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N cycling in food/excretion systems: potential of human excretions used as fertilizers

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Context: Current food/excretion systems are unsustainable⁴. Recycling human excreta as fertilizers could improve circularity and reduce pollutions.

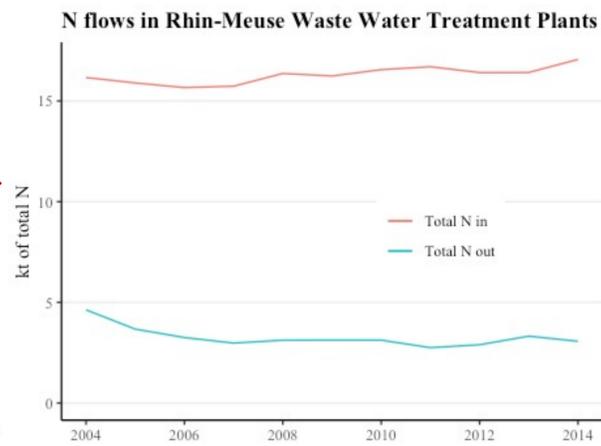
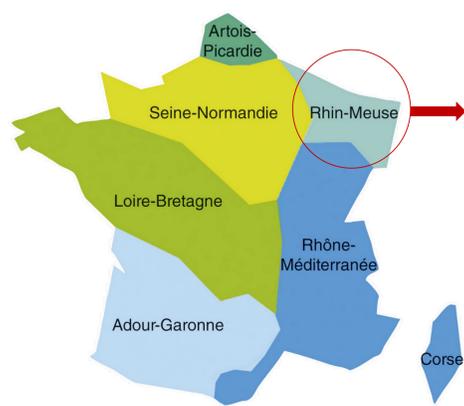
Objectives: Perform a global evaluation of N flows in the current French excretion system and assess the potential of human excreta used as fertilizers.

Step 1 : Assessment of N flows in French Wastewater Treatment Plants

We are currently producing a **unique dataset of the more than 20 000 wastewater treatment plants** in France. These data are decentralized for the 6 different French Water Agencies. We gather, clean, and harmonize these different datasets.

The final dataset will provide useful information beyond our scope of study: type of treatment, BDO5 flows, nominal capacity, sludge production... As an example, we focus here on N flows in the Rhin-Meuse basin.

The 6 French Water Agencies



N yield of Rhin-Meuse WWTP in 2014

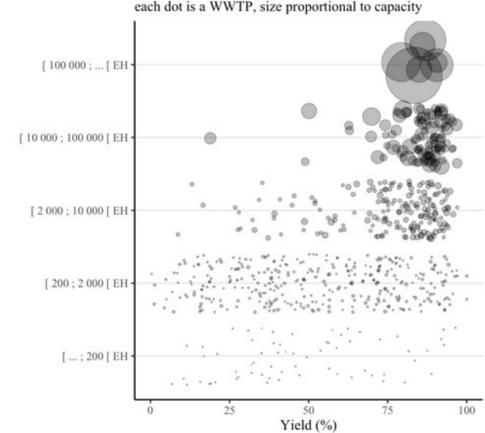


Figure 1. Example of information extracted from the dataset. **Left** : total N in and out of Rhin-Meuse wastewater treatment plants. **Right** : N yields of Rhin-Meuse individual wastewater treatment plants, sorted by reglementary capacities. We can see the effect of the European directive for N-sensitive zones. Beyond a capacity of 2 000 Population Equivalent, a minimum N yield of 70% (or a certain outflow N concentration) is mandatory.

Step 2 : Assessment of the whole French excretion system

Current estimations of N flows after excretion are already available, based on rough estimations of average wastewater treatment plant yields¹. Our dataset would allow to **use more precise operational data to perform a global N flow diagram** of the current French excretion system. To produce this result, we combine our data with information about food intakes, sewer connections, individual autonomous system yields, and sludge destination.

These are **preliminary results**. About **1/3 of the N** present in French excretions ends up in the **aquatic environment**, potentially contributing to eutrophication. **50% returns to the atmosphere as N₂** after denitrification. This unreactive N is not polluting, however from the N cycle perspective this is a net loss and reduces circularity. Moreover, denitrification is associated with substantial energy consumption and N₂O emissions, which could be avoided if N was recycled. Currently, **only 5-10% of the N is recycled in the farming system**.

This is an assessment at the French territory scale, but our dataset would allow to perform flow analyses at finer scales.

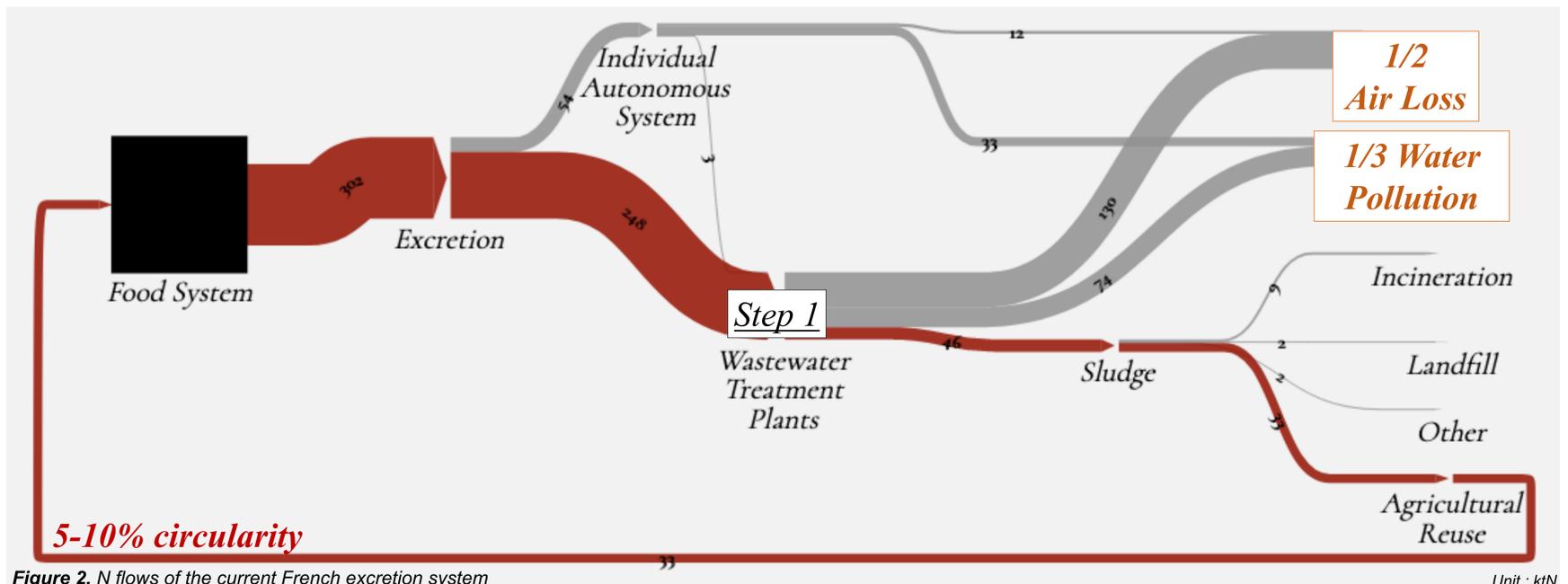


Figure 2. N flows of the current French excretion system

Unit : ktN

Step 3 : Human excreta recycling as potential fertilizers in France

The final aim would be to use our data to **estimate the potential of human excreta recycled as fertilizers** in agroecological scenarios. Most of the N is excreted in **urine** and could be **collected through urine-diversion toilets**³. Depending on the local context, a large variety of source-separation systems could be used. Below is an **example at the French national scale adapted from Billen et al. (2021)**, but our data would allow finer-scale assessments.

Currently, human excretions represent 10-20% of the food/excreta N losses and pollution, and only 1% of N inputs into the food system. Drastically redesigning the food/excreta system could reduce N losses and pollution by 2 to 3. Human excreta would then represent 10-20% of N inputs.

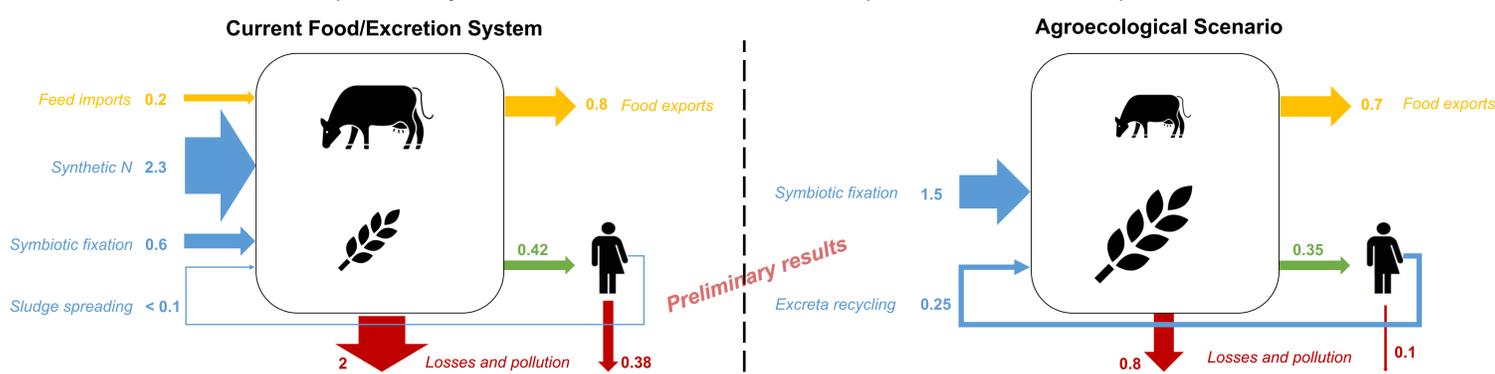
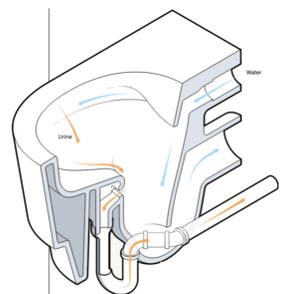


Figure 3. Main N flows in the current food/excretion system (left) and in an agroecological scenario (right). Units : ktN.



Example of urine-diverting toilets
Credit Jasiolek Krzysztofak³

References :

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- 3 - Wald, Chelsea. "The urine revolution: How recycling pee could help to save the world." *Nature* 602.7896 (2022): 202-206.
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