# Nitrogen Recovery from Source-Separated Urine

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The eutrophication of aquatic environments can stem from an excess of nutrients not adequately removed at waste water treatment plants. The discharge of nitrogen into the environment can be reduced with the incorporation of an ion exchange cartridge into source-separating toilets, toilets that function by separating urine from feces for distinct treatment. Development and implementation of an ion exchange cartridge makes nitrogen recovery from source-separated urine possible. The nitrogen that would otherwise be lost to the environment is recovered with the ion exchange cartridge and is used for the alternative production of fertilizers. Comprising 1% of wastewater volume, urine is ideal for the recovery of nitrogen due to the high quantity of nitrogen available from a concentrated waste stream. However, the nitrogen that can be recovered must be present as ammonium ($NH_4^+$) and thus the success of the ion exchange cartridge is dependent on the storage of urine. It is only after urine has been stored for a period of time that ammonium is generated through urea hydrolysis.

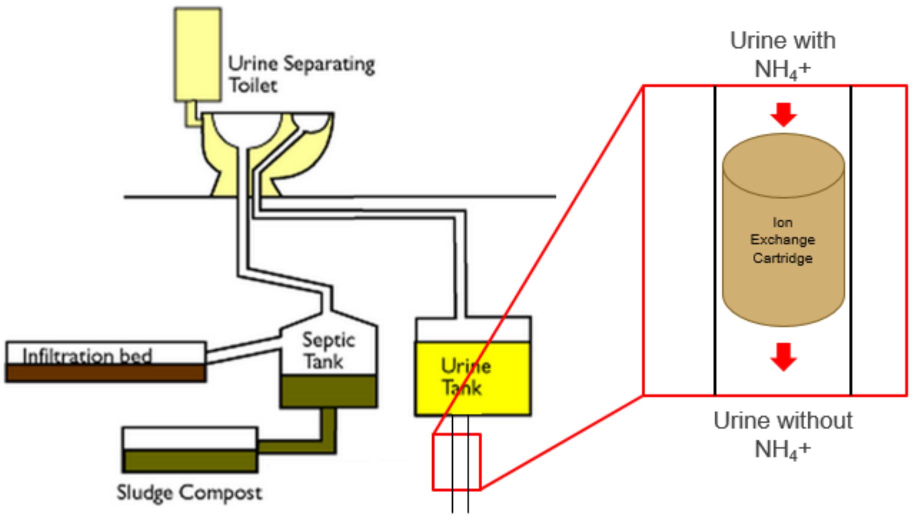


**Figure 1.** Visualization of the application and use of the ion exchange cartridge in a source-separating toilet

To optimize nitrogen recovery from source-separated urine, a cation exchange resin capable of adsorbing high quantities of ammonium had to be identified to develop the proposed ion exchange cartridge. The resins clinoptilolite and faujasite (natural occurring minerals) and Dowex 50 and Dowex Mac 3 (synthetic materials) were characterized with equilibrium adsorption isotherms to determine their capability of adsorbing ammonium. Running a series of 24 hour batch experiments for each resin and an ammonium chloride solution allowed the generation of the necessary equilibrium adsorption isotherms. The equilibrium adsorption isotherms, representative of the amount of ammonium as nitrogen bound to the surface of the resin as a function of the amount of ammonium as nitrogen present in

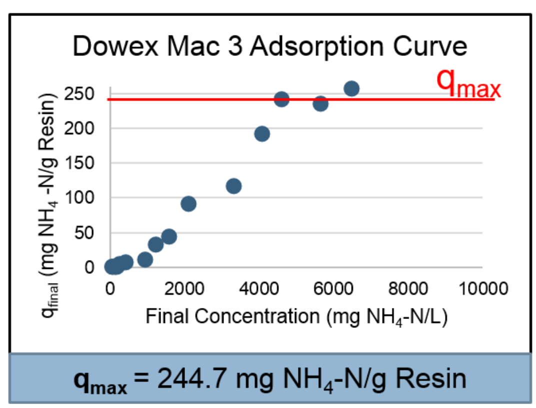


**Figure 2**. Equilibrium adsorption isotherm for Dowex Mac 3, the maximum adsorption density (qmax) is representative of the maximum amount of ammonium the resin can uptake

solution, demonstrated that Dowex Mac 3 adsorbed the greatest amount of ammonium in comparison to the other resins. The results identified Dowex Mac 3 to be the ideal resin for the design of the ion exchange cartridge.

Considering urine contains potassium ($K^+$), and sodium ($Na^+$) ions in addition to ammonium, it became vital to understand how the uptake of ammonium onto each resin would be affected given the presence of $K^+$ and $Na^+$. By running a series of 24 hour batch experiments between each resin and a NaCl solution, along with another set of batch experiments between each resin and a KCl solution, and relying on data previously generated from the ammonium chloride batch experiments, a Competitive Adsorption Langmuir Model could be created for each resin. The Competitive Adsorption Langmuir Model would describe the ideal uptake of ammonium onto each resin given the presence of the other cations found in urine, $K^+$ and $Na^+$. Constructing a Competitive Adsorption Langmuir Model for each resin is work in progress because the samples are currently being processed via inductively coupled plasma mass spectrometry (ICP-MS) and ion chromatography. Essentially, after the model has been completed for each resin it would serve as a reference point to compare the data obtained from the synthetic urine batch experiments and see how the uptake of ammonium from the synthetic urine compared with what was expected in the model. The model is expected to overestimate the uptake of ammonium onto each resin given the presence of $K^+$ and $Na^+$. In comparison to having one cation present in solution, as was the case in the ammonium chloride batch experiments where only the ammonium cation was present, the uptake of ammonium from the synthetic urine batch experiments is expected to be considerably less as a result of competitive adsorption.

To begin understanding how the uptake of ammonium from the ion exchange cartridge would be affected given the continuous flow of an ammonium solution ($NH_4Cl$, synthetic urine, or actual urine), potential dimensions for the ion exchange cartridge had to be identified. The cartridge has been thought to have a cylindrical shape. To attain such shape a series of parameters were considered to derive potential lengths and diameters. For instance, the size of the pipe where the cartridge is to be placed was considered as well as the type of toilet (gallons/flush). The mass transfer zone, or the area where the uptake of ammonium would occur on the cartridge as a function of time, was also considered. It was the expression describing the movement of the mass transfer zone that allowed the derivation of another expression that could be used to derive potential lengths and diameters for the cartridge. A plot showing the relationship between the potential lengths and diameters of the cartridge was thus obtained. Preliminary results showed the cartridge length could be more than 50 meters. To get smaller length values, flow rates more representative of source-separating toilets will have to be obtained.

Developing an ion exchange cartridge that can effectively recover nitrogen in the form of ammonium from source-separated urine to produce fertilizers involves a series of steps. From the ammonium chloride batch experiments it was determined that Dowex Mac 3 was the appropriate resin to use in the cartridge design. In addition, working with the synthetic urine batch experiments will provide insight about the amount of ammonium uptake that is to be expected given the presence of more cations found in urine. The final step would then include identifying the appropriate dimensions for the cartridge so that the uptake of ammonium can continue being quantified via continuous and intermittent experiments in the future. Completion of all steps will inform the creation of an ion exchange cartridge for nitrogen recovery from urine.