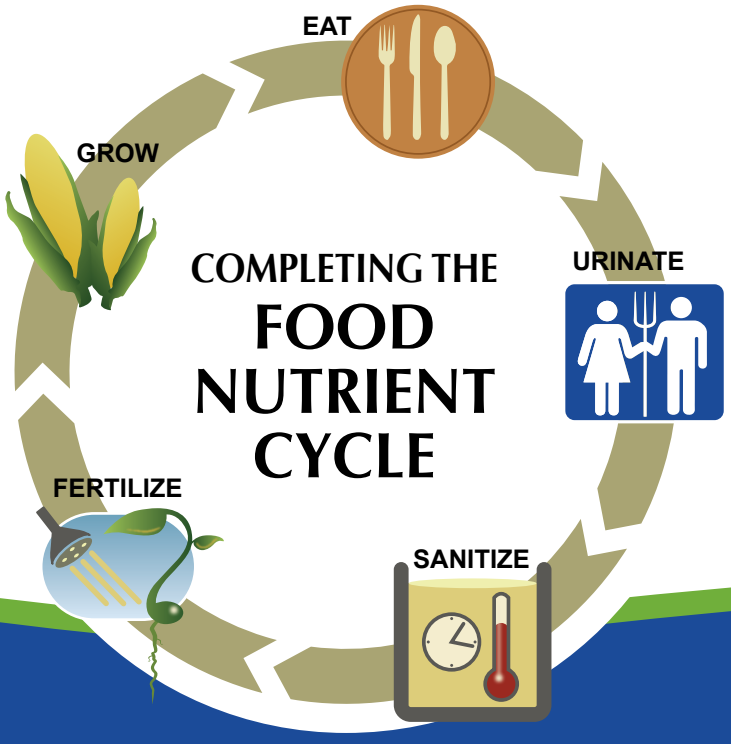
Urine Diversion and Reuse

Advancing the Agenda in the United States

A Report by the Rich Earth Institute
Brattleboro, Vermont
March 2018



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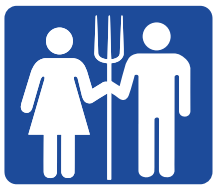

The Rich Earth Institute established the United States' first community-scale urine recycling program, the Urine Nutrient Reclamation Project (UNRP), in 2012. Conceived as a platform for research and practical demonstration, the UNRP has facilitated several of the Institute's key activities, including the development of an array of technologies for producing urine-derived fertilizer (UDF), and the execution of controlled agricultural field trials using UDF products. This work has been supported by funding from the EPA, USDA, Water Environment & Reuse Foundation (WE&RF), and the National Science Foundation (NSF).

The Institute, an independent research and demonstration non-profit, initiated an annual conference in 2015 to bring people in this emerging field together. Pioneers of source separation and nutrient recovery from human urine gathered in Brattleboro, Vermont, the home-base of the Rich Earth Institute, for the first Urine Diversion Summit (referred to in this document as the "Summit"). Fifteen participants, with academic and industry backgrounds, convened to meet and share experiences around urine diversion for the first time. The event doubled in size in 2016, and a second day was added, in order to increase the scheduled time for sharing new research results in this emerging field. Forty-three people gathered in 2017 for the third Summit, including keynote speaker Tove Larsen from the Swiss Federal Institute of Aquatic Science and Technology (Eawag), whose address was also heard via webinar by an additional 46 participants around the globe.

The Summit has been successful because of a recent surge of interest in urine diversion, which is directly related to the growth of interest, passion, and momentum around re-imagining the broader food-nutrient cycle. This moment coincides with a critical juncture in the United States, when much of the centralized sewer and wastewater treatment infrastructure is reaching its design life expectancy and needs to be replaced.

This report is intended to provide a framework for understanding the issues in the emerging field of urine diversion, and guidance for advancing the implementation of urine diversion and nutrient recovery in the United States. The report includes a synthesis of information shared by Summit participants during formal presentations and group discussions. Section **(i)** frames the issues and references accomplishments to date by multiple entities, with specific mention of work reported by attendees during lightning talks at the three Summits; section **(ii)** lays out ways to advance the agenda—current short term wins and longer term objectives; and section **(iii)** identifies critical concepts and actions that participants believe will lead toward achieving a higher level of acceptance and marketable deployment of urine diversion and resource recovery practices in the U.S.

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Glossary

ANSI - American National Standards Institute

Class A Biosolids - (also referred to as a class A Product) a material produced from sewage sludge, suitable for land application without restrictions, which complies with requirements of the US EPA Part 503 Rule regarding pathogens, heavy metals, odor, vector attractiveness, and other criteria

CEWAS - Swiss non-profit association specializing in improving business practices in water and sanitation through training and awareness-raising, in order to increase the sector's integrity and sustainability

DEC - Vermont Department of Environmental Conservation

Eawag - Swiss Federal Institute of Aquatic Science and Technology

Ecological Sanitation - commonly abbreviated to ecosan (also spelled eco-san or EcoSan), is an approach which is characterized by a desire to safely "close the loop" (mainly for the nutrients and organic matter) between sanitation and agriculture

EZP - stand-alone urinal for festivals, manufactured by Pluto Urinals, Switzerland

IAPMO - International Association of Plumbing and Mechanical Officials

INFEWS - Innovation at the Nexus of Food Energy and Water Systems, a National Science Foundation grant program

ISO - International Standards Organization

N, P, K - the elements nitrogen, phosphorus, and potassium, which are the three most commonly applied agricultural fertilizer macronutrients

POOP Project - People's Own Organic Power Project, an arts and advocacy organization based in New York City, founded by Shawn Shafner

pStyle - device that allows women and trans men to pee standing up without undressing

RECODE - a non-profit based in Portland, Oregon that works to ensure access to and accelerate adoption of sustainable building and development practices

Septage - excrement and other waste material contained in or removed from a septic tank

Source separation - the process of collecting individual waste materials separately, rather than commingling them into a combined waste flow

TMDL - Total Maximum Daily Load refers to the quantity of nutrients allowed (by the EPA or other governing body) to be discharged into a given body of water

Urine Diversion (UD) - the capture of urine at the source in the bathroom, separate from feces, in order to exclude it from the wastewater stream

Urine-Derived Fertilizer (UDF) - a fertilizer product produced using source-separated (diverted) urine

UNRP - Urine Nutrient Reclamation Project - Applied research program in Brattleboro, Vermont, initiated in 2012, involving a community-scale urine-diversion project which demonstrates the ongoing collection, processing, and distribution of diverted urine and urine derived fertilizers

VUNA - Valorisation of Urine Nutrients in Africa - A project aimed at recovering nutrients from urine, by developing a dry sanitation system, which is affordable, produces a valuable fertiliser, promotes entrepreneurship and reduces pollution of water resources. Project duration: 2010 to 2015

Wastewater - water that has been used in the home, in a business, or as part of an industrial process

Wastewater treatment - a process used to convert wastewater into an effluent (outflowing of water to a receiving body of water) that can be returned to the water cycle with minimal impact on the environment or directly reused

WWTP - Wastewater treatment plant

Section i - Framing the Issues

Urine diversion (collecting urine before it is combined with water to create wastewater) is being explored by researchers and practitioners around the globe as a step toward a more holistic and sustainable form of human sanitation in which 'wastes' (e.g. nutrients, organic matter, and water) are recovered as valuable resources. Because urine contains most of the nutrients[1] (N, P, and K) excreted by humans, urine diversion provides a means of: **1)** recovering a concentrated stream of nutrients before it is combined with other wastewater components; **2)** reducing nutrient burdens on waters receiving treated wastewater; and **3)** reducing the energy and infrastructure required at wastewater treatment plants (or onsite treatment works) to remove nutrients from highly diluted wastewater streams.

Growing scientific interest exists in the potential for urine diversion, illustrated by recent NSF funding of a significant urine-diversion research project, detailed below. Urine diversion also presents numerous economic opportunities for technology and business development in the areas of toilet design and manufacture, urine-derived fertilizer production (storage, transport, treatment, and conversion of urine into fertilizers), and application of those fertilizers to agricultural fields.

To facilitate development of the products, services, and interest that could support broader deployment, funding is needed for basic research, product development, and communication strategies. It is imperative to identify investors who share the vision of a sustainable built environment, integrating innovative toilets and sanitation infrastructure that will meet the needs of the future. It is crucial to engage with sanitary fixture manufacturers and the wastewater engineering industry, leveraging their entrepreneurial spirit and research and development capacities in order to bring urine diversion into the mainstream of wastewater management. Economic, environmental, and practical performance metrics of conventional vs. innovative systems need to be carefully quantified, compared, and presented to diverse stakeholders, including policy makers, regulators, wastewater industry leaders, conservation groups, architects, government officials, and farmers.

In 2016, Summit participants mapped potential trajectories and necessary activities leading to wide-scale practice of urine diversion by 2050. In 2017, participants identified significant current accomplishments and future tasks which are critical to complete. Five key themes emerged *(Figure 1)* which require action for urine diversion and reuse to be more broadly adopted and scaled for implementation in the U.S. These themes are discussed below, with reference to specific contributions reported by summit attendees.

Five Key Themes for Advancing Urine Diversion and Reuse in the United States

1. Basic Research
2. Technology, Infrastructure and Applied Research
3. Funding and Financial Models
4. Federal and State Statutes and Policies
5. Public Perception and Education

Figure 1. Key themes identified through the 2016 – 2017 Urine Summit meetings.

Basic Research

The return of nutrients from human waste back into soils has the potential to conserve energy, create sustainable nutrient cycles, and reduce water pollution. Significant research has been done over the past 25 years, largely in Europe, to understand the distinct characteristics of source-separated urine, and the safety, utility, and practicality of its collection and processing for use as fertilizer in agriculture[2,3]. A variety of individuals and institutions in the U.S., many of them represented at the Summits, are now making progress in this field as well, including a new research initiative funded through the NSF Innovations at the Nexus of Food Energy and Water Systems (INFEWS) program: Advancing Technologies and Improving Communication of Urine-Derived Fertilizers for Food Production Within a Risk-Based Framework, led by Nancy Love of the University of Michigan[4]. This project is focused on producing a variety of fertilizer products derived from urine, and assessing the potential risks and benefits associated with them. This same project is also identifying concerns, attitudes and beliefs of both farmers and the general public around ideas of safety and benefit, in order to develop effective communication and educational strategies for outreach concerning urine diversion and use of urine-derived fertilizers.

Summit attendees have reported on the development of methods to detect chemical and biological contaminants of concern in urine-derived fertilizers and the agricultural environment. Research by K. Wigginton and H. Goetsch evaluated microbial communities in urine-derived fertilizer, while R. Mullen developed methods to detect residual pharmaceuticals in plant tissues, soil, and groundwater. Current research at the University of Michigan, University at Buffalo, and the Rich Earth Institute includes the development and testing of new urine treatments to enhance nutrient stability and recovery, and reduce odor, volume, and residual pharmaceuticals.

Research is also focused on analyzing existing data on nutrient and energy flows in wastewater and agriculture. E. Roy, reported a geographic analysis of nitrogen and phosphorus sources (from wastewater) and demands (in agriculture) in New England, which helps determine the most viable and compelling locations for introducing urine diversion as a solution to nutrient pollution problems. W. Mo and M. Aghababaei Shahrestrani presented their respective life cycle assessments of a resource recovery process at a large wastewater treatment plant, and the Rich Earth's urine diversion project.

Further research on the agricultural impacts of urine-derived fertilizers (UDFs) is necessary in order to: determine the most effective fertilizer formulations and application methods to increase plant utilization of nutrients and minimize nutrient losses through volatilization and leaching; quantify possible greenhouse gas emissions stemming from UDF application; better understand the impact of UDFs on soil microbial communities; and assess the ability of soils under different management conditions to retain nutrients from UDFs.

Technology, Infrastructure and Applied Research

Currently, only a handful of demonstration projects incorporate all the steps of urine diversion and reuse in agriculture: urine diverting toilets, urine treatment systems, urine-derived or urine-enhanced fertilizer production, customized transport vehicles, and appropriately modified farm equipment. Mature technologies do not yet exist in many of these areas, especially in the designs of toilets or urine treatments systems. For urine diversion to become widespread, an array of new designs and technologies need to be imagined, constructed, tested and prepared for market.

Summit attendees making contributions in this area include the Rich Earth Institute, whose Urine Nutrient Reclamation Project (UNRP) demonstrates a full-system approach at the scale of 6,000 gallons of urine collected, transported, treated and applied to hay fields annually. The UNRP serves as a test platform for tools and technologies relating to each stage of the urine-diversion process. Pee Local, developed by D. Cedarolm, is the first ongoing replication of the UNRP, and is located in Lee, NH. H. Maingay and E. Barnhart reported on a municipally-funded alternative toilet pilot project in Falmouth, MA, which included urine diverting flush toilets and composting toilets.

Attendees also reported significant developments in technologies for collecting and processing urine into fertilizer. Research on acid treatment of fresh urine at the point of collection (the toilet fixture) was reported by T. Boyer, D. Saetta and H. Ray (laboratory investigation into reducing the potential for phosphorus scaling in plumbing), and by D. Raye-Leonard and A. Noe-Hays (public demonstration of toilets connected to a treatment works producing concentrated fertilizer through reverse osmosis and distillation). T. Kohn reported on implementation of a process for nitrification and distillation in Durban, South Africa and at Eawag, in Switzerland, on a building-scale. W. Tarpeh is testing a treatment technology using ion exchange to produce a concentrated nitrogen product from diverted urine. A. Gagnon has produced struvite prills (phosphorus) from urine using Ostera technology. H. Leverenz has developed a skid-mounted system for ammonium bicarbonate recovery from hydrolyzed urine. E. Rodrigues is developing a mass balance modeling tool to assist in the design of multi-step treatment processes for the production of urine-derived fertilizer.

While most presentations concerned systems for use in areas where water-based sanitation was already available, some presentations focused on source separation of urine as part of a strategy for providing sanitation in areas where it was otherwise lacking. B. Southerland demonstrated a low-cost container-based system produced using locally available materials in the Ejo Herzo project in Rwanda, and L. Volat outlined an initiative to provide source-separation urinals in Syrian refugee camps.

Funding and Financial Models

After the Clean Water Act of 1972, extensive federal funding was allocated to construct centralized wastewater treatment systems. Today, many of these federal grants have been replaced by revolving loan funds, which places a much greater financial burden on local governments which must use bonding and/or rate increases to fill the funding gap. Decentralized wastewater infrastructure such as septic systems are funded by individual homeowners, while sewers and centralized treatment works are funded through taxation at the municipal, state and federal level.

Although many US residents live in urban areas with the population and tax base to support plant upgrades, nearly 30% of the US population lives in towns with fewer than 50,000 people[5]. In smaller towns, treatment systems typically cost more per capita (reverse economy of scale), and less local money is available to upgrade treatment plants or build new centralized systems. As controls on centralized and decentralized treatment works become more strict in terms of the allowable levels of nitrogen and phosphorus emissions, the financial burden on small towns increases. If innovations such as urine diversion prove to be less expensive than conventional options, people in small communities may have the strongest economic reason to advocate for early implementation of these alternatives.

Federal and State Statutes and Policies

In order to protect public health and water quality, federal and state statutes and policies guide the management of sewage and septic collection and conveyance, and the complex water and wastewater treatment industry that processes those wastes. Plumbers, treatment plant operators, utility managers, local government officials and design engineers work within the framework of regulations that govern standard practices. Currently, these regulations do not contain management and processing requirements specific to diverted urine.

Despite this gap, the Rich Earth Institute received the first permit in the U.S., through the Vermont Department of Environmental Conservation (DEC), to collect and pasteurize urine to produce a Class A product, which is currently applied to hay grown as livestock feed. E. Twohig, a regulator from the Vermont DEC Waste Management and Prevention Division, attended the Summit and summarized current policy and regulation affecting nutrient reclamation from human waste. Although the Rich Earth Institute's permit was innovative, Vermont regulators issued it under the EPA Part 503 Biosolids Rule—a rule that was developed to regulate sewage sludge, and does not account for the characteristics of urine that make it very different from sewage sludge, such as vastly lower levels of pathogens and heavy metals. Urine-derived fertilizer production and marketing would be greatly facilitated by a regulatory approach that classified and allowed management of urine as a substance distinct from sewage sludge and septage.

Another significant regulatory development has been the inclusion of urine-diverting and composting toilets in a new national building standard. Attendee M. Lippincott had a leadership role on the national team of experts who worked for 1.5 years to develop language which is included in the "Water Efficiency and Sanitation Standard for the Built Environment (WE•Stand)" supplemental building code, by the International Association of Plumbers and Mechanical Officials (IAPMO) and American National Standards Institute (ANSI). Currently available for pre-order, a draft version of the supplement has already served as a guideline for installations including Hampton Roads Sanitation District's Administration Building and the University of Michigan's George G. Brown Laboratories facility.

K. Koss reported working with the ANSI Technical Advisory Group (TAG) as a part of the International Standards Organization (ISO) to prepare standards for new kinds of toilets. She gave an overview of how standards impact innovation, new products and markets. State by state, we discover that regulations and policy differ significantly in the United States. B. Howard presented his review of varying practices and policies around land application of septage in Ohio, and outlined the potential for including urine-derived fertilizers within this regulatory framework. E. Brands reported on his survey of wastewater treatment plant operators regarding the wastewater challenges in small Minnesota communities. C. Bryars shared her research into how sanitation systems are integral to the work of urban and regional planners, as they work with communities to protect and manage their landscapes and natural resources.

The lack of specific policy and regulation can be a significant barrier to the adoption of ecological sanitation infrastructure and industry investment. It is critical to synchronize the innovative advances in the field of urine diversion with regulatory oversight that continues to protect public health and the environment.

Public Perception and Education

Urine Diversion is a relatively new concept in the United States. Active outreach about the potential benefits of diverting urine for use as an agricultural resource could promote acceptance and encourage adoption of this alternative waste management strategy.

Summit participant N. Mory promoted "peeponics," a hydroponic system using urine fertilizer in an outdoor art installation in Montreal. Comic performer Shawn Shafner showcased material from his New York-based POOP Project, which uses humour to confront issues of shame associated with human waste. An educational animation developed by New Water Resources was debuted, narrated by a droplet named Uri who communicates key concepts about urine diversion in a humorous yet scientifically accurate light. The Rich Earth Institute operates an ongoing outreach campaign, earning extensive media coverage and offering in-person tours of its projects.

These initiatives have enjoyed success in educating people about the impact of sanitation on human health and the environment, and in moving the topic of human waste from a taboo subject to a lively conversation topic about resource management, social equity, environmental preservation, water conservation and pollution prevention[6]. This conversation is nested in broader conversations about limited resources, global warming, climate change and human impact on ecosystems.

A. Pallmeyer, M.Sahai, and C. Askew reported on the first year results of survey data collected for the INFEWS National Science Foundation Social Research project. T. Schreiber reported on Rich Earth Institute's first years of data collection from participants in the Vermont urine diversion project, which found that participants' comfort with urine diversion increased significantly over time. Because implementation of urine diversion involves a diverse set of stakeholders, there is a need for new publications, communication tools and forums for engaging at multiple levels.

Section ii - Advancing the Agenda

For each of the five thematic areas, conference attendees worked as a team to identify short-term wins as well as critical points for advancement in 2020 and beyond. The group also identified seven milestones that must be accomplished to normalize the practice of urine diversion and reuse.

Basic Research

Current research is

- clarifying the characteristics of urine including nutrient, micronutrient, and organic contents; changes in pH over time in storage; and impacts on a wide variety of crops.
- estimating the risks associated with urine-derived fertilizers compared to synthetic and fertilizer and biosolid products.
- exploring a variety of treatment methods to create concentrated fertilizer products that are sanitized, have minimal odors and are simple to apply in the field.
- seeking to understand nutrient bioavailability and losses at the point of application, and to correct for material science issues and solutions within urine systems such as corrosion.

2020 and Beyond

- Determine the long-term impact of urine-derived fertilizer on soil health, including physical, chemical and biological components.
- Develop methods for improving aesthetics of urine collection, treatment, and fertilizer handling.
- Refine technologies for removing pharmaceuticals from UDF.
- Expand scope of recovery to areas such as micronutrient fertilizers, or phosphorus for industrial use or food processing.

Technology, Infrastructure and Applied Research

Short-term wins

- Current research is underway to make a sustainability case for urine diversion via models that use life-cycle analysis to convey the energy, greenhouse gas and economic costs of urine diversion and re-use as compared to current practices.
- There is an ongoing community-scale urine diversion and fertilizer application program in Brattleboro, Vermont, operated by the Rich Earth Institute. Research conducted there has established the effectiveness of undiluted, surface-applied, sanitized urine as a replacement for synthetic fertilizer in the production of hay.
- UD installations by the Hampton Roads Sanitation District and the University of Michigan have set a precedent for additional institutional pilot projects.

2020 and Beyond

- Design and manufacture of improved urine-diversion toilets and urinals, potentially including vacuum flush systems, retrofits for existing toilets, and female urinals.
- Develop an efficient service model for collecting urine from buildings and transporting it for treatment.
- Develop community-scale facilities for co-processing urine and other organic wastes.
- Development of tools for precision application of UDFs.
- Facilitate decentralized (home-scale) UDF processing/use, as a compliment to centralized collection and distribution.
- Create institution-scale demonstration projects (e.g. entire campus, housing development, or large-scale building) with centralized treatment and nutrient recovery systems.

Funding and Financial Models

Short-term wins

- The Bill and Melinda Gates Foundation has funded the Reinvent the Toilet Challenge.
- Funding from the USDA, EPA, and Water Environment & Reuse Foundation has supported the Rich Earth Institute's research and demonstration project.
- The National Science Foundation's INFEWS project is a $3 million investment on the exploration of urine diversion specifically in the United States.

2020 and Beyond

- Build relationships across sectors.
- Develop information for foundations, investors, and marketers emphasizing environmental impacts and social responsibility.
- Strengthen the network of industries that have interests in becoming involved with a new model, including septic haulers and those who pay for waste disposal, toilet manufacturing companies who could gain significant profit with wide scale adoption, wastewater engineers who build and maintain centralized systems, homeowners who ultimately pay for their waste management system, and those in agricultural industries involved with fertilizer production and application.
- Map current intellectual property and create a consortium for protecting and sharing intellectual property.
- New EPA and state-driven TMDL and other water quality requirements are a useful leveraging tool for substantiating the benefits of urine diversion. Give ample information to policy makers who can consider urine diversion as a nutrient management strategy.
- Create tax incentives for nutrient recycling (similar to solar installation tax incentives).

Federal and State Statutes and Policies

Short-term wins

- The World Health Organization offers guidelines for the informal re-use of urine as a fertilizer.
- ISO and ANSI standards are being developed for new toilets and sanitation technologies.
- Research permits have been used as an initial avenue for pilot projects.
- Rich Earth Institute's project sets a precedent, and the permits are available as a reference to new projects.

2020 and Beyond

- Develop "How to" reference materials and "packaged presentations" to assist in the permitting processes at state and local levels.
- Acquiring organic certification for UDFs would increase marketability.
- Complete a policy brief for the green plumbing guide (IAPMO) and create professional training experiences for architects and plumbers.
- Convene a national team of experts to create new federal regulations distinguishing urine as a unique substance.

Public Perception and Education

Short-term wins

- The United Nations denoted November 19 as World Toilet Day beginning in 2013.
- Books including *the Humanure Handbook* by Joe Jenkins, *Liquid Gold:The Lore and Logic of Using Urine to Grow Plants* by Carol Steinfeld and *The Big Necessity* by Rose George have gained notoriety for early adopters across the US.
- Urine collection products currently on the market include the Pstyle and Pluto EZP festival urinals.
- Portable nutrient recovery toilets are being piloted in public settings in Vermont and Oregon.
- US advocacy groups include RECODE in Oregon, PEE Local in New Hampshire, Rich Earth Institute in Vermont, Eco Toilet Center in Massachusetts, and the People's Own Organic Power (POOP) Project in New York.
- An animation has been developed by New Water Resources. It features the character "Uri" to communicate key concepts about urine diversion in a humorous yet scientifically accurate light. Research is underway to test the animation's effectiveness in influencing attitudes and perceptions.
- Standardized terminology in this field is evolving as a growing body of research, media coverage and scientific publications supports urine diversion.
- Social research is being conducted in Vermont and Michigan to addresses public perceptions. Surveys, focus groups and interviews with key stakeholders will yield valuable insights about public concerns and attitudes. The interests and needs of farmers are being assessed so as to ensure that fertilizer products meet their needs.

2020 and Beyond - For Increased awareness:

- Build connections with local food and agriculture movements, environmental advocacy organizations, and social justice groups.
- Create curriculum for students in K-12 settings on the nutrient cycle and reclaiming nutrients through urine diversion.
- Spread awareness about diverse types of toilets and how to use them, as new products become available.

Section iii - Seven Critical Actions for Advancement

These seven actions are considered major milestones that need to be accomplished to normalize and advance the practice of urine diversion and reuse.

1. **Design improved source-separating toilets and urinals.**

2. **Develop the demand for and visibility of urine-diverting toilets through collaborations with architects, building owners and design engineers for large-scale buildings (dormitories, universities, "green" buildings).**

3. **Develop business models for the manufacture and marketing of urine-derived fertilizers, urine diverting toilets, waterless urinals, and source-separating portable toilets.**

4. **Identify multiple methods for collection and conveyance of urine (centralized, decentralized, and hybrid solutions).**

5. **Establish urine as a distinct substance for regulatory and certification purposes.**

6. **Complete social research on attitudes, values and beliefs of all stakeholders, and market research for urine-derived fertilizer products.**

7. **Research the long-term impact of urine-derived fertilizers on soil health, and produce guidance for farmers on the use and benefits of these fertilizers.**

Footnotes

1. Jönsson H, Vinnerås B, Höglund C, Stenström TA, Dalhammar G, Kirchmann H. 2000. Recycling source separated human urine. (Källsorterad humanurin). VA-Forsk Report 2000-1, VAV AB, Stockholm, Sweden. (In Swedish, English summary).

2. Höglund C. 2001. Evaluation of microbial health risks associated with the reuse of source separated human urine. PhD thesis, Department of Biotechnology, Royal Institute of Technology, Stockholm, Sweden.

3. Larsen T, Udert K, Lienert J. (Eds.) 2013. Source Separation and Decentralization for Wastewater Management. London UK. IWA Publishing.

4. Love NG. 2016. INFEWS/T3: Advancing Technologies and Improving Communication of Urine-Derived Fertilizers for Food Production within a Risk-Based Framework [abstract]. In: National Science Foundation Innovations at the Nexus of Food, Energy and Water Systems. Ann Arbor, Michigan. Abstract nr 1639244.

5. US Census Bureau. 2012. "2010 Census Urban and Rural Classification and Urban Area Criteria." 2010 Urban and Rural Classification - Geography - U.S. Census Bureau. www.census.gov/geo/reference/ua/urban-rural-2010.html

6. Rich Earth in the News. Brattleboro (VT): Rich Earth Institute; [accessed 28 Feb 2018.] www.richearthinstitute.org/publications/rich-earth-in-the-news/

Appendices

Appendix A: Lightning Talks

Selected summit participants give 5-8 minute lightning talks about their work.

2017

Heather Goetsch, PhD candidate, University of Michigan
Microbial Risks in Urine for Fertilizer Use

Daniella Saetta, PhD candidate Arizona State University
Nonwater Urinal Testbed of Urea Hydrolysis

Audrey Pallmeyer, MS candidate, University of Michigan,
Malavika Sahai, MS candidate University of Michigan;
Chris Askew, MS candidate, University of Michigan
National Science Foundation Social Research

David Cedarholm, consulting engineer, Tighe & Bond
PEE LOCAL, the Sitzpee, and other Innovations

William Tarpeh, Postdoctoral Research Fellow, University of Michigan
Novel Approaches to Recovering Nitrogen from Urine

Mina Aghababaei Shahrestani, PhD Candidate, University of New Hampshire
Life Cycle Analysis

Dylan Raye-Leonard, BA Candidate, University of Michigan
GG Brown Installation at University of Michigan

Ben Howard, MPA, Ohio State University
Policy Pathway - A Review of Land Application of Septage in Ohio

Ed Brands PhD, Associate Professor of Environmental Studies, University of Minnesota Morris
Wastewater Challenges in small Minnesota Communities

Bruce Southerland, Ejo Herza
Ejo Herza, A project in Rwanda

Enrique Rodriguez, MA Candidate University of Michigan
Urine Derived Fertilizer Tool

Karleen Kos, Executive Director, Portable Sanitation Association International
Report from the International Standards Organization

Eamon Twohig, Residuals Waste & Emerging Contaminants Program
of the Vermont Department of Environmental Conservation
Regulation, telling the Vermont story

Eric Roy, PhD, Assistant Professor of Environmental Sciences, University of Vermont
Nutrient Cycling - Mapping the Landscape

Appendix A: Lightning Talks

Selected summit participants give 5-8 minute lightning talks about their work.

2016

Lillian Volat, CEWAS Middle East
Emergency sanitation in Syria

Hilde Maingay and Earle Barnhart, The Green Center, Massachusetts
Cape Cod Eco-Toilet Project

Ali Gagnon, Hampton Roads Sanitation District, Virginia
Hampton Roads Sanitation District Urine Diversion and Struvite Production Project

Catherine Bryars, Regional Planner, Bennington, Vermont
Sanitation and Planners

Nic Mory, Las Verduras, Canada
Peeponics - An art installation in Montreal

Matthew Lippincott, RECODE, Oregon
Green Plumbing Code supplement for IAPMO (International Association of Plumbers and Mechanical Officers)

Heather Goetsch– PhD candidate, University of Michigan
EPA study - Microbes

Rachel Mullen, PhD Candidate, University at Buffalo
EPA study - chemistry results - pharmaceuticals in urine

Daniella Saetta and Hannah Ray, MS candidates Arizona State University
Urea hydrolysis

Abe Noe-Hays - Research Director, Rich Earth Institute
Reverse Osmosis - Creating a concentrated product

Tatiana Schreiber - PhD, Board Member, Rich Earth Institute
Rich Earth Institute's Social Research

Nancy Love - PhD, Borchardt and Glysson Collegiate Professor, University of Michigan
New National Science Foundation INFEWS project

Appendix A: Lightning Talks

Selected summit participants give 5-8 minute lightning talks about their work.

2015

Catherine Bryars, MRP Candidate, University of Massachusetts
Comparison of municipal-based promotion of sani-toilets versus non-profit

Treavor Boyer, PhD, Arizona State University
Urea hydrolysis reaction and urinals

Harold Leverenz, PhD, University of California, Davis
Ammonia recovery in hydrolyzed urine

Tamar Kohn, VUNA Project, South Africa
VUNA project in S. Africa

Krista Wigginton, PhD, University of Michigan
WERF pharmaceutical project overview

Ali Gagnon, Hampton Roads Sanitation District, Virginia
Hampton Roads Sanitation District and struvite production

Weiwei Mo, PhD. University of New Hampshire
Life Cycle Assessment of resource recovery from centralized wastewater treatment

David Cedarholm, consulting engineer, Tighe & Bond
The Peebus Project, bringing urine diversion to New Hampshire

Appendix B: 2017 Keynote Speaker, Tove Larsen

Tove Larsen is a chemical engineer with a PhD in process engineering from the Department of Environmental Science and Engineering, Technical University of Denmark. In 1999, she came to Eawag, the Swiss Federal Institute of Aquatic Science and Technology, to set up a cross-cutting project on urine source separation (Novaquatis). Novaquatis was successfully terminated in 2006 (www.novaquatis.eawag.ch) and won the swiss-academies award for transdisciplinary research in 2008 for its visionary, innovative and integrative approach to urban water management. At present Tove Larsen heads a group on "Concepts" in the Department of Urban Water Management at Eawag. Tove Larsen led the Eawag project "Diversion for safe sanitation," which won a special recognition price in the Reinvent The Toilet Challenge competition, launched by the Bill & Melinda Gates Foundation.

Her keynote can be viewed here.

Appendix C: Summit Participants 2017

Kneeling: Shawn Shafner, Carl Etnier, Tatiana Schreiber, Paige Bridgens, David Cedarholm, Earle Barnhart, Catherine Bryars, Dan Marks

First Row: Neil Patel, Mina Aghababaei, William Tarpeh, Karleen Kos, Audrey Pallmeyer, Daniella Saetta, Heather Goetsch, Hannah Ray, Enrique Rodrigues, Nancy Love, Kim Nace, Tove Larsen, Rosa Olivan-Pliego, Melissa Hays, Malavika Sahai, Conor Lally, Phoebe Gooding

Back Row: Dylan Raye-Leonard, Ngai-Yin Yip, Stephen Hilton, Jed Blume, Ellena Baum, Lowell Howard, Richard Hauck, Barry Gutwein, Parker Cornbrooks, Ben Goldberg, Nadav Malin, Eric Roy, Amelia Luna, Ed Brands, Chris Askew-Merwin

Not pictured: Abe Noe-Hays, Glynis Berry, Hideaki Ariizumi, Lauren Bomeisl

Appendix C: Summit Participants 2016

Kneeling: Dan Marks, Tatiana Schreiber, Earle Barnhart, Shawn Shafner, Iishana Aartra, David Cedarholm

First Row: Phoebe Gooding, Weiwei Mo, Hannah Ray, Alena Warren, Daniella Saetta, Hilde Maingay, Abraham Noe-Hays, Kim Nace, Rachel Mullen, Lillian Volat, Heather Goetsch, John Hatton

Back Row: Harold Leverenz, Ben Goldberg, Conor Lally, Neil Patel, Nadav Malin, Mathew Lippincott, Nancy Love, Konrad Scheltema, Nicolas Mory, Bojana Koleravik, Eric Roy

Appendix C: Summit Participants 2015

Kneeling: Dan Marks, David Cedarholm, Daniel Michael

Standing: Neil Patel, Nancy Love, Abraham Noe-Hays, Kim Nace, Krista Wigginton, Alexandra Gagnon, Trevor Boyer, Konrad Scheltema, Tamar Kohn, Lola Olabode, Harold Leverenz