaluated will include recyclables, waste by-products, and natural first use products like peat and sand. Some of the materials to be evaluated include mattress cotton enmeshed with steel wool, prepared finely ground steel recovered from mattress springs, waste construction and horticultural perlite fines, conventional iron filings, and taconite tailings.

2. **Background -** According to EPA 625/R-00/008 addition of iron, aluminum, or calcium compounds to the waste water reduces the phosphorous level by producing a precipitate. A brief review of literature from about the last 15 years indicates that research has been conducted on the potential ability of potential of iron bearing materials such as steel wool, iron oxide tailings, steel slag, and iron filings to remove phosphorous from waste water with some positive results (Bowden, 2009; Erickson et al., 2007; James, 1992; Strom, 2004; Zeng, 2004). Particulate phosphorous was removed from waste water stream by filtration and by absorption were demonstrated. This project will evaluate the effectiveness of several iron containing by-products produced in Minnesota to produce a filtration system capable of removing phosphorous from waste water to meet targeted discharge limits. Potential iron containing waste or processing byproducts include magnetite (Fe_3O_4) and hematite (Fe_2O_3) bearing iron ore mining byproducts and co-products such as coarse tailings and concentrate; and metallic iron such as iron filings, recycled mattress bed springs, and steel wool.. Filter materials can include recycled mattress fabric (RMF), peat, sand and horticultural perlite fines. Captured phosphorous will be evaluated for disposal either at landfills or as an amended fertilizer.

3. **Hypothesis** - There are several product configurations in the marketplace today having iron as a complexing agent for the removal of phosphorus. BayOxide 33, an iron based adsorption media reportedly has a particular affinity for both phosphorus and arsenic. These attributes have made it successful as a commercial media for phosphorus reduction. In addition, natural materials such as peat and sand amended with iron oxides and steel wool have also reportedly been effective for phosphorus removal from municipal wastewater (James, 1992, Farnham and Brown 1972, Blaney,2006) and stormwater (Erickson et al., 2007). These successful product configurations and previous research all point to the active functionality that iron has towards mitigating phosphorus pollution and represents a solid foundation by which future products can be developed from natural or engineered materials. (James, B.R, 1992, Water Environment Research, vol 64, No. 5) (Farnham, R.S and Brown, J.L., 1972, Advanced wastewater treatment using organic and inorganic materials. Part 1. Use of peat and peat-sand filtration media. Proc., Fourth Intl. Peat Cong. 4:271-286)
http://www.adedgetech.com/pdfs/litpdfs/E33%20literature/E33_MEDIA_0309.pdf
(Blaney,L.M. 2006, Hybrid anion exchanger for trace phosphate removal from water and wastewater, Water Research 41, 1603-1613).

4. **Methodology** – Both engineered and natural forms of iron and iron by products will be evaluated for their phosphate reduction potential in conventional column contactors by developing a breakthrough curve. Breakthrough curves developed for each media type will show the phosphate concentration in the effluent as a function of the number of bed volumes of wastewater passed through the media. Efficacy will be judged by the ratio of the amount of phosphate removed per unit mass of each media type via mass balance. In general, we will design our bench-scale experiments to assure that the test parameters/variables are well-defined, manageable in number, and representative of realistic ranges of operating conditions, including pH, Eh, and temperature. For example, columns could include: 1) C33 sand in the form of silica sand; 2) C33 sand as taconite tailings from Mine A; 3) C33 sand as taconite tailings from Mine B; 4) 1,2, and 3 augmented with iron-bearing materials; 5) 1,2,3, and 4 augmented with recycled mattress fiber (RMF); and so on. We will employ appropriate laboratory and analytical methods for determining P speciation, using both external analytical laboratory services and NRRI's in-house analytical chemistry capabilities, but Total P reduction will be our primary initial screening criterion for choosing an optimal combination of materials/media. The size distribution of the particulate and/or granular iron-bearing materials will be known and/or determined in advance, and should be reflected in planned hydraulic conductivity tests. We also expect that a finite amount of P will be removed before the treatment columns need recharging (i.e., breakthrough reached). Repeated column tests will be run on identical column constituents to establish a statistically meaningful set of data. Based on these column test-derived data, an extrapolation/estimate of a scaled-up treatment system's longevity could be attempted, and used as a point of comparison to an optimized bench-scale system. Empty bed contact times will be held constant at nominal 15 minutes, with column ID (inside diameter) of 1 inch and bed depth of 24 inches; however, column dimensions may be modified. The media type or configuration showing the greatest efficacy for phosphate removal will be selected for further study in which the effect of contact time, pH and particle size distribution are optimized. Engineered granular media consisting of a matrix of iron particles immobilized onto a sintered perlite substrate will be prepared using perlite fines, finely ground iron and an appropriate organic pore forming agent (the methodology for forming this media is considered proprietary

and protected). An engineered fiber matrix consisting of cotton and polyester fibers enmeshed with steel wool will also be prepared (methodology considered proprietary and protected).

Taking an approach similar to Erickson et al. (2007) is envisioned, by: 1) preparing a "standard" solution diluted to appropriate (waste water-like) P levels; and 2) working with a single source of actual municipal waste water, such as WLSSD, Two Harbors, or Beaver Bay, to assess how other variables can impact the system. With regard to project test waters, particularly the municipal waste water source, the speciation of P will be determined in advance of its project use, or provided by the treatment facility. Likewise, the speciation of P (during treatment and in post-treatment effluent) will also be determined, either in-house or via external laboratory analysis.

The potential for heavy metals leachate generation will be addressed by conducting appropriate screening analyses (such as TCLP and SPLP) on the various media used in our study, and trace metals analysis of treatment effluent.

Redox potential will also be measured, but this assessment will focus on the final combination of materials that achieves best P reduction/removal during our initial column tests. For example, ORP probes could be inserted through side ports in our test column(s), and the influence of column depth and saturated versus flow-through conditions on redox could be evaluated.

5. **Results and Deliverables** – the specific breakthrough curves for each media type will be presented. The expected outcome from this research will be the basis for the design of an optimized phosphorus treatment system. The breakthrough curve will be used to develop a kinetic equation based on the derivation by Thomas (1948) and can be used for the design of a full scale treatment system. The expression by Thomas for an adsorption column is:

$$\mathbf{Ln\{Co/C - 1\} = \frac{k_1 qoM}{Q} - \frac{k_1 CoV}{Q}}$$

Where C is the effluent concentration, C_o the influent concentration , k_1 the rate constant, q_o maximum solid phase concentration of the sorbed solute (g/g), M mass of adsorbent, V the throughput volume, and Q the flowrate.

The data collected during our project will be made available upon completion and presented during an end-of-project workshop. Again, the project is bench scale, with a focus on identifying an optimal combination of iron-enhanced alternative treatment/filtration components/media to achieve maximum phosphorus reduction in waste water systems, with the goal of designing an optimized bench-scale waste water treatment filter system. Should the results show promise, advancing to the pilot scale would be the next step and require a field stage follow-up project.

6. **Timetable** – This project will require 2 years to complete. Activity 1 will be completed in the first three quarters (July 2011 – March 2012) of the project. Activities 2 – 4 completed between April 2012 and the end of June 2013. An informational meeting will be held at the conclusion of the project to share an overview of the project and its findings with local waste water professionals. Refer to updated proposal/scope of work (starting on the next page) for more details regarding dates for individual results and deliverables.

2011-2012 MAIN PROPOSAL
CONFIDENTIAL FOR LCCMR ONLY
PROJECT TITLE: Waste Water Phosphorous Filtration Using Recycled By-Products

I. PROJECT STATEMENT
Phosphorous from house hold activities can end up in either municipal waste water treatment plants or septic systems and eventually in surface and ground water. If the level of phosphorous becomes elevated in surface waters, it can create increased algal blooms, reduction of available oxygen in aquatic habitats, and degrade waters for recreational use. Human waste, dishwashing, and garbage disposals contribute up to 17% of the total phosphorous load in Minnesota from point source discharges. Waste water treatment facilities receive not only house hold waste water, but also receive waste water from commercial and industrial sources contributing another 14% of the total phosphorous discharge in Minnesota. In order to improve/preserve water quality, Minnesota's allowable phosphorous limits will likely be lowered. Elevated levels of phosphorous are a state wide concern for our lakes and rivers.

The goals of this study are to evaluate the use of different forms and quantities of iron with several different filter media and to construct a waste water treatment filter that will benefit Minnesota by reducing the amount of phosphorous discharged to the environment; ultimately a limit of 0.1 mg/L may be required.

In an effort to create an improved filtration media or method for municipal waste water as well as septic systems, materials evaluated will include recyclables, waste by-products, and natural first use products like peat and sand. Some of the materials to be evaluated include mattress cotton enmeshed with steel wool, prepared finely ground steel recovered from mattress springs, waste construction and horticultural perlite fines, conventional iron filings, and taconite tailings.

II. DESCRIPTION OF PROJECT ACTIVITIES
Activity 1: Select several iron bearing by-products and filtration material for testing. Characterize physical and chemical properties of material. Complete column tests and evaluate material for its ability to remove phosphorous from waste water. **Budget:** $ 73,625

Outcome	Completion Date
1 A progress report that reviews data produced by Activity 1 and recommends combination of materials to be used together for Activity 2 based on best filtering properties and best phosphorous removal properties.	April 2012

Activity 2: Evaluate best texture for phosphorous filter using by-products. Test phosphorous filter materials to compare the effect of granular texture and fibrous texture on phosphorous removal. Analyze both water samples and the filter materials for phosphorous content. Also compare flow rates when textures are used together. **Budget:** $ 28,700

Outcome	Completion Date
1. Compile data from Activity 2 into a progress report that also contains evaluation of best filtering properties based on texture, and recommendations for the next phase of testings based on results from Activities 1 and 2.	April 2013

Activity 3: Evaluate best combination of materials. Construct test columns and test the best combinations of by-products and filtration materials from Activities 1 and 2 for phosphorous removal. Use chemical analyses of water samples to determine effectiveness of filters. Analyze the filter materials to determine where the removed phosphorous goes. Use water flow similar to that of typical waste water treatment systems. **Budget:** $ 64,675

Outcome	Completion Date
1. Produce a progress report that contains data from all three Activities and provides recommendations for the best phosphorous filter based on material, texture and combinations. The materials will be considered successful based on physical performance and phosphorous removal. 2. Captured phosphorous will be evaluated for disposal either at landfills or as an amended fertilizer; other project materials will be similarly assessed for final disposition.	December 2012

Activity 4: Host an informational meeting to presentation of results to regional and state agency representatives. **Budget:** $3,000

Outcome	Completion Date
1. An educational workshop will be held to present findings to a select audience.	June 2013

III. PROJECT STRATEGY

A. Project Team/Partners

Larry Zanko, NRRI, Principle Investigator/Project Manager, LCCMR Funding
Tim Hagen, NRRI, Materials Engineer, LCCMR Funding
Marsha Meinders Patelke, NRRI, Geologist/Research Scientist, LCCMR Funding

Other project participants/collaborators
Steve Hauck, NRRI, Technical Review, LCCMR funding
Technician/Scientist (To Be Determined): NRRI/UMD, SEM, XRD, XRF Technician, LCCMR Funding
Brett Ballavance, MPCA – Regulatory Compliance Evaluation, time donated in kind
Two Harbors, Beaver Bay Waste Water Treatment, contribute waste water

B. Timeline Requirements

This project will require 2 years to complete. Activity 1 will be completed in the first three quarters (July 2011 – March 2012) of the project. Activities 2 – 4 completed between April 2012 and the end of June 2013. An informational meeting will be held at the conclusion of the project to share an overview of the project and its findings with local waste water professionals.

C. Long-Term Strategy and Future Funding Needs

Positive test results of the new filter will demonstrate the ability to reduce phosphorous. The next step in filter development will be to scale up testing. Fielding test to assist in filter design for smaller personal property septic systems would be the first task. Once accomplished larger commercial property septic systems could then be created. The ultimate goal is to scale the filter up for use at municipal waste water treatment systems. For example, NRRI and MPCA have already discussed the potential for taking advantage of Beaver Bay's tertiary filter rehab project as a field testing location. Beaver Bay's system is oversized and could allow for part of one filter being used as a demonstration cell for various media using actual municipal wastewater.

7. Budget – The total (two-year) project budget is $170,000

2011-2012 Detailed Project Budget

revised

IV. TOTAL TRUST FUND REQUEST BUDGET - 2 years

BUDGET ITEM	AMOUNT
NOTE: NRRI researchers, including the project manager and project team listed below, rely entirely on soft-money support for conducting research	
Personnel: Lawrence Zanko, Project Management, 5% FTE, 33.3% Fringe	$ 9,222
Steve Hauck, Technical Review, 1% FTE, 33.3% Fringe	$ 2,682
Tim Hagen, Senior Composite Materials Engineer, 25% FTE, 33.3% Fringe	$ 51,206
Marsha Meinders Patelke, Project Scientist/Researcher, 20% FTE, 40.1% Fringe	$ 20,854
Igor Kolomitsyn, Project Chemist, 10% FTE, 33.3% Fringe	$ 14,748
Lab Technician, 10% FTE, 40.1% Fringe	$ 9,138
Student Worker, 50% FTE, 0% fringe, up to 2 part time students for total of 75% FTE	$ 16,310
Total Personnel Budget	$ 124,160
Contracts:	
ERA Laboratories, Duluth, Minnesota, Chemical analyses of water samples including total phosphorous, dissolved phosphorous, total suspended solids, metals.	$ 23,600
Precision Testing, Virginia, Minnesota, grain size analyses & Hydraulic Conductivities	$ 2,030
Equipment/Tools/Supplies: Test columns,apparatus for conducting phosphorous flow experiments, includes pumps, tubing, and sample collection containers.	$ 5,710
Safety Equipment	$ 500
Travel: Travel to local waste water treatment facilities	$ 1,000
Additional Budget Items: Attend and present at waste water Treatment/Phosphorous Conference/meeting	$ 3,000
UMD Scanning Electron Microscope Lab (SEM) services - characterize material size, morphology, chemical composition, and element mapping.	$ 10,000
TOTAL ENVIRONMENT & NATURAL RESOURCES TRUST FUND $ REQUEST	$ 170,000

SOURCE OF FUNDS	AMOUNT	Status
Other Non-State $ Being Applied to Project During Project Period:	none	*none*
Other State $ Being Applied to Project During Project Period: MPCA and Lake County have indicated a willingness to provide non-cash (in-kind) advisory/site support to the project. Two Harbors, Beaver Bay Waste Water Treatment, contribute waste water and site support (see below)	none	*Pending*
In-kind Services During Project Period: MPCA: Regulatory Compliance Evaluation, time donated in kind, etc; and Two Harbors/Beaver Bay waste water and site support	not determined	*Pending*
Remaining $ from Current ENRTF Appropriation (if applicable):	n/a	*Other*
Funding History: (This is a new project)	none	n/a

8. Credentials for principal team members are presented on the following pages

Project Manager
Mr. Lawrence Matthew Zanko
1360 W. Knife River Road
Two Harbors, MN 55616
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Work e-mail: lzanko@nrri.umn.edu
Phone: (218) 720-4274
FAX: (218) 720-4329

Mr. Zanko is a Senior Research Fellow and Group Leader for By-Product Reuse and Remediation within the Minerals Division of the Center for Applied Research and Technology Development of the Natural Resources Research Institute (NRRI), University of Minnesota Duluth. He has worked in the minerals field and has conducted geological, mineral resource and minerals industry-related applied research for most of his 27-year career. Since his start with NRRI in 1988, he has participated in or led a broad spectrum of research projects – often conducted in cooperation with private industry – dealing with non-ferrous minerals, ferrous minerals, industrial minerals (most recently focusing on construction aggregates), contaminated sediment remediation and reuse, and related policy issues. He regularly interacts and collaborates with public and private sector professionals and academicians in the geological, minerals, transportation, and environmental fields, inside and outside Minnesota. He is a graduate of the University of Minnesota – Twin Cities, where he received bachelor degrees in Geological Engineering and Microbiology, and a Masters degree in Geological Engineering.

PROFESSIONAL PREPARATION/EDUCATION

- Master of Geological Engineering, University of Minnesota, Minneapolis, 1995
- Bachelor of Geological Engineering, University of Minnesota, Minneapolis, 1986
- Bachelor of Science, Microbiology, University of Minnesota, Minneapolis, 1986

POSITIONS, MEMBERSHIPS, and HONORS

Positions and Employment History

2010-	Senior Research Fellow and Group Leader, By-Product Reuse and Remediation, NRRI Minerals, Center for Applied Research and Technology Development, Natural Resources Research Institute, University of Minnesota Duluth
2008-2010	Research Fellow and Group Leader, By-Product Reuse and Remediation, NRRI Minerals, Center for Applied Research and Technology Development, Natural Resources Research Institute, University of Minnesota Duluth
1998-2008	Research Fellow, NRRI Minerals, Economic Geology Group, University of Minnesota Duluth
1992-1998	Scientist, NRRI Minerals, Economic Geology Group, University of Minnesota Duluth
1988-1992	Assistant Scientist, NRRI Minerals, University of Minnesota Duluth
1986-1988	Research Assistant, NRRI Minerals, University of Minnesota Duluth
1983-1986	Data Entry Supervisor, Department of Soil Science, University of Minnesota, St. Paul, MN
1981-1982	Associate Mining Engineer, Reserve Mining Company, Babbitt, MN
1980-1981	Student Worker, Minerals Division, Minnesota Department of Natural Resources, St. Paul, MN

Professional Memberships

Society for Mining, Metallurgy, and Exploration (SME)
Mineral Aggregates Committee of the Transportation Research Board (TRB)
The Geological Society of America (GSA)

Honors

2006	Recipient: Outstanding Researcher Award, Natural Resources Research Institute, University of Minnesota Duluth
2005	Co-recipient: Special Recognition - Research Partnership Award, University of Minnesota Center for Transportation Studies (CTS)

SIGNIFICANT RESEARCH ACTIVITIES

2000-present
A large part of Mr. Zanko's work since 2001 has focused on NRRI's efforts to research and expand the use of taconite mining byproducts for construction aggregate purposes within and beyond Minnesota. He has had major responsibilities in the conceptualization, organization, coordination, and implementation of a 5-year taconite aggregate research program led by NRRI, titled, *Research, Development and Marketing of Minnesota's Iron Range Aggregate Materials for Midwest and National Transportation Applications*. This $1.67 million program, supported by the U.S. Department of Commerce, Economic Development Administration (EDA), the NRRI, and the private and public sector, began on January 1, 2006, and continued through June 30, 2010. Included in this effort are research activities for quantifying and characterizing the size, shape, and mineral content of taconite particles from the areas to be sourced for road aggregate.

In July, 2007, he and his NRRI colleagues began their participation in the Minnesota Taconite Workers Lung Health Partnership, a group of organizations with an interest in the health of Minnesota's Iron Range taconite workers, their families and their communities. Organizations include the University of Minnesota, mining companies, unions, health care providers, legislators, and local, state, and federal agencies. The University of Minnesota's School of Public Health and NRRI are leading the multi-year $4.9 million research effort, with NRRI providing geological, mineralogical, and mining industry expertise. More details about the Partnership can be found at:
http://www.sph.umn.edu/lunghealth/about.html

Other Research Activities
Since 2000, Mr. Zanko has also conducted projects related to the remediation of contaminated sediment and soil, and the beneficial reuse of uncontaminated sediment and soil. Project collaborators have included the U.S. Army Corps of Engineers (Detroit District and Duluth Area Office) via the United States Environmental Protection Agency (USEPA) Great Lakes National Program Office (GLNPO); and the private sector, i.e, ElectroPetroleum, Inc. (EPI) of Wayne, PA, and electrochemical processes, llc (ecp) of Stuttgart, Germany. Much of this work has focused on evaluating: 1) electrochemical remediation technologies (ECRTs) via simulated *in-situ* and *ex-situ* bench- and pilot-scale studies; and 2) electro-kinetics for sediment dewatering potential and dike and levee stabilization applications. Investigation of other potential soil, sediment, and water cleanup technology applications is ongoing.

SYNERGISTIC ACTIVITIES
Member – University of Minnesota Pavement Research Institute Advisory Committee
Member– Transportation Research Board Mineral Aggregates Committee

REPORTS/PUBLICATIONS: Lawrence M. Zanko

The following is an abbreviated list of selected reports/publications:

Reports/Publications

Zanko, L.M., 1988, The Impact of State and Provincial Tax and Royalty Policies on Non-ferrous Mining Ventures: A Comparative Economic Analysis: University of Minnesota, Duluth, Natural Resources Research Institute, Technical Report NRRI/GMIN-TR-88-07, 119 p.

Hauck, S., Heine, J., Zanko, L., Power, B., Geerts, S., Oreskovich, J., and Reichhoff, J., 1990, LCMR Clay Project: NRRI Summary Report: University of Minnesota, Duluth, Natural Resources Research Institute, Technical Report NRRI/GMIN-TR-89-12A, 201 p.

Zanko, L.M., Severson, M.J., and Ripley, E.M., 1994, Geology and Mineralization of the Serpentine Copper-Nickel Deposit: University of Minnesota, Duluth, Natural Resources Research Institute, Technical Report NRRI/TR-93/52, 90 p.

Hauck, S.A., Severson, M.J., Zanko, L., Barnes, S.-J., Morton, P., Alminas, H., Foord, E.E., and Dahlberg, E.H., 1997, An overview of the geology and oxide, sulfide, and platinum-group element mineralization along the western and northern contacts of the Duluth Complex, in Ojakangas, R.W., Dickas, A.B., and Green, J.C., eds., Middle Proterozoic and Cambrian Rifting, Central North America: Boulder, Colorado, Geological Society of America Special Paper 312, p. 137-185.

Zanko, L.M., 1997, Transportation Cost Evaluation of Southeastern Minnesota Carbonates: University of Minnesota, Duluth, Natural Resources Research Institute, Technical Report NRRI/TR-97/08, 38 p.

Zanko, L.M., Oreskovich, J.A., Heine, J.J., Grant, J.A., and Setterholm, D.R., 1998, Mapping Industrial Clay Potential in the Minnesota River Valley: University of Minnesota, Duluth, Natural Resources Research Institute, Report of Investigation NRRI/RI-98/03, 53 p.

Zanko, L.M., and Setterholm, D.R., 1998, Correlating Particle Size, Geochemical, and Gamma-Ray Log Data Relationships at the Ochs Brick and Tile Company Springfield Clay Mine, Springfield, Minnesota: University of Minnesota, Duluth, Natural Resources Research Institute, Technical Report NRRI/TR-98/25, 51 p.

Heine, J.J., and Zanko, L.M., 1999, Testing of Selected Samples From Mapping of Industrial Clay Potential in the Minnesota River Valley, South-Central Minnesota: University of Minnesota, Duluth, Natural Resources Research Institute, Technical Report, NRRI/RI-99/03, 35 p., 1 diskette.

Benner, B.R., Wu, C. and Zanko, L.M., 2001, Alternative Technology for Sediment Remediation - Demonstration Plant: University of Minnesota, Duluth, Natural Resources Research Institute, Technical Report, NRRI/TR-2001-05

Zanko, L.M., 2002, A Comparative Economic Analysis of the Impact of Taxes and Royalties on Potential Non-Ferrous Mining Projects: Minnesota's Rank--Nationally and Internationally--at the start of the 21st century: Interim Report, University of Minnesota, Duluth, Natural Resources Research Institute, Technical Report, NRRI/TR-2002/15, 13 p.

Zanko, L.M., Severson, M.J., Oreskovich, J.A, Heine, J.J., Hauck, S.A., and Ojakangas, R.W., 2003, Oxidized Taconite Geological Resources for a Portion of the Western Mesabi Range (West Half of the Arcturus Mine to the East Half of the Canisteo Mine), Itasca County, Minnesota - A GIS-based Resource Analysis for Land-Use planning: University of Minnesota, Duluth, Natural Resources Research Institute, Technical Report, NRRI TR-2001/40, 86 p.

Zanko, L.M., Niles, H.B., and Oreskovich, J.A., 2003, Properties and aggregate potential of coarse taconite tailings from five Minnesota taconite operations, University of Minnesota, Duluth, Natural

Resources Research Institute, Technical Report, NRRI/TR-2003/44; and Local Road Research Board Report Number 2004-06, 227 p.

Oreskovich, J.A., Zanko, L.M., Patelke, R.L., and Heine, J.J., 2004, Technical Reference for Minnesota's Industrial Mineral Wastes/By-Products, University of Minnesota, Duluth, Natural Resources Research Institute, Technical Report, NRRI/TR-2003/47, 234 p., 1 data CD.

Zanko, L., Heine, J., and Setterholm, D., 2005, Field Trip 8: Geology of the Pre-Cretaceous Weathering Profile and Cretaceous Strata of the Minnesota and Cottonwood River Valleys, in Robinson, L., ed., 2005, Field trip guidebook for selected geology in Minnesota and Wisconsin: Minnesota Geological Survey Guidebook 21, 78 p.

Oreskovich, J.A., Patelke, M.M., and Zanko, L.M., 2007, Documenting the Historical Use of Taconite Byproducts as Construction Aggregates in Minnesota—A GIS-based Compilation of Applications, Locations, Test Data, and Related Construction Information: Natural Resources Research Institute, University of Minnesota Duluth, Technical Report NRRI/TR-2007/22, 43 pp.

Zanko, L.M., Ogard, E.E., and Stewart, R.D., 2008, The Economics and Logistics of Transporting Taconite Mining and Processing Byproducts (Aggregate): Minnesota and Beyond, Final Report to the Minerals Coordinating Committee: Natural Resources Research Institute, University of Minnesota, Duluth, MN, Technical Report NRRI/TR-2008/19, 73 pp.

Zanko, L.M., and Peterman, J., 2007, A Comparative Economic Analysis of the Impact of Taxes and Royalties on Potential Non-Ferrous Mining Projects: Minnesota's Rank – Nationally and Internationally – at the Start of the 21st Century (Part 1): Natural Resources Research Institute, University of Minnesota, Duluth, MN, Technical Report NRRI/TR-2007/26, 31 p.

Zanko, L.M., Fosnacht, D.R., and Hauck, S.A., Research, Development, and Marketing of Minnesota's Iron Range Aggregate Materials for Midwest and National Transportation Applications: January 2008 Progress Report to the Economic Development Administration, Natural Resources Research Institute, University of Minnesota, Duluth, MN, Technical Summary Report NRRI/TSR-2008/01.

Wittle, J.K., Zanko, L.M., Doering, F., and Harrison, J., 2008, Enhanced stabilization of dikes and levees using direct current technology: Geosustainability and geohazard mitigation*, in* Proceedings of Sessions of GeoCongress 2008, American Society of Civil Engineers (ASCE), Geotechnical Special Publication No. 178, p. 686-693.

Zanko, L.M., Niles, H.B., and Oreskovich, J.A., 2008, Mineralogical and microscopic evaluation of coarse taconite tailings from Minnesota taconite operations, Regulatory Toxicology and Pharmacology, International Symposium on the Health Hazard Evaluation of Fibrous Particles Associated with Taconite and the Adjacent Duluth Complex - Taconite Symposium, Volume 52, Issue 1, Supplement 1, October 2008, Pages S51-S65.

Wittle, J.K., Pamukcu, S., Bowman, D., Zanko, L.M., and Doering, F., 2009, Field Studies on Sediment Remediation, *in* Electrochemical Remediation Technologies for Polluted Soils, Sediments and Groundwater, Reddy, K.R. and Cameselle, C., eds., John Wiley & Sons, Inc., Pages 661-696.

Zanko, L.M., Benner, B., Wittle, J.K., and Doering, F., Final Summary Report to EPA Region 5: Evaluation of Electrochemical Geo-Oxidation (ECGO) Treatment of New Bedford Harbor Sediment PCBs: 2003-2010, in prep.

Tim Hagen
Education: B.S. Chemical Engineering
1986 – University of North Dakota

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Superior, WI 54880
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PROFESSIONAL EXPERIENCE:

Oct 2007 – Present **Natural Resources Research Inst.** **Duluth, Minnesota**
Program Coordinator

Develop novel and innovation solutions for transforming wood, lignite, recycled plastics, tear-off shingles and cotton linters into useful green-based products for re-use. Successfully developed an agglomeration technique in which lignite fines are converted into an engineered carrier for azospirillum. Pioneered an agglomeration process in which delicate corn stover fibers are converted into highly absorptive, free flowing, granules uniquely capable of displacing inefficient clay type absorbents in the market place.

- Developed new partners and identified new funding sources
- Developed funding strategies for sustainable development
- Successfully designed and developed a spheronizer capable of combined growth agglomeration in combination with slow release coatings
- Successfully completed agglomeration, pelletizing, prilling, spheronization, extrusion and dehydration trials on a variety of substrates including perlite fines, lignite fines, corn stover, hematite and proprietary filtration media
- Successfully converted a variety of woody biomass materials into torrefied fuels for validation and testing.

February 2005 – Oct 2007 **Contech Stormwater Solutions** **Portland, Oregon**
Operations Engineer

Lead, manage and guide the development of enhanced media strategies for the removal of priority pollutants from storm water.

- Successfully optimized a 1 million lb/yr process in which composted tree leaves are converted into a valuable porous granule with unique filtration properties.
- Successfully integrated a batch step wise process into a continuous free-flowing operation consistent with lean manufacturing techniques.
- Developed a process in which perlite agglomerates are coated with chemical reagents, kiln fired and converted into a highly stable, porous filtration media.
- Surpassed media production goals allowing the company to exceed sales targets, dominate the industry and enter new market areas.

April 2004–Jan. 2005 **BeckerUnderwood, Inc.** **Ames, Iowa**
Operations Engineer

Guided the development and enhancement of peat media strategies for BeckerUnderwood and its subsidiaries. Key responsibilities include the design, construction, engineering and fabrication of a state-of-the-art, prilling plant equipped with extrusion, spheronization and dehydration circuits.

- Completed the design, engineering and construction of a 1 million lb/yr prilling plant ahead of schedule.
- Coordinate production support activities including raw material inventory, parts, maintenance, sub-contracting electrical and engineering services.
- Implement and track cost reduction initiatives.
- Defined and implemented automated process control functions throughout the dehydration and low pressure extrusion circuits.

- Responsible for new product development initiatives.

1999–April 2004 **Peat Technologies Corporation** **Siren, WI**
VP Research and Marketing

Managed a three person support staff in the research and development of new products. Developed sales and marketing strategies to introduce spheronized and granular peat into the agricultural inoculant and wastewater treatment sectors. Gained national recognition by offering unique and customized peat-based formularies specifically designed to harbor rhizobia bacteria and proprietary microbial formulations. Implemented a national sales and marketing strategy for granular peat with direct distribution to six inoculant companies. Successfully developed an advanced treatment concept utilizing spheronized peat to remove heavy metals and nutrients from storm water and domestic waste water. Increased sales revenues from $100 thousand in 1999 to $1.8 million in 2001.

- Successfully acquired over $688 thousand dollars from the USDA/Small Business Innovative Research Program for the advanced treatment of septic tank effluent and for removing heavy metals from storm water and electroplating waste water.

1989 – 1999 **Natural Resources Research Institute** **Duluth, MN**
Research Engineer

Responsible for the creation and evolution of new products and applications using Minnesota's peat resources.

- Created and patented a novel process by which peat is densified into a pellet having unique disintegration and solution properties when exposed to water.
- Successfully led the efforts of a small project team to develop oil absorbent wipes made from modified-sheared wood fiber.
- Guided the commercialization of an improved carrier formulation from peat.
- Proven track record of acquiring state funded research dollars and matching them with private industry dollars to develop real products and opportunities in the marketplace.
- Generated royalty monies through technology transfer for the University of Minnesota.

1987-1989 **University Of Minnesota-Duluth** **Duluth, MN**
Chemical Engineering Department
Assistant Scientist

- Conducted research on improving the energy, equilibrium moisture and sodium content of a western subbituminous coal through wet carbonization/hot water drying.

Reports/Publications for Mr. Hagen

Hagen, T., "Treatment of Septic Tank Effluent Using a Granulated Peat BioFilter," Final Report Submitted to USDA/SBIR Phase II Research Program, Phase II SBIR AWARD GRANT NO. 00-33610-9439, 2002.

Hagen, T,, "Modified Soybean Hulls for Heavy Metal Removal", USDA Phase I SBIR Mid Term Progress Report, No. 2002-00397, Submitted May, 2002.

Hagen, T, "An evaluation of Minnesota Peats as Oil Absorbents", Confidential Report submitted to Confidential client, 1991.

Hagen, T, "Peat as an Adsorption Medium for Dissolved Organics," August 1993, NRRI/TR/44, Prepared for Minnesota Technology, Inc.

Hagen, T, G. Anderson, T. Malterer, "Peat as a Tunnel Wash Water Filter Medium," September 1996, NRRI/TR-96/18, Prepared for the Minnesota Department of Transportation.

Hagen, T, "The Use of Peat In Bilge Filters" March 1992, Confidential report submitted to Confidential client.

Hagen, T, "Peat-Based Oil Sorbent Socks and Booms," August 1993, NRRI/TR-93/40, Prepared for Minnesota Technology, Inc.

Hagen, T, T. Malterer, "Peat-Based Sorbent Mats," August 1993, NRRI/TR-93/42, Prepared for Minnesota Technology Inc.

Hagen, T, "The Feasibility of Using Granulated Peat to Remove Heavy Metals and Organics from Wastewaters" August 1993, Confidential report Prepared for Peat Technologies Corporation.

Hagen, T, Kastner, J. , Berguson, B, "Granulated Peat For Targeted Industrial Applications," October 1994, Project No. 544820, NRRI/TR-94/37.

Hagen, T, "The Feasibility of Using B^2 Granules to remove Sodium Ions from a Contaminated Aquifer", March 1995, Project No. 545801, NRRI/TR-95/23.

Hagen, T, "The Commercialization Potential of Peat Based Socks and Booms," August 1993, Final Report to Minnesota Technology, Incorporated.

Hagen, T, "Fiber Based Oil Sorbent Pads: A Commercialization Perspective" June 1992, Confidential report submitted to Confidential Client.

Hagen, T, T. Malterer, T. Levar, "Evaluation of Carex peat, Sphagnum Moss Peat, and Sphagnum Top Moss as Oil Absorbents," 1991, NRRI Internal report.

Hagen, T, T. Malterer, T. Levar, B. Berguson, “Oil Sorptive Properties of several Minnesota Peats”, Proceedings of the International Peat Symposium: Peat and Peatlands: The Resource and Its Utilization. Duluth, Minnesota, August 19-20, 1991.

Malterer, T, Adams, R., Hagen, T. , 1994. Product development utilizing Minnesota Peats. International Conference ‘94 on Wetland Environment and Peatland Utilization, Changchun, China, August 9-11, 1994. Chinese Academy of Science, Changchun, China.

Baria, D, Hagen, T., “Hot water Drying of Rosebud Subbituminous Coal: A Conceptual Design for Continuously Hot Water Drying 50 Ton/hr of Rosebud Subbituminous Coal,” December 1987, Submitted to Minnesota Power. Materials Processing Engineering Department, Engineering and Science Research Center, University of Minnesota, Duluth.

Marsha Meinders Patelke - NRRI

Marsha Meinders Patelke is a registered professional geologist (PG) and scientist with the Economic Geology Group at the Natural Resources Research Institute (NRRI)

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Marsha Meinders Patelke is a scientist with the Economic Geology Group at NRRI. Prior to coming to NRRI, she worked for 15 years as project geologist and project manager at environmental/engineering consulting firms, completing a variety of investigation and remediation projects across northern Minnesota. Soil, ground water, surface water, and sediment investigation were completed at sites with contaminants ranging from petroleum, polycyclic aromatic hydrocarbons (PAHs), and metals. During her year in consulting she conducted environmental investigation and remediation projects along St. Louis River, Duluth Harbor Historic Use sites, and various sites across NE Minnesota while at Service Engineering Group, American Engineering Testing, and GME Consultants.

She graduated from Eastern Illinois University with at bachelor degree in Geology and is currently finishing her Masters degree in stratigraphy geology at the University of Minnesota Duluth.

Ms. Patelke came to NRRI in 2006 and has worked on projects such as beneficial re-use of harbor sediments, historical use of taconite tailings as aggregate for road construction, literature and available data review related to water quality and taconite tailings, and the stratigraphy of the Biwabik Iron Formation, from which taconite aggregate materials are generated.

9. **Dissemination and Use** – Research findings will be disseminated via an educational workshop held in the spring of 2013. The workshop audience will include municipal, county, and state agency representatives/regulators responsible for oversight and implementation of waste water treatment practices. A positive project outcome would be a demonstrated ability to effectively reduce phosphorous discharge levels; therefore, the workshop would also act as a feedback forum for guiding the next steps in filter development and design, and scaled-up field testing for smaller personal property septic systems. A technical report will also be posted on NRRI's website following completion of the project.

9/10/2010