Assessing nitrogen fluxes: From human food intake over urine and faeces to wastewater treatment and disposal

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Abstract

The nitrogen (N) pathways from human food intake to the various final whereabouts are discussed. The major wastewater pathways including the respective N stream are quantified. Specifically, the N emissions into the environment and the shares valorised in agriculture are discussed for current EU28. Suggestions to improve the wastewater system with the focus on N valorisation are made. They allow to re-capture a large N share. Specifically, an innovative decentralized approach consisting of blackwater collection with vacuum toilets, anaerobic digestion of blackwater, ammonia stripping and scrubbing is introduced.

Keywords: human excrements, wastewater collection, sludges, treatment, effluents, anaerobic digestion

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1. From food to excrements

Humans consume nitrogen (N) with food and drinks. 42% of the post-farm gate N is ingested and this N humans almost completely (99.6 %) excrete (Corrado et al. 2020)

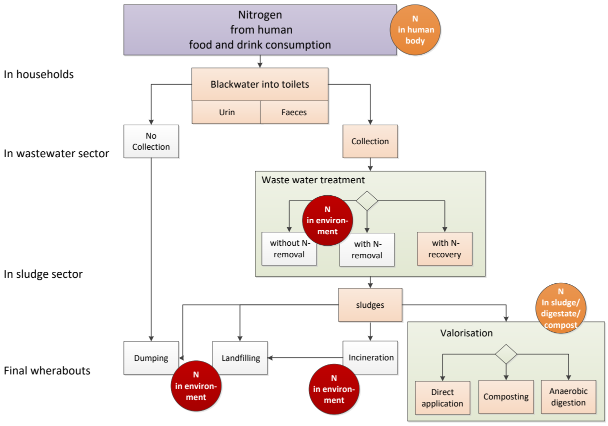

Fig. 1: Current nitrogen flows and whereabouts after human food intake

Based on excrement data from Rose et al. 2015 the average amount and N-content for excrements were estimated: urine - 511 kg/yr & capita with 7.8 g N /kg; faeces - 47 kg/yr & capita with 14.1 g N/kg. Based on consumed food data, Corrado et al. 2020 calculated an average excretion of 5.9 kg N/yr & capita. This N is commonly delivered into toilets as blackwater. The options for the follow-up pathways of N are summariezed in Fig. 1 and explaine in more detail in chapters 2-4.

2. Excrements collection

In EU28, 284 Mio Mg of excrements were generated in 2015, whereas 35 Mio Mg (13 %) were not collected (calculated based on EEA 2017, EUROSTAT 2018).The situation varies regionally. The following percentual shares of the total wastewater of the EU28 regions were not collected in 2015: Central - 3 %; Northern - 14 %, South Eastern - 22 %, Southern - 23 %, Eastern - 25 % (calculated based on EEA 2017). If wastewater is not collected, reactive N compounds of excrements end up in environment, whereas ammonia into water bodies is the dominating pathway.

3. Waste water treatment

Collected wastewater consists mainly of water. Only a part goes back on excrements. The major water part is from toilet flushing, greywater from e.g. showers and washing mashines and/or rainwater. The wastewater mixtures are cleaned in wastewater treatment facilities, whereas a wide type range of decentralized and centralized facilities exist. They can be divided into primary, secondary or tertiary systems. The major output is the effluent, which is discharged into a water body. Additionally, sludges are generated as by-products. System specifics are described in the following.

3.1 Primary wastewater treatment

In this system, wastewater particles settle. The effluent contains the majority of the soluble reactive N with ammonia dominating. In the effluent N is highly diluted and reaches environment. Corrado et al. 2020 (Data sources_2) assume that 90 % of the N is lost in reactive formes with the effluent.

3.2 Secondary wastewater treatment

This treatment type includes additional aerobic or anaerobic process steps, which can lead to biodegradation of e.g. half of the excrement organics. A high share of N is still in the effluent an reaches environment. Corrado et al. 2020 (Data sources_2) assume that 75 % of the N is lost in reactive formes with the effluent.

3.3 Tertiary wastewater treatment

Besides biodegradation steps, further process steps (mainly nitrification combined with denitrification) transform a large part of the reactive N into not reactive atmospheric N_2. However, a low share of reactive N still remains in the effluent. By Corrado et al. 2020 (Data sources_2) it was assumed to be 30 %. In EU28 tertiary treatment is the most important sytstem and used with a share of more than two third (Corrado et al. 2020).

4. Sludge disposal and treatment

Sludges from the various treatment systems are often dewatered. Than they can take different disposal or treatment pathways such as dumping, landfilling, incineration, direct application in agriculture, composting and anaerobic digestion. The effluent composition depends on the sludge type. The whereabout of sludge N depends on the disposal or treatment pathway. Reactive N can go into environment in multiple ways (e.g. incineration: NOx into air; landfilling: leaching of organic, nitrate and ammonia N). N in the outputs of composting and anaerobic digestion are considered as valorized since compostes and digestates are commonly applied in agriculture. However, the specific share depend on the agricultural application practice. In EU28, currently 56 % of sludges are composted or anaerobically digested (calculation based on EUROSTAT 2018).

5. Options to reduce N emissions from wastewater

N emission reduction from the excremts fluxes can be achieved by increasing the share of conventional tertiary wastewater treatment (Corrado et al. 2020). However, the N is transformed into N_2 and therefor lost for valorization. Innovative techniques for excrement handling exists. Vacuum toilets can concentrate blackwater (e.g. 1 L water per flush compared to 6-8 L in conventional toilet; Hertel et al. 2015). Also, toilets for separation of excrements into urine and faeces exist. These procedures may be useful for N valorization, since ammonia from concentrated streams can be removed via stripping and re-captured by scrubbing to gain mineral fertilizer. Stripping is energy demanding, but less than nitrification and denitrification. Additionally a product can be generated, which can substitute mineral fertilizers produced by the energy intensive Haber Bosch process (Hertel et al. 2015).

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References

Corrado S, Caldeira C, Carmona-Garcia G, Körner I, Leip A, and Sala S 2020 Unveiling the potential for an efficient use of nitrogen along the food supply and consumption chain *GFS_2018_159* (submitted)

EEA 2017 Changes in urbam waste water treatment Europe.https://www.eea.europa.eu/data-and-maps/daviz/changes-in-wastewater-treatment-in-8#tab-chart_3

EUROSTAT 2019 population on 1 January by ssex and age http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=demo_pjan&lang=en

EUROSTAT 2018 Treatment of waste by waste category, hazardousness and waste management operations http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_wastrt&lang=en

Hertel S, Navarro P, Deegener S and Körner I 2015 Biogas and nutrients from blackwater, lawn cuttings and grease trap residues - experiments for Hamburg’s Jenfelder Au district. *Energy Sustain. Soc.* 5(1)29

Rose C, Parker A., Jefferson, B. and Cartmell, E. 2015. The characterization of feces and urine: a review of the literature to inform advanced treatment technology. *Critic. Rev. Environ. Sci. Technol.* 45(17) pp. 1827-1879