Farmer Guide to Fertilizing with Urine

Version 1.0

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Our Vision

A world with clean water and fertile soil achieved by reclaiming the nutrients from our bodies as elements in a life sustaining cycle.

Our Mission

The Rich Earth Institute engages in research, education and technological innovation to advance the use of human waste as a resource.

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INTRODUCTION

Farmers around the world have harnessed the fertilizing power of human urine for millennia. In recent years, interest in urine nutrient reclamation has been surging, driven by spiking synthetic fertilizer prices, global supply disruptions, and increasing regulations on aquatic nutrient pollution.

The Rich Earth Institute has been researching the production and use of fertilizer derived from human urine since 2012. It operates the first urine nutrient reclamation program in the United States, providing over 12,000 gallons of urine-derived fertilizer to local farmer partners each year. Rich Earth is now facilitating the creation of new urine nutrient reclamation programs in other communities.

Get In Touch!

Interested in learning more about fertilizing with urine? Rich Earth can support farmers with urine fertilizer application methods and rates. Rich Earth also invites farmers practicing urine fertilization to reach out and share their experiences and contribute to this growing body of knowledge. Contact us at info@richearthinstitute.org or complete our surveys (*on page 22**)*

This guide is primarily intended for farmers interested in partnering with established urine reclamation projects. If you are interested in establishing your own urine collection system, please visit Rich Earth's Guide to Starting a Community-Scale Urine[1] Diversion Project. For guidance working with urine fertilizer at the home garden scale, visit Rich Earth's Guide to Using Urine Fertilizer for Home Gardens.[2]

This guide compiles information and best practices from Rich Earth's research with farmer-partners in Southern Vermont, as well as the literature from a growing community of researchers and farmers around the world who are reconnecting links in the food nutrient cycle.

REGULATION

Rich Earth Institute has worked with Vermont regulators to make the farm-scale application of urine fertilizer permissible in Vermont. Currently, the Vermont Department of Environmental Conservation (VT DEC) regulates Rich Earth Institute's pasteurized urine fertilizer as a unique material that is separate from biosolids, but has many of the same testing requirements and pathogen reduction methods.

The Rich Earth Institute holds a Solid Waste Management permit from the VT DEC that allows us to process and distribute urine to farmers and gardeners for general use as a soil amendment. Regulations vary from state to state, and we have supported others in obtaining the necessary regulatory approvals in Vermont and other states. **The Rich Earth Institute can provide assistance for farmers to work with local and state regulators to identify and obtain approval for use of urine in agriculture.**

FOOD SAFETY MODERNIZATION ACT

The federal Food Safety Modernization Act (FSMA) is focused on preventing pathogen contamination of food crops. The Produce Safety (PSR) rule of the FSMA regulates what type of human waste-derived fertilizers may be used on commercial farms to grow **produce that is generally eaten raw** (like tomatoes or summer squash).[3] How this relates to urine-derived fertilizer is clear in some cases and less clear in others.

The FSMA-PSR is very clear that it does not apply to non-produce crops like grains or hay, or produce not generally eaten raw like sweet corn or potatoes. Furthermore, farms that sell produce that is generally eaten raw, but that sell less than a certain dollar value of produce annually (approximately $31,000 in 2024), are exempt from the FSMA-PSR.[4]

Therefore the following activities are exempt from the FSMA/PSR:

- Using urine to fertilize non-produce crops (like grains or hay)
- Using urine to fertilize produce not generally eaten raw (like sweet corn, potatoes)
- Using urine to fertilize any crops (including produce generally eaten raw) on farms selling less than a certain amount of produce per year (about $31,000 in 2024)
- Using urine to fertilize produce for personal consumption only

In contrast, farms must comply with the FSMA-PSR if both of the following are true: **1)** they sell produce that is generally eaten raw, and **2)** they sell more than the cut-off dollar-value of produce of any kind. In this case, the only human waste-derived fertilizer that is allowed to be used for growing produce that is generally eaten raw is "sewage sludge biosolids used in accordance with the requirements of 40 CFR part 503, subpart D, or equivalent regulatory requirements." Whether sanitized urine is allowed in this case is somewhat ambiguous, because some regulators may consider pasteurized urine to be a biosolid, (and therefore allowed,) while others may not consider urine to be a biosolid at all (and therefore technically not allowable), even if it is processed using the same pathogen destruction method.

Please feel free to contact the Rich Earth Institute for updated information on this topic.

Please note that this section represents our best understanding of the FSMA/PSR, but we are not experts in this area. Online resources such as this tool from the University of Massachusetts can help you understand these regulations in more detail.

ORGANIC CERTIFICATION

Is urine an allowable amendment on organic farms?

As of this writing, urine is neither explicitly allowed, nor explicitly prohibited by the United States Department of Agriculture (USDA) National Organic Program (NOP) for use on certified organic farms. Therefore, it is within the purview of each state's certifying agency to make that determination.

The NOP does prohibit the use of "sewage sludge" on certified organic farms. However, there is a strong argument that urine diverted from the waste stream is not sewage sludge, because it is not a residue of wastewater treatment. The Vermont Department of Environmental Conservation classifies the urine that Rich Earth processes as a distinctly different product than "biosolids." Rich Earth is working with regulators and others to clarify this situation.

SAFETY

SANITIZATION

Urine is typically very low in pathogens (though not truly sterile). The primary pathogen risk in working with diverted urine is from fecal cross-contamination.

For home-scale urine fertilization, World Health Organization[5] guidelines clarify that treatment is not necessary prior to application, though certain handling and use guidelines are recommended, as detailed in our Guide to Urine Fertilizer in Home Gardens.

Beyond the scale of a single home, it is important to implement a pathogen management strategy. The following are two commonly used treatment methods:

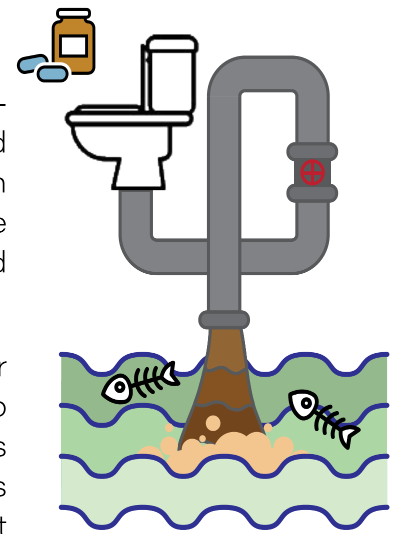
Storage: The simplest treatment method available today for pathogen reduction is storage in a sealed container at 68°F or higher for one to six months, depending on the intended use.[6] This allows time for pathogens to be destroyed by the high pH and high ammonia levels found in stored urine. This method is recommended by the United Nations World Health Organization, but is not recognized by the EPA as a standard method for treatment. After applying for special permission from the VT DEC, we have received short-term permits (now expired) to use this method for treating urine for fertilizing hay.

Pasteurization: Pasteurization kills pathogens with heat. The primary advantages of pasteurization over long-term storage are speed, ability to operate in cool weather, and official recognition by the US EPA and state environmental departments as an approved method for destroying pathogens in human waste. This is the method the Rich Earth Institute currently uses for treating all of our urine under a long-term permit from VT DEC. Rich Earth Institute's spin-off company, Brightwater Tools, sells a patented urine pasteurizer that heats urine to 176°F degrees for about 1.5 minutes and meets the EPA 40 CFR part 503 standards for the use or disposal of sewage sludge.

HEAVY METALS

Heavy metals are low to non-detectable in urine; amounts are much lower than some other common fertilizers, such as commercial phosphate fertilizers, manure, and biosolids.[7]

PHARMACEUTICALS



Urine can contain pharmaceutical residues. When we flush urine into wastewater treatment systems, many of these chemical compounds are not removed by the treatment process and accumulate in downstream water bodies, with disruptive effects on the species who live there.[8] By diverting urine from the wastewater stream, we can protect these sensitive aquatic ecosystems and water supplies.

When urine is applied to the soil as a fertilizer, our own research and a number of other studies have found that pharmaceuticals do not accumulate in crop tissues at significant levels.[9, 10, 11, 12, 13] A Rich Earth study of urine-fertilized carrots and lettuce found extremely small levels—in the nanogram per gram (or parts per billion) range—of pharmaceuticals in plant tissue.[14] Caffeine was the most abundant drug we detected in human urine, but it was present in such tiny amounts in urine-fertilized lettuce that a person would have to eat a pound of the lettuce every day for over 1,000 years in order to ingest the equivalent of one large cup of coffee. The levels of other pharmaceutical compounds (including antibiotics, over-the-counter anti inflammatories, and other drugs found in significant concentration in wastewater), were comparable to or even lower than this.

With regard to antibiotics, there can be concern that antibiotics in urine may lead to the development of antibiotic resistant bacteria. Sanitizing urine through pasteurization, or 6 months of storage, can ensure that those bacteria are killed.[15] When they die, the released DNA doesn't appear to transfer resistance genes to bacteria in the soil when the fertilizer is applied.[16]

Rich Earth currently does not have data on the effect of antibiotics on soil microbes. The low levels of pharmaceuticals found in urine-fertilized crops may be attributed to soil microbial activity, which research findings suggest may be helping to break down the pharmaceuticals.[17, 18, 19] Rich Earth is now conducting research to better understand how urine fertilization affects soil microbial communities.

As just explained, the pharmaceuticals in urine do not appear to pose a problem. That said, there are methods that can be used to reduce the level of pharmaceuticals in urine before it is used as fertilizer. Researchers at Rich Earth and elsewhere have tested activated carbon filtration as an additional filtration treatment step for urine, and it is able to remove most of the residual pharmaceuticals from urine.[20,21]

PFAS

Some levels of PFAS may be present in urine, since they are common in human blood and leave the body slowly over time, mostly through urine.[22] A study of highly exposed individuals found an average PFOA concentration of 27 ng/L in urine.[23] Recent third-party testing of urine collected through two community-scale programs in Vermont (operated by Rich Earth Institute and by Wasted*) revealed no detectable PFOA, PFOS, or other regulated PFAS compounds.

Rich Earth is currently researching activated carbon filtration, which can be used to significantly reduce PFAS levels in urine.

CHARACTERISTICS OF URINE FERTILIZER

This guide describes on-farm applications of sanitized urine with no further treatment. Additional processing options can create custom fertilizers, such as struvite, dehydrated alkalized urine, and concentrated nitrified urine.[24]

NUTRIENT CONTENT

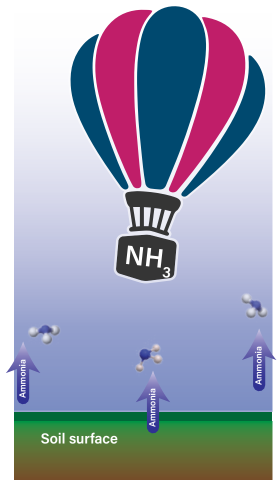
Urine is rich in macronutrients, including nitrogen, phosphorus and potassium, as well as secondary and micronutrients. As a nitrogen-rich fertilizer, urine is generally applied in amounts needed to meet the nitrogen needs of plants. **Contact Rich Earth Institute for support calculating application rates for urine fertilizer.**

The NPK fertilizer value of urine varies, but based on analysis of Rich Earth's stored urine, it is roughly 0.6 - 0.1 - 0.2. Rich Earth has worked with university extension soil labs to test our urine for nutrients and heavy metals using their manure analysis packages. If urine is collected using urine-diverting flush toilets, substantial flush water may dilute the urine, resulting in lower concentrations.

Nutrient	lbs/100 gallons of urine	%
Nitrogen	4.8	0.57
Phosphorus (as P2O5)	0.69	0.082
Potassium (as K2O)	1.6	0.19
Sulfur	0.37	0.044
Calcium	0.019	0.0023
Magnesium	0.0059	0.00071
Boron	0.0016	0.00019
Zinc	0.00025	0.00003
Iron	0.00017	0.00002
Copper	0.00017	0.00002
Sodium	1.2	0.15

Table 1: *typical concentrations of nutrients in urine*

AMMONIA VOLATILIZATION



The main form of nitrogen in urine is urea, which is naturally converted to ammonia once it leaves the body. Ammonia is highly volatile, meaning it can easily evaporate out of the urine as ammonia gas when stored in an unsealed container.

To prevent ammonia volatilization from occurring—and retain the nitrogen content of your urine fertilizer—it is important to take care when storing urine and when applying it to soil. This can be done through storing urine in airtight containers, minimizing spraying during application, and integrating urine into the soil.

SALT ACCUMULATION

Urine contains significant levels of salt, but this isn't generally a problem for outdoor farmers in humid climates, including the Northeast. In these climates, annual precipitation is greater than soil evaporation, with the result that rainwater/snowmelt will wash the salts out of the topsoil, preventing buildup of salt in the root zone.[25]

However, if you are growing in an enclosed environment, like a greenhouse, or in an arid or semi-arid region, build-up of salts is a potential concern. We do not yet have recommendations for using urine in these environments. If you want to try it, be sure to monitor your soil for salt accumulation. If salt becomes a problem, you can periodically flush the soil with water through irrigation or a sprinkler system to correct it.[26, 27]

EFFECT ON SOIL PH

Urine is an ammonia-based fertilizer, and soil science suggests that adding ammonia to soil will either: **1)** have no lasting effect on pH if plants absorb and utilize all the nitrogen from the fertilizer [28, 29, 30] or **2)** cause a drop in pH if a substantial portion of the nitrogen leaches out of the soil before it can be absorbed by the crop, due to excess irrigation or rainfall.[31, 32, 33] These effects are related to the natural soil process that converts ammonia into nitrate, and is explained in the footnoted references.

APPLICATION METHODS

As with all fertilizers, application of the right amount, at the right time, and in the right location is essential to minimize nutrient losses to the environment.[34] Because the nutrients in urine are soluble and readily plant-available, it is important to apply urine during the period when the crop is actively taking up nutrients. Otherwise, significant amounts of nutrients (especially the nitrogen) may be lost, negating all of your hard work! When possible, smaller applications applied with greater frequency will lead to greater nutrient retention.

> *At Rich Earth*
>
> *For partnering farms growing hay, Rich Earth applies 1000 gallons of urine per acre, providing 50 lbs. nitrogen/acre. If multiple cuttings of hay is made per year, an equal number of 1000-gallon applications can be made.*

CALCULATING APPLICATION RATES

Farmers and gardeners can use urine's typical NPK analysis of 0.6 - 0.1 - 0.2 to calculate appropriate application per acre or per square foot for different crops, using published guidelines for specific crops.[35] (See **"Table 1: typical concentrations of nutrients in urine"** above for a list of typical concentrations of macro and micronutrients.) For more accurate results, submit a sample of the urine you will be applying to an extension laboratory for analysis. If available, chose the TKN method for nitrogen analysis.

Soil testing: An inexpensive soil test from your Extension service will tell you how much N, P, K, and other nutrients you need to add to your soil for the specific crops you are growing. It will recommend how many pounds of each nutrient to apply per acre or per 1,000 ft^2 per year. You can then calculate how much urine it will take to satisfy your crop's fertilizer needs and apply that amount. Ideally, make several small applications over the growing season, rather than one large one.

Because there is more nitrogen in urine than any other nutrient, in most cases you should use the nitrogen recommendation to calculate your application rate. If this amount of urine does not supply enough potassium or phosphorus, you can add compost, mineral fertilizer, wood ash, or other fertilizer products.

Amount of urine to apply (gallons/acre) = N target (lbs/acre) / % Nitrogen x 100

One uncommon exception could occur if: **1)** you are growing a nitrogen-hungry crop that requires little phosphorus, and **2)** your soil contains high or excessive levels of phosphorus. In that case, you should be careful that the urine and other amendments you are applying do not add more phosphorus than the crop will remove, because that would result in your soil phosphorus levels growing even higher. Calculate: **1)** the amount of phosphorus that your crop will remove, (consult your extensionist if needed,) and **2)** the total phosphorus that you will be adding through urine and any other amendments. If the phosphorus added by amendments is higher than the phosphorus removed by the crop, reduce the amount of urine or other amendments accordingly. You can then supplement with phosphorus-free fertilizers like urea to meet your nitrogen goals. **Please note** that while urine contains both nitrogen and phosphorus, it actually has a much higher N:P ratio than most manures and composts, meaning that overapplication of phosphorus is a much less of an issue with urine fertilizer than with manure or compost than with urine fertilizer.

Most recommendation rates are for the entire growing season, but it's best if you can split your urine application into several smaller applications while the plants are growing. So don't forget to divide your total application amount by the number of times you plan to fertilize during the growing season.

APPLICATION TIMING

Nutrients in urine are plant-available and, like other quick-release fertilizers, should be applied most heavily as plants begin their period of rapid vegetative growth.

At Rich Earth:

The majority of Rich Earth's partnering farmers apply urine to hayfields. Application is typically done shortly after the first cutting is harvested, though some farmers apply it before the first cutting in the spring. Rich Earth has also at times applied urine in the late fall due to limited storage capacity. Fall application is best avoided unless it is necessary due to limited storage, due to the potential for large nitrate leaching losses over the winter. If urine must be applied in the fall, wait until the soil temperature has reached a steady 50°F and is trending lower, because the ammonia in aged urine binds to the cold soil and does not convert to the more-easily-leached nitrate until the soil warms again in the spring. Avoid applying urine to frozen ground.[36]

DILUTION

If urine fertilizer is applied with care, it is not necessary to dilute it with water beforehand. Rich Earth's farmer partners generally apply urine full-strength, without dilution. However, dilution can be helpful in some contexts to prevent over-fertilization, to avoid stressing sensitive plants, and to facilitate incorporation into the ground, especially in dry soil. Urine fertilizer can also be applied prior to irrigation, or before or during rain, to achieve the same effect. If dilution is desired, suggested dilution ratios range from 1:1 to 1:10, depending on the fertilization context and the dryness of the soil.

Research conducted by Rich Earth for fertilization of second-cut hay tested applications of undiluted urine, urine diluted 1:1, and urine diluted 1:3 (urine:water ratios) and found no significant effect on yields.[37]

APPLICATION EQUIPMENT

Urine fertilizer can be applied using existing, modified, or custom-design equipment, depending on the context.

Applicator Design Tips

Application equipment should apply urine to the ground surface as directly as possible to prevent ammonia volatilization. Significant amounts of ammonia can be lost from urine through volatilization if it is allowed to evaporate into the air during application. Ammonia volatilization can be reduced by incorporating the urine directly in the soil immediately after application, either via tilling, pouring urine into a furrow and covering it, watering the urine in directly after application, or distributing urine along with water through an irrigation system. In general, applicators should pour or drip, instead of producing fine droplets that evaporate quickly.

An inexpensive, simple applicator for a small amount of urine could consist simply of a 250-gallon IBC tote on a trailer, plumbed to a perforated pipe for a spreader boom.

A design limitation of such a gravity-driven system is that flow can be uneven, with the flow rate decreasing as the tank level drops, and uneven flow from the two ends of the boom when driving across sloped land. Locating the tank as high as possible and the boom as low as possible reduces this issue by increasing the operating pressure. Applicators that incorporate a pump can avoid this issue by delivering urine to the spreader boom at a constant flow rate and pressure. The pump should be corrosion-resistant (e.g. either plastic or stainless steel).

Liquid manure injection equipment could be used to further reduce ammonia losses from unstabilized urine. Injection equipment uses disks or tines to create furrows in the ground, and hoses to apply liquid directly into each furrow. Different types of equipment are available, including shallow, deep, and partial injection ("trailing shoe"), which have advantages and disadvantages for different soils and different crops. We have never used broadcast liquid manure spreaders, because ammonia losses and odors would probably be very high.

On-farm logistics are improved by locating storage tanks uphill so that the applicator tank can be gravity-fed rather than requiring a pump.

Rich Earth's Custom Field Applicator

For Rich Earth's hay farm partners, urine is applied using a purpose-built urine applicator consisting of a 500-gallon trailer tank plumbed to a transverse, perforated boom, mounted on a tractor or horse-driven trailer. An electric valve between the tank and boom allows the driver to easily initiate or shut off flow when the applicator reaches the end of the field. (see **"Figure 1. A schematic of the Rich Earth Institute's custom field applicator."**)

While Rich Earth has mainly used this system for hayfields over the last decade, there are other potential uses for row crops as well. Rich Earth has used this applicator on four-foot-wide beds of nursery trees. The booms on the applicator can be designed to deliver urine to crop rows, while avoiding the aisles between the rows.

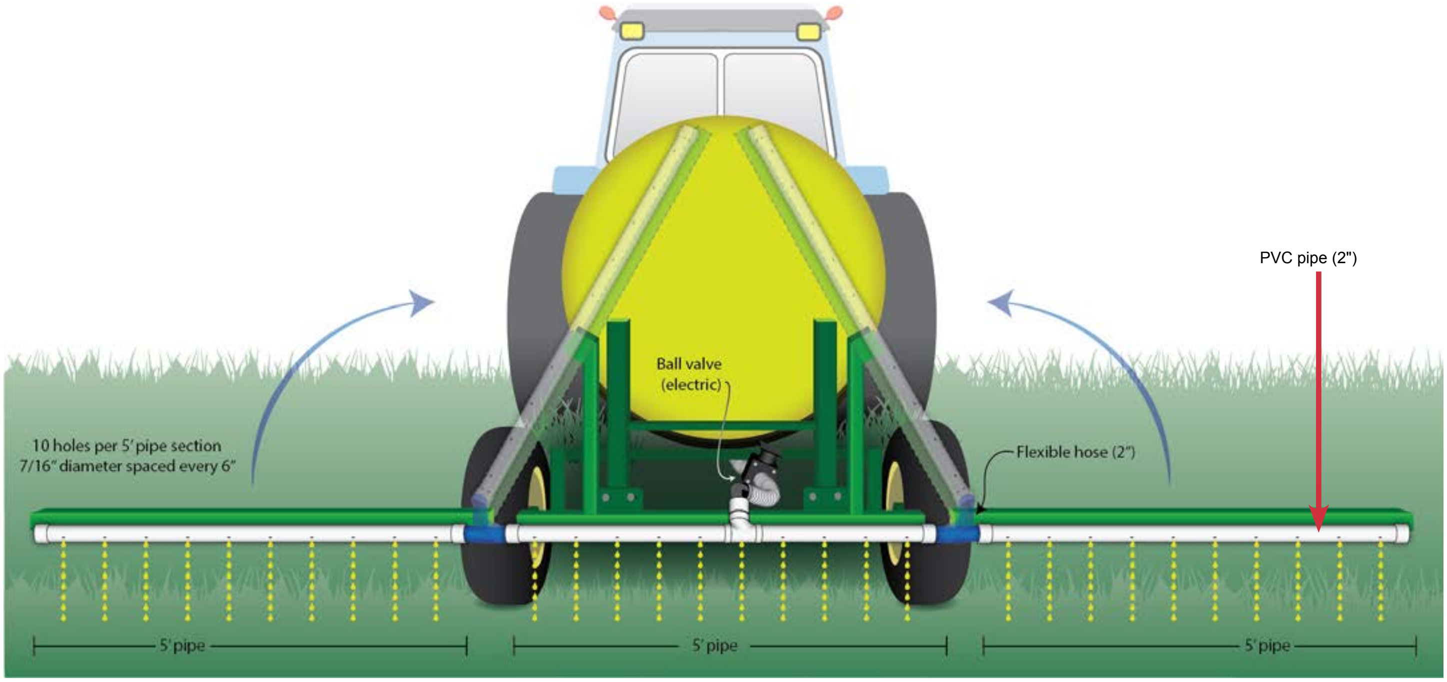


Figure 1. *A schematic of the Rich Earth Institute's custom field applicator.*

Figure 2: *A tractor pulls the Rich Earth applicator, fertilizing a hay field.*

Figure 3: *Side view of the Rich Earth applicator applying urine on a hay field.*

Figure 4: *The Rich Earth applicator with one boom retracted, delivering urine to a bed of nurserytrees at Yellowbud Farm.*

Figure 5: *A modified tractor with a tank attached to a 3-point hitch applies urine while cultivating corn rows at Pete's Stand.*

Modified Equipment

Efficient row crop fertilization can be achieved by integrating a urine fertilization design into equipment that will already be passing over a field for another purpose. Rich Earth demonstrated this practice with John Janiszyn of Pete's Stand, who grows sweet corn at a field in Westminster, VT. Around the time that the corn is ready for nitrogen fertilizer, Janiszyn also goes through the field to cultivate the rows. To adapt his equipment, we attached a tank to the 3-point hitch on the tractor and set up a hose that terminated close to the ground just in front of the cultivating tines (see **"Figure 5: A modified tractor with a tank attached to a 3-point hitch applies urine while cultivating corn rows at Pete's Stand."**). As the tractor drove down the row, the urine poured onto the row and was immediately covered up by soil hilled into the row by the cultivating tines.

Another design could be to use an IBC tank on the forks of a tractor. IBC tanks are common and inexpensive and also have a built-in valve at the bottom of the tank.

Plastic Mulch

Farmers growing crops under plastic mulch could apply urine after tilling or other method of field preparation but right before laying down the plastic mulch rows. This method could trap the nitrogen in the soil under the plastic, leaving it available for the plants that are transplanted into the rows. Rich Earth has trialed this method with Janiszyn. As can be seen in **Figure 6**, an IBC tote of pasteurized urine was positioned on the forks of the tractor, and the plastic layer hooked up to the rear of the tractor. The bottom valve of the IBC tote was opened, and as the tractor moved through the field the urine was deposited on the ground, and then immediately covered with soil and plastic sheeting. A few days later, Janiszyn planted pumpkin seedlings in these rows.

To achieve the desired fertilizer application rate, a test was performed to determine the flow rate of the liquid coming out of the tank. Using this flow rate, the width of the row, the nitrogen content of the urine, and the speed of the tractor when laying plastic, a calculation was made to determine the correct amount of urine and water to add to the tank in order to achieve the target nitrogen application rate.

This method could be modified using a pump instead of gravity flow. Depending on the desired fertilizer application rate, urine could be diluted as just described, or pre-concentrated urine could be used for higher application rates.

Janiszyn said that he has done a similar process before when he needed to lay plastic over dry soil. In those cases, he said he has filled the IBC tote with water to moisten the soil, and has often added some liquid fertilizer as well. This use case seems a great fit for urine fertilizer, involving only minor modification of the farm's existing practices.

Figure 6. *A tractor carries an IBC tote of urine fertilizer on forks while pulling a plastic layer from the rear*

Fertigation

Fertigation is the application of soluble fertilizers to crops through an irrigation system. Fertigation using drip irrigation systems has special promise with urine fertilization because it:

- Incorporates the fertilizer into the soil, greatly reducing ammonia volatilization potential
- Combines fertilization with an existing process, reducing labor demands
- Avoids compaction caused by tractor-based application
- Allows multiple small, precise fertilization applications, matched to crop needs and field conditions, potentially reducing nitrogen run-off and leaching
- Uses standard and widely-used agricultural equipment

One potential challenge of fertigation with urine is that if the irrigation water is too hard, the minerals it contains can react with the urine to create solid deposits can clog drip emitters. Rich Earth has conducted both controlled experiments and on-farm field trials **(Figures 7** and **8)** using fertigation methods.[38] The fertigation trial looked at the effect of fertigation using sanitized urine fertilizer and water of different hardness levels to see if clogging of emitters in the drip irrigation equipment was a problem. Two methods of fertigation were tested: **1)** injecting urine and water into the irrigation simultaneously to create a mixture within the irrigation system (mixing method), and **2)** supplying pure water, followed by urine, followed by pure water to the irrigation system (alternating method) in order to minimize the amount of mixing of urine and water and thereby minimize precipitation of solids that could clog the emitters. These trials showed that with standard drip tape, at a water hardness of 124 PPM (classified as "hard" water by USGS), no decrease in flow rate due to clogging was observed with either the mixing method nor the alternating method. However, when the water hardness was increased to 255 PPM (very hard water), a decrease in flow rate due to clogging was seen when using the mixing method. However, the alternating method did not result in observable clogging, indicating that fertigation using very hard water and urine can be successful if the alternating method is used. For best results, it is important to use an inline screen filter as recommended by the drip tape or emitter manufacturer.

This trial showed that urine can successfully be delivered via fertigation either by mixing it with irrigation water or by delivering it in an alternating fashion with the irrigation water and that measuring the hardness of water to be used can be useful in determining the method of delivery of urine into the irrigation system.

Figure 7. *An on-farm fertigation system using urine fertilizer.*

Figure 8. *Pouring pasteurized urine into a barrel connected to a drip irrigation line.*

COMBINING WITH OTHER AMENDMENTS

Bioacidification (Fermentation with Whey)

As described earlier, the ammonia in urine can volatilize if application conditions are not ideal. One way to reduce ammonia volatilization is to acidify (lower the pH of) the urine before it is applied to the field. This can be done through fermentation. Organic acid byproducts of fermentation naturally acidify the urine such that more of the volatile ammonia is converted to non-volatile ammonium. Exploratory research by the Rich Earth Institute used additions of sweet whey and acid whey (waste products from the local dairy industry) to ferment and acidify urine, finding that nitrogen retention in acidified urine increased with the amount of whey added. However, it may not be practical to add large volumes of whey to stored urine, and trials found low rates of acid whey addition at 1:16 and 1:8 by volume resulted in the greatest nitrogen retention per unit of whey additive in urine, significantly reducing nitrogen loss compared to non-acidified urine. The trials also demonstrated that urine fermented at lower temperatures was slower to acidify than urine stored at high temperatures. It is also important to note that the bio-acidification of urine (which does not contain many bacteria) is greatly enhanced by the addition of a starter culture, such as a probiotic pill, to inoculate the fermentation.[39]

Compost

Farmers who are not able to store or apply liquid urine, or who prefer to apply compost instead of soluble nutrients, may choose to use urine as an ingredient for making compost, rather than applying it directly to the soil as a liquid fertilizer.

Adding urine to a compost pile increases the nitrogen content in the compost and accelerates the composting process. If the compost pile is made of high-carbon (aka low-nitrogen) materials such as dead leaves, straw, paper, or sawdust, then the addition of nitrogen from urine can help the pile heat up and compost more rapidly, and result in a nitrogen-enriched finished compost. On the other hand, if the compost is mostly high-nitrogen material like food scraps, green plant matter, or manure, then it may already have ideal or excessive nitrogen levels, in which case adding urine will result in nitrogen loss. The nitrogen content of compost is hard to estimate by eye, and manures can range greatly in their nitrogen content, especially when mixed with bedding. An inexpensive laboratory analysis (available through extension services) is an excellent way to determine if a compost pile could benefit from added nitrogen, in which case adding urine would help improve the composting process.

Rich Earth Institute has conducted lab-scale and small-scale compost pile experiments, in which we tested compost recipes using urine + hardwood leaves, or urine + horse manure + wood shavings. In all cases, urine was added to the solid ingredients until they would not hold any more liquid. Then they were composted at temperatures between 30 and 55°C.

Both approaches (composting urine with leaves or with a manure/shavings mixture) were shown to be viable methods for creating nitrogen-enhanced compost with safe ammonia and salinity levels.[40, 41] However, the ratio of urine used in the recipes had a large effect on the characteristics of the resulting compost. For instance, dry leaves (11% moisture) were able to absorb and hold large volumes of urine, and the resulting compost contained high levels of ammonia (up to 9,000 mg/kg), and about 3.5% total nitrogen (dry basis). While this compost contained an exceptional amount of nitrogen, the high ammonia levels could potentially be problematic. On the other hand, when damp leaves were used (60% moisture), the ammonia level in the final compost was low (below 200 mg/L), while nitrogen content was still relatively high at 2% (dry basis). These values are in line with typical mature compost. Therefore, when co-composting urine with very dry leaves, care should be taken to not add too much urine, but if leaves are damp (60% moisture) to begin with, urine can be added up to the holding capacity of the leaves.

When making compost with urine, it is also best to be cautious with recipes that primarily consist of slow-degrading high-carbon ingredients such as wood shavings or shredded paper. Because the nitrogen in the urine is highly available, it pairs best with a fast-degrading carbon source like leaves, otherwise high ammonia losses are likely. In Rich Earth's trials, results using leaves were excellent, but results using wood shavings were only good when shavings were combined with substantial amounts of horse manure.

Urine may also be applied to fields as a complement to traditional compost applications. In this case, the compost can build soil structure and supply a variety of slow-release soil nutrients, while urine supplies immediately-available nutrients (especially nitrogen) at the time of application.

Biochar

Amending agricultural soils with biochar is known to improve soil properties including increasing soil water retention[42, 43, 44] cation exchange capacity,[45] and soil pH.[46] It can also decrease nitrogen and phosphorus leaching,[47] increase nitrogen utilization efficiency[48] and reduce ammonia volatilization.[49]

Biochar can be 'charged' or 'inoculated' with plant nutrients prior to application to soils, can increase fertility, and minimize nutrient immobilization. Poultry litter slurry has been tested as a biochar inoculant, resulting in increased soil nutrient retention,[50] and human urine has been proposed.[51]

Other Combinations

Growers have explored combining urine with other amendments not yet studied in a formal capacity. Enriching a straw bale[52] or wood chip pile with urine fertilizer can accelerate the decomposition process and feed soil microbes. Sheep wool[53] (used as a soil amendment to retain moisture and release nitrogen through its decomposition) can also be combined with urine fertilizer. If you experiment with these combinations, it is important to keep in mind guidance about reducing ammonia volatilization detailed earlier in this guide.

URINE FERTILIZATION EXPERIENCES WITH SPECIFIC CROPS

Studies across the globe demonstrate that urine fertilization produces yields on par with synthetic fertilization across many crops, listed in the table below. Urine fertilization of cucumbers, okra, and grain have even been shown to increase yields relative to synthetically-fertilized crops.

Crops where urine fertilization produced yields on par with synthetic fertilization
Amaranth[62]
Cabbage[63, 64, 65, 66]
Corn[67, 68, 69, 70, 71, 72]
Cucumbers[73]
Straw[74]
Barley[75]
Hay[76]
Okra[77]
Rice[78]
Tomato[79]

Yet the effectiveness of urine fertilization may vary across environmental conditions. Some studies found no improvement to okra[54] or bean[55] growth from urine application, though the latter example may be attributed to the low nitrogen needs of beans. Another study found urine fertilization to increase cabbage yield in some locations but not others.[56] In instances where yield is not increased by urine fertilization, improvements to other plant traits such as leaf number, plant height, and stem diameter have been found.[57]

Regions with climates similar to New England, such as Finland and Copenhagen, have demonstrated successful use of urine fertilization on crops including barley, cabbage, cucumbers, and grains.[58, 59, 60, 61]

AT RICH EARTH

Rich Earth has conducted the only known field studies of human urine fertilizer in the US Northeast region.

Below we describe our research with local farmer partners, including controlled hay trials and qualitative trials with hemp, sweet corn, figs, cut flowers, and nursery trees.[80] All farmer-partners reported observations indicating positive results from their experiments, with either comparable or better yields and/or robustness from their urine treated plants.

Hay

Rich Earth's multi-year controlled trials found no significant difference between hay yields when using urine fertilizer or synthetic fertilizer to grow second cut hay.[81, 82] In addition to yield, the relative feed value was also maintained across urine and synthetic fertilization regimes, ranging from 105 to 108.[83] Fairwinds Farm and Wild Carrot Farm (which share hayfields) apply only human urine and animal manure and no other amendments.

Fairwinds Farm was Rich Earth's first farm partner, and has been fertilizing their hay field with urine for the past 11 years, as a supplement to their use of manure. Jay Bailey believes the urine has increased hay yields considerably, enabling a second cutting without depleting soil nutrients. "*Putting [urine] on a healthy field that has good strong plants in it, you can increase your yield, vastly. [It allows you to] take significantly greater volume of feed off the field...without taking away from the health of the plants."* Bailey also believes that, over time, continuing to feed the plants with urine will likely increase the nutrient bank in the soil because *"with the urine, if it's producing more top growth, it's probably also producing more root growth, and that's what would change the soil."*

Wild Carrot Farm, owner Jesse Kayan says, *"Our farm uses land that has been the recipient of Rich Earth's urine applications for many years now. Having used their product as fertilizer on our small, diversified farm we have had the opportunity to experience the benefits of this system directly. As a result of past destructive practices, our hay land is fragile and low-yielding. Over the several years the Rich Earth Institute has applied urine, we have watched our yields increase dramatically. As a result, we can now make a whole additional cutting of hay each season, increasing our productivity and profits. The urine has not only increased our land's value, it has helped make significant improvements to the soil's fertility and resilience. We feel extremely good to be building our soil while removing a pollutant from the waste stream."*

At Elm Lea Farm, Pete Stickney applied dairy manure to his entire hay field and then applied urine to one side only of the field at an estimated rate of 40 lbs/acre of nitrogen, leaving the other side as a manure-only control. Stickney observed that first cut hay was darker and more lush when fertilized with urine and manure, rather than manure only. He noted that his cows found both equally palatable.[84] His qualitative assessment of yield, based on the size of the windrows after haying, was an approximate 20% higher yield for the urine-treated field after the first cutting. He noted that the improved yield and green color he observed from his one application did not carry over into his second cutting, so he felt a second (and potentially even a third and a fourth) application would be valuable. Stickney is also interested in adding urine to his barnyard/wastewater lagoon, and then using this urine-enhanced water for fertigation in the future.

Hemp

Rich Earth worked with hemp farmer **Adam Hubbard** to utilize a fertigation system for urine application, and trialed urine in two dosage amounts compared to Hubbard's usual soy-based organic fertilizer. He found the application method worked well, noting that *"the urine is much easier for me to use ... I have an organic fertilizer that is a powdered form, and it's water soluble, so I mix up batches, and then inject it into my irrigation line, and apply it that way, whereas the urine fertilizer was very convenient for use, because it was pretty stable in its barrel over a period of time."* His usual fertilizer was not as stable, and needed to be re-mixed prior to each application. Urine was applied weekly for 10 weeks and had a low dose of 1.2 gallons of urine per week for 25 plants and a high dose of 2.4 gallons of urine per week for 25 plants. Hubbard did not observe a difference between his "high dose" and "low dose" treatments. With regard to plant development, he found his urine-treated crops to be "slightly bushier and taller" than those grown with his usual fertilizer.

Figure 9. *Adam Hubbard's hemp, treated with urine.*

Rich Earth also worked with farmer partner **Andy Loughney** to fertilize hemp, using the same low and high dose application rates per plant. Loughney observed successful hemp growth and reported increases in the one specific type of cannabinoid content from urine-fertilized plants. A handful of tissue samples (not enough for statistical analysis) provided anecdotal evidence that Loughney found to be exciting. He wrote: *"The 6% overall rise in cannabinoid content is solid, but the real excitement comes from the huge gains in the cannabinoid that this variety was bred for (CBDV)..... Big gains: 32% in the [ow-dose trial and] 25 % [in the high dose trial] I'm quite pleased with the numbers for the CBDVA and overall cannabinoid content and we will certainly explore nitrogen application at this point, even if it cannot be urine for our organic operation at this juncture."*

Sweet Corn

At Pete's Stand, farmer John Janiszyn trialed sweet corn, fertilized at planting time with a 10-5-40 commercial fertilizer + cow manure. At the six-leaf stage, some corn rows were side-dressed with urea (46-0-0) and later with potash. Other rows were treated with urine (a higher dose and a lower dose), or assigned to a control group that received no side-dressing. Janiszyn did not find performance differences between the conventional and urine side-dressed corn. Qualitative observations indicated the urine-treated corn did significantly better than the control, and the higher dose of urine did better than the lower dose. Tissue samples of the sweet corn leaves found nitrogen and phosphorus levels were similar in all fertilized samples, and lower in the unfertilized control. No differences in disease or pest pressure were observed.

Figure 10. *John Janiszyn brings urine-fertilized corn to a field day for participants to taste.*

The tissue samples of urine side-dressed corn leaves had higher levels of potassium, sulfur, iron, manganese, and zinc when compared to conventionally-fertilized controls. Janiszyn was particularly intrigued by the higher potassium levels because he normally applies a side dressing for potassium, and speculated that urine fertilization might reduce the need for as much of this additional input.

Based on the favorable results of this experiment, Janiszyn decided to trial urine fertilization under plastic mulch prior to planting a pumpkin crop in 2024. (See **"Application Methods"** above)

Cut flowers

Figure 11. *Zinnias: Urine treated on right*

At **Tapalou Guilds Flower Farm, Hanna Jenkins** hand-applied urine to a bed of cut flowers alongside an unfertilized bed of the same varieties of cut flowers to do a side-by-side comparison. Both beds also received their usual treatment of compost tea. Jenkins observed no major differences between the urine treated crops and those fertilized with her usual treatment, but some of the urine treated celosia, amaranth and sunflowers appeared taller, on average, than her controls. She was unable to quantify any differences in numbers of blooms (as she was pinching and pruning the plants throughout the season) but felt there were no negative outcomes. She had no significant disease or pest pressure on either the urine treated or control crops. The foliage on the urine application was darker, and appeared more "lush" which she found beneficial from an aesthetic point of view. She wrote: *"Based on the results that I saw I plan on switching to using urine fertilizer as my predominant nitrogen source for field grown plants and potentially for use in high feeding plants in the hoop houses as well."* In the future she would like to apply using some type of pressurized applicator.

Figs

Figure 12. *Fig saplings in a hoop house.*

At **Rebop Farm**, four treatments (urine, urine + compost, compost alone, control) were applied in June to figs grown in a greenhouse. **Ashlyn Bristle** was enthusiastic about the results she observed through August of the trial year. She described the urine-treated sections as having *"the heaviest fruit-set"* and best growth overall, and added "*it's spectacular, fruit all the way down,"* and the crop was branching abundantly, providing opportunity for more fruit development. She felt that the best results at that point were being seen in a urine + compost treatment, where she estimated three to four times the usual fruit set. The next best fruit-set was in a urine only treatment, then manure only, then the control. Unfortunately, at the end of the season Bristle reported failure to ripen in all but one fig variety. This problem occurred across all treatments, and was not attributed to urine fertilizer. She believed that the problem was the excessive rain the region experienced that season, which led to "wet feet" in the soil even within the greenhouse (located on a hillside), which is not optimal for figs. In the future, she would move her application timing up to early May, and do a second application in early June, and then no further fertilization. She did observe some extra vegetative side growth with the urine treatments, which could be excessive, so she would reduce fertilization after June.

Bristle did note a fairly strong urine odor that did not dissipate for several days due to application inside the enclosed space of the greenhouse. Vents could not be opened further at the time of application because the figs needed more warmth.

Nursery Trees

At **Yellowbud Farm**, our farmer-partners **Eric Cornell** and **Jesse Marksohn** fertilized chestnut nursery stock planted in the ground.[85] All saplings were fertilized in two June applications, using pasteurized urine from the Rich Earth Institute applied at a 2:1 dilution rate of water:urine using an applicator tank and boom. Each 450 foot bed received approximately 30 gallons of urine. Marksohn reported exceptional results in seedling health and in mycorrhizal colonization of plant roots. They applied just before rain avoiding nitrogen loss to volatilization. Cornell noted, with regard to odor, that "*when you walk[ed] right next to the bed, you know, you can notice that pee was just applied, but it's not like extreme, it's not extremely offensive and it was gone...by the next day."* No burning of seedling leaves was observed. They noted that they believe the nursery stock could benefit from higher rates of urine application in the future.

In a controlled experiment, Bitternut Hickory nursery stock grown in air-pruned beds had larger stem and root diameters when urine was applied at 0.03 gallons/square foot than non-fertilized controls, yet these growth effects were not seen when urine was applied at half this rate. There were no differences in stem height or mass between urine-fertilized plants and non-fertilized plants.

Figure 13. *Rich Earth's custom field applicator applies urine fertilizer to nursery stock.*

COMMUNICATION WITH EMPLOYEES, CONSUMERS AND BUYERS

FARMERS

In 2020, Rich Earth Institute conducted on-farm research with several farmer partners; interviews with these farmers included questions about their conversations with others about their participation in the project.[86] Most reported customers and employees being intrigued, and that some in the farming community were "really excited." Ashlyn Bristle of Rebop farm noted that ***"the big black hole is human nutrient recapture and it's so cool to me to have that be part of anything that's happening on the farm."*** She did note that some younger employees were ***"a tiny bit grossed out by the smell"*** [while fertilizing inside a hoop house] but felt that presented a valuable educational opportunity. She also noted only positive responses to her mention of the experiment on social media. Hanna Jenkins of Tapalou Guilds also found the experiment valuable from an educational standpoint. She said that ***"some people would be turned off by*** [knowing the product was urine-treated] ***but I've come to terms with that's not the ideal customer for us then, you know, and I would really want to celebrate it and create education around it."***

John Janiszyn has not talked to customers about the experiment but emphasized the importance of transparency, saying ***"I would probably come from a place of saying 'Yeah, I think this is a great thing, I'm glad to be a part of this project,' trying to figure out how to use this thing we're just sending down the drain, you know, we've got to start re-thinking on how we source our fertilizers, and you know, everything, really."***

Eric Cornell and Jesse Marksohn of Yellowbud Farm had talked to some of their wholesale customers. Cornell noted that ***"my experience has been generally overwhelmingly positive and interested. I think there are, are certainly people that are maybe just don't have the understanding or they're removed from it or there's just like a...cultural distancing from waste and they would yeah, react the similarly to maybe using a composting toilet but, [generally] people are very intrigued and excited about about the concept."***

WHOLESALE BUYERS

Four individuals based in Vermont who buy produce or other agricultural products from local farmers were interviewed in 2024 about their perceptions concerning the use of urine fertilizers.[87] These included one buyer for a food co-op, one business owner who buys produce for creating fermented foods for sale, and two buyers for farm-to-institution agencies. Familiarity with the concept of urine diversion and re-use varied, from very little prior knowledge to one person who was very familiar and already diverted urine for fertilization personally. Perceptions varied, but a common theme was that if urine based fertilizers were readily available, were regulated in some way (i.e. such as by being permitted for use as a fertilizer by a government agency), and were applied appropriately, they would be comfortable with this use, and it might in fact be preferable to synthetic fertilizers. One commented, ***"it makes so much sense to use what we do, what we need to do, many times each day,"*** and wants to support local farmers who keep nutrients out of the waste stream.

A buyer for a food coop that prioritizes purchasing local and organic produce felt that organic certification would be very helpful. Without that, he would want information about when and how the material was applied on any edible crops (such as time from application to harvest.) He would have fewer concerns for non-edible crops like flowers or animal feed.

With regard to whether farmers should disclose their use of urine fertilizer, the food co-op buyer did not think that would be necessary, as long as it was being used under some type of state or federal permitting or regulation. This buyer also felt that having information about the positive things farmers are doing to steward the land and protect waterways is an incentive for customers' purchases, so having information, (either in the store or on farmers' websites) that farmers were using urine fertilizer and it was working well, would generate support for those farmers. All but one of the buyers interviewed had some concerns about the perceptions of their customers, but felt that with education, these perceptions could be addressed. The two "farm-to-institution" buyers both felt that having educational materials they could provide to their customers would be helpful, such as a brochure with "FAQ" about urine safety, etc. They felt that providing such information was part of their responsibility at their agencies. In order to alleviate potential concerns of institutional buyers (schools, hospitals), one buyer felt it would be essential to provide education regarding the steps that are taken to maintain food safety when processing or applying urine fertilizer. One buyer also wanted to ensure that the farmers they bought produce from had received adequate education concerning appropriate application guidance. However, given that this buyer prioritizes buying from farms that use ecological growing methods, the concept of using urine fertilizer was appealing.

With regard to labeling at the point of sale, opinions were mixed. While not all buyers felt that labeling was necessary, there was the sense that labeling, or having educational material available to customers, could be a way of introducing the concept, potentially leading to wider acceptance. One buyer thought, ***"It would be new and kind of groundbreaking...it would be a process obviously, but I think with a little marketing, it would definitely be readily accepted...I'm torn! I want the consumer to know what they're getting, but in the beginning it would be a hard sell."*** Similarly, another thought that ***"It would be great to be much more vocal about the benefits of this work,"*** but worried about misinformation or misperceptions until the practice becomes more widespread and/or has received organic certification. With regard to terminology, most of the buyers felt an acronym (such as UDF for "urine-derived fertilizer") would be best. "Urine-derived" was also noted as conveying the idea that some sort of processing or treatment (such as sanitization) had occurred which would be seen as positive by customers.

The idea of a locally available source of nutrients, utilizing a material that is currently being wasted, and mitigating greenhouse gas emissions and energy cost of synthetic fertilizer production were the most salient potential benefits of urine-derived fertilizer for the buyers interviewed. One buyer concluded, ***"I don't see any reason not to keep going forward with it...like why not, you gotta start somewhere, because what we have been doing [with regard to how we are managing human waste] isn't working!"***

PRODUCE CONSUMERS

In 2024, three dialogue groups were held, with participants recruited from customers at farmers' markets, farm stands, and via CSA memberships in southern Vermont. These facilitated conversations addressed general attitudes about the use of urine as a fertilizer on agricultural crops, information needs, and whether and how urine-fertilized crops should be labeled.

Initial reactions to the idea of fertilizing crops with urine was generally positive. "Excited" and "curious" were common words used. As one participant put it, "***learning of urine separation, and its being decoupled from industrial processes and industrial fertilizer, that seemed amazing that we weren't already doing it on a much larger scale!"*** When asked which of the potential benefits of urine diversion and its re-use as fertilizer was most important to their thinking, participants frequently cited the nutrient make-up of urine, something most participants were unfamiliar with previously.

Participants were generally most comfortable with the use of urine on non-edible crops (flowers, animal forage), and on fruits and berries, as opposed to leafy greens, although this varied, with some unconcerned about urine use on any crops, as long as appropriate application methods were followed. Concerns about safety were generally alleviated when sanitation methods were described. The potential presence of pharmaceuticals in urine was mentioned; however, when the discussion shifted to what consumers generally know about other fertilizers and amendments that farmers use, participants noted that they have little knowledge about the likely presence of these constituents in other fertilizers. A frequent sentiment was that urine fertilization ***"sounds great compared to all the other things we could be doing with it," such as allowing it to enter the wastestream.***

With regard to labeling, perspectives varied considerably. Some participants would very much like labeling at the point of sale and/or on farmers' websites. Others felt that this was unnecessary, and could be confusing. When asked what criteria participants found most important in making their purchasing decisions, *"local"* and knowing their farmer/s and their practices, were key to many. For some, the idea of farmers being able to tout the environmental benefits of UDF [urine-derived fertilizer] was seen as potentially very positive: *"Being able to say....'As a UDF farm, we have prevented x amount of the bad stuff going into the watershed,' I love that."*

ADDITIONAL RESOURCES

Practical Guidance on the Use of Urine in Crop Production EcoSanRes Series, 2010-1
https://www.sei.org/publications/practical-guidance-use-urine-crop-production/

Guide to Urine Fertilizer for Home Gardens. Rich Earth Institute, 2022.
https://richearthinstitute.org/publications/home-use-guide/

Guidelines for the safe use of wastewater, excreta and greywater - Volume 4 Excreta and greywater use in agriculture. World Health Organization, 2006.
https://www.who.int/publications/i/item/9241546859

Guide to Starting a Community-scale Urine Diversion Program. Rich Earth Institute, 2019.
https://richearthinstitute.org/urine-diversion-guide/

Utiliser l'urine humaine en agriculture. Fiches pratiques. Agrocapi, 2022.
https://www.leesu.fr/ocapi/wp-content/uploads/2023/07/fiches_urine_agriculture_OCAPI-e%C-C%81cran-juillet_23.pdf

L'urine de l'or liquide au jardin. Renaud De Looze. 2016.
https://www.terran.fr/produit/71/9782359811001/l-urine-de-l-or-liquide-au-jardin

CONTACT US

Rich Earth Institute can provide consultations and regulatory support for farmers interested in practicing urine fertilization. Email: info@richearthinstitute.org Phone: 802-631-0196

SURVEYS

Farm Guide Feedback Survey

Thank you for reading the Rich Earth Institute's Farmer Guide to Urine Fertilizer! Please take this very short (four question) guide feedback survey to provide your feedback. This will be very helpful to inform our future research and farmer communications.

Home Garden Community Science Survey

Do you already fertilize with urine? Share your experiences via our community science survey. This survey helps Rich Earth Institute grow the body of knowledge about where, how, and why people fertilize with urine around the world.

Community Peecycling Interest Survey

Are you interested in helping grow a peecycling program near you? Complete our community peecycling interest survey. Rich Earth Institute uses this survey to grow networks in different geographic hubs, connecting individuals along the different steps of completing the food nutrient cycle.

Endnotes

1 https://richearthinstitute.org/urine-diversion-guide/

2 https://richearthinstitute.org/publications/home-use-guide/

3 https://www.ecfr.gov/current/title-21/chapter-I/subchapter-B/part-112

4 Visit this tool for more information about FSMA PSR compliance and exemptions: https://ag.umass.edu/resources/food-safety/for-farmers/fsma-produce-rule

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