



HAL
open science

Integrated environmental assessment of source separation scenarios for water resource recovery

Mathilde Besson, Ligia Tiruta-Barna, Etienne Paul, Sylvaine Berger, Mathieu Spérandio

► **To cite this version:**

Mathilde Besson, Ligia Tiruta-Barna, Etienne Paul, Sylvaine Berger, Mathieu Spérandio. Integrated environmental assessment of source separation scenarios for water resource recovery. Watermatex 2019, Sep 2019, Copenhagen, Denmark. hal-03340962

HAL Id: hal-03340962

<https://hal.science/hal-03340962v1>

Submitted on 10 Sep 2021

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Integrated environmental assessment of source separation scenarios for water resource recovery

M. Besson*, L. Tiruta-Barna* E. Paul*, M. Spérandio*, S. Berger**

* 135 avenue de Rangueil, LISBP, Université de Toulouse, CNRS, INRA, INSA, Toulouse, France.

mathilde.besson@insa-toulouse.fr, ligia.barna@insa-toulouse.fr, etienne.paul@insa-toulouse.fr, mathieu.sperandio@insa-toulouse.fr

** Solagro - 75 Voie du TOEC – CS 27608 – 31076 TOULOUSE Cedex 3. sylvaine.berger@solagro.asso.fr

Abstract: This work aims to assess by Life Cycle Assessment (LCA) the transition towards Water Resources Recovery Facility of sanitation system considering the benefits of source separation systems and advanced technologies in treatment plant. Considering urban district, urine diversion with centralised treatment, blackwater decentralised treatment and greywater management are compared.

Keywords: modelling; LCA; WWTP; source separation; nutrients and water recovery

Introduction

Nowadays wastewater treatment plant (WWTP) is intended to become WRRF (Water Resources Recovery Facility) where not only preservation on environment is performed but also production of resources (Guest et al., 2009) as: water, carbon, phosphorus and nitrogen recovery. In parallel of WWTP improvements, several studies sought for a paradigm shift in sanitation where wastewater can be separated at source. Indeed a large part of pollutants in wastewater comes from human excreta, especially nutrients from urine (Larsen and Gujer, 1996) which led to urine separation projects (Larsen et al., 2013) and blackwater (water from toilets) separation (Skambraks et al., 2017). Several studies attempted to evaluate these solutions by modelling and compare them to conventional sanitation (Wilsenach and van Loosdrecht, 2006). However such simulations have not been compared to the most advanced solution on WRRF, which will be implemented on the long time horizon of source separation. Moreover none takes into account the urbanism of the installed district. To fulfil this lack, a modelling tool (named MUSES) has been developed for modelling the whole sanitation system (production, transport, treatment). Geographical information system, energy balance and LCA help to compare the technical choices for guiding stakeholders and designers. This study aims to determine the limitation of the water resource recovery approach on WWTP for estimating how source separation (blackwater, urine, greywater management) helps to achieve this goal.

Material and Methods

The modelling approach is presented in Figure 1. Modelling of the district is performed with MUSES tools (Besson et al., 2017) which aimed to design sanitation at district scale taking into account the urbanism typology (especially density). The WRRF is simulated with SUMO software and LCA is performed with UMBERTO.

Four different scenario are compared (see Figure 2) : i) an advanced solution for WRRF (*Reference*), ii) urine source separation (*Urine*), iii) blackwater/greywater separation and decentralised treatment (*BW/GW*), iv) decentralised treatment of blackwater and greywater to WRRF (*BW/GW- WRRF*). The study is conducted for a new district in a city which has a WRRF already treating 57 450 PE with 12 900m³/d. The urbanism type of the district is discontinuous blocks (Bonhomme et al., 2012) and has a surface of 6.25 ha and is composed majority with collective building and housing building.

1390 inhabitants live in the district and 469 employees work there and all together represents 792 PE.

The advanced WRRF (Figure 2) is based on biological removal of phosphorus coupled to digestion of sludge and struvite precipitation in the digested sludge. Nitrogen will be recovered thanks to a transmembrane chimio-sorption (TMCS) also known as ammonia stripping through hydrophobic membrane (industrial pilot in the WWTP of Altenrhein and Yverdon-les-Bains (Böhler et al., 2018)).

The scope of the LCA study covers collection and treatment of wastewater (foreground processes) but also production and transport of chemicals and electricity (background processes). Avoided processes are also taken into account as fertiliser production and tap water production avoided thanks to less flush water and reuse of greywater. The methodology follows the work of (Bisinella de Faria et al., 2015) with the adjunction of collection transport. Moreover in order to take into account only the impact of the new district, the impact of district without city will be subtracted from the impact of city with district. Functional unit is 1PE considering the EU normalized definition: 1PE = 60gDBO₅/d. The midpoint impact assessment method from ReCiPe H has been chosen, only climate change results will be presented here.

Results and Discussion

From Table 1, it can be concluded that the nitrogen is the less recovered compound in WRRF due to its limited capture in the sludge. Nitrogen concentration is too low in the wastewater to be extracted. Therefore, source separation is the best option to currently increase nitrogen recovery rate up to 62%. Similar phosphorus recovery rate (around 50%) are obtained in the three scenarios of source separation thanks to biological removal of phosphorus in the water line of WRRF. Finally there is a slight increase in carbon recovery with the last scenario where blackwater is directly digested.

From Figure 3, it can be concluded that Reference scenario has the largest climate change impact and the three other scenario have comparable impacts. The main contributions for Reference scenario are the WRRF infrastructure, production of iron chloride and direct emissions (N₂O, methane, CO₂ into air and water emissions...).

Thanks to the substitution of nitrogen fertilizer the three other scenario present an improved balance of climate change impact. For decentralised blackwater and greywater treatment (BW/GW) the emissions linked to energy consumption represent 44% of the impact, increasing the emissions compared to Reference scenario. They are not completely balanced by fertiliser avoided and reuse of greywater for non-potable use. Moreover all greywater are assumed to be reused, replacing tap water, but flush water will only represents 7% of the available greywater. To achieve this water recovery level, new uses need to be found as green area irrigation, road cleaning...

Conclusions

This study aims to compare several options to enhance resources recovery from wastewater at the WRRF with or without coupling it with source separation systems. It has been shown that nitrogen recovery is the main beneficial aspect regarding LCA results; however, nitrogen recovery is very limited in WRRF (around 15%). Source separation of urine or blackwater can solve this limitation. Both scenarios can achieve the same range of nutrient recovery. However high tech treatment for water reuse, with high energy consumption, can only be installed if it couples high recovery rate of water and nitrogen.

References

- Besson, M., Bisinella de Faria, A.B., Spérandio, M., Paul, E., 2017. Impacts of urban typologies on efficiency of source-separation systems with decentralized treatment, in: Session: Ressource Oriented Sanitation Systems. Presented at the The IWA S2Small2017 Conference on Small Water & Wastewater Systems and Resources Oriented Sanitation, Nantes, France.
- Bisinella de Faria, A.B., Spérandio, M., Ahmadi, A., Tiruta-Barna, L., 2015. Evaluation of new alternatives in wastewater treatment plants based on dynamic modelling and life cycle assessment (DM-LCA). *Water Res.* 84, 99–111. <https://doi.org/10.1016/j.watres.2015.06.048>
- Böhler, M., Hernandez, A., Gruber, W., Fleiner, J., Seyfried, A., 2018. POWERSTEP. WP4 : Nitrogen management in side stream. D 4.3: Operation and optimization of membrane ammonia stripping (Deliverable No. 4.3). Eawag.
- Bonhomme, M., Ait Haddou, H., Adolphe, L., 2012. GENIUS: A tool for classifying and modelling evolution of urban typologies. Presented at the 28th Conference, Opportunities, Limits & Needs Towards an environmentally responsible architecture, PLEA2012, Lima, Peru.
- Guest, J.S., Skerlos, S.J., Barnard, J.L., Beck, M.B., Daigger, G.T., Hilger, H., Jackson, S.J., Karvazy, K., Kelly, L., Macpherson, L., Mihelcic, J.R., Pramanik, A., Raskin, L., Van Loosdrecht, M.C.M., Yeh, D., Love, N.G., 2009. A New Planning and Design Paradigm to Achieve Sustainable Resource Recovery from Wastewater. *Environ. Sci. Technol.* 43, 6126–6130. <https://doi.org/10.1021/es9010515>
- Larsen, T.A., Gujer, W., 1996. Separate management of anthropogenic nutrient solutions (human urine). *Water Sci. Technol.* 34, 87–94.
- Larsen, T.A., Udert, K.M., Lienert, J. (Eds.), 2013. Source separation and decentralization for wastewater management. IWA Publ, London.
- Skambraks, A.-K., Kjerstadius, H., Meier, M., Davidsson, Å., Wuttke, M., Giese, T., 2017. Source separation sewage systems as a trend in urban wastewater management: Drivers for the implementation of pilot areas in Northern Europe. *Sustain. Cities Soc.* 28, 287–296. <https://doi.org/10.1016/j.scs.2016.09.013>
- Wilsenach, J.A., van Loosdrecht, M.C., 2006. Integration of Processes to Treat Wastewater and Source-Separated Urine. *J. Environ. Eng.* 132, 331–341. [https://doi.org/10.1061/\(ASCE\)0733-9372\(2006\)132:3\(331\)](https://doi.org/10.1061/(ASCE)0733-9372(2006)132:3(331))

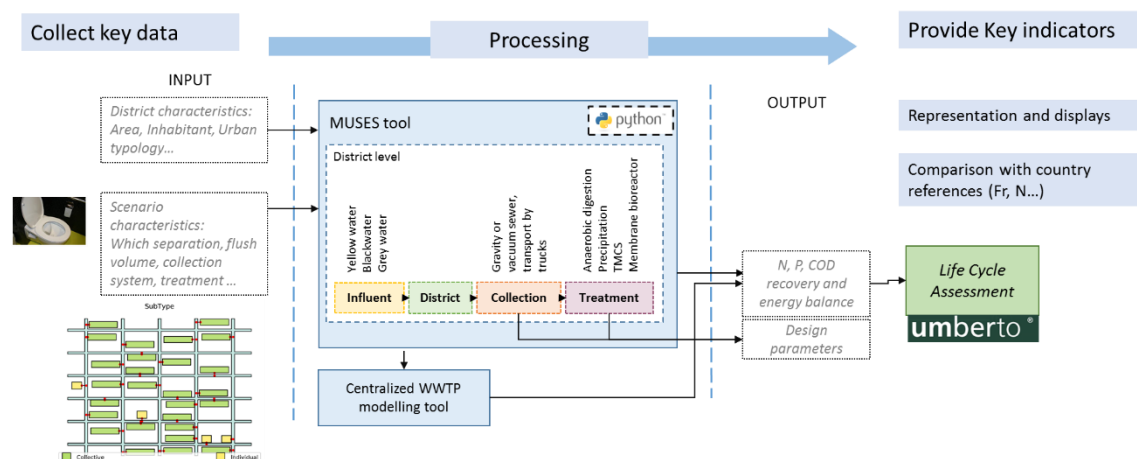


Figure 1 Modelling approach of MUSES tool

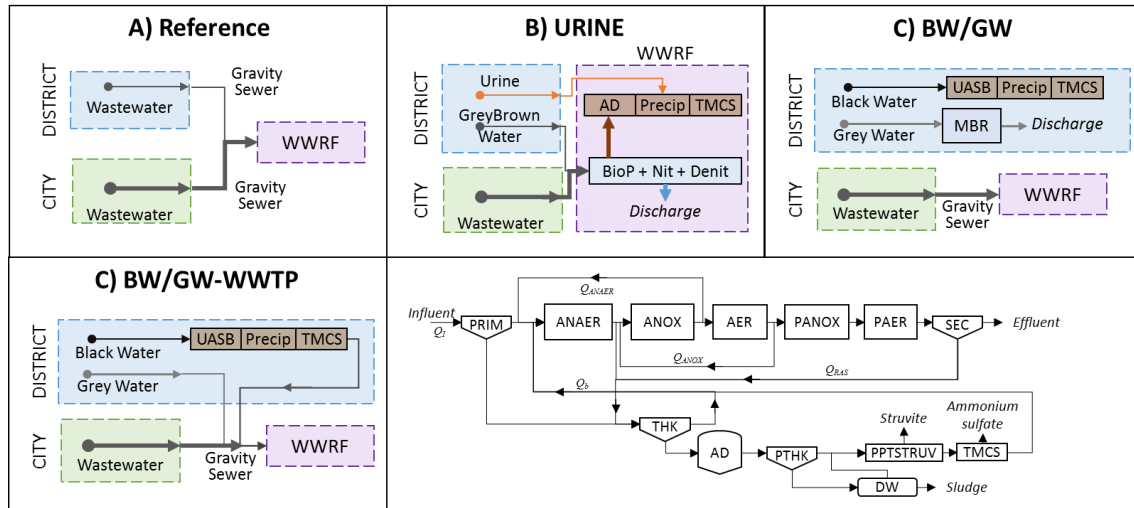


Figure 2 Presentation of the four scenario and the WRRF

Table 1 Recovery rates for each scenario and each compound

| Recovery rate | Reference scenario | Urine scenario | Blackwater scenario |
|---------------|--------------------|----------------|---------------------|
| Nitrogen | 8.7% | 62% | 62% |
| Phosphorus | 29.4% | 53% | 53% |
| COD | 29% | 27% | 39% |

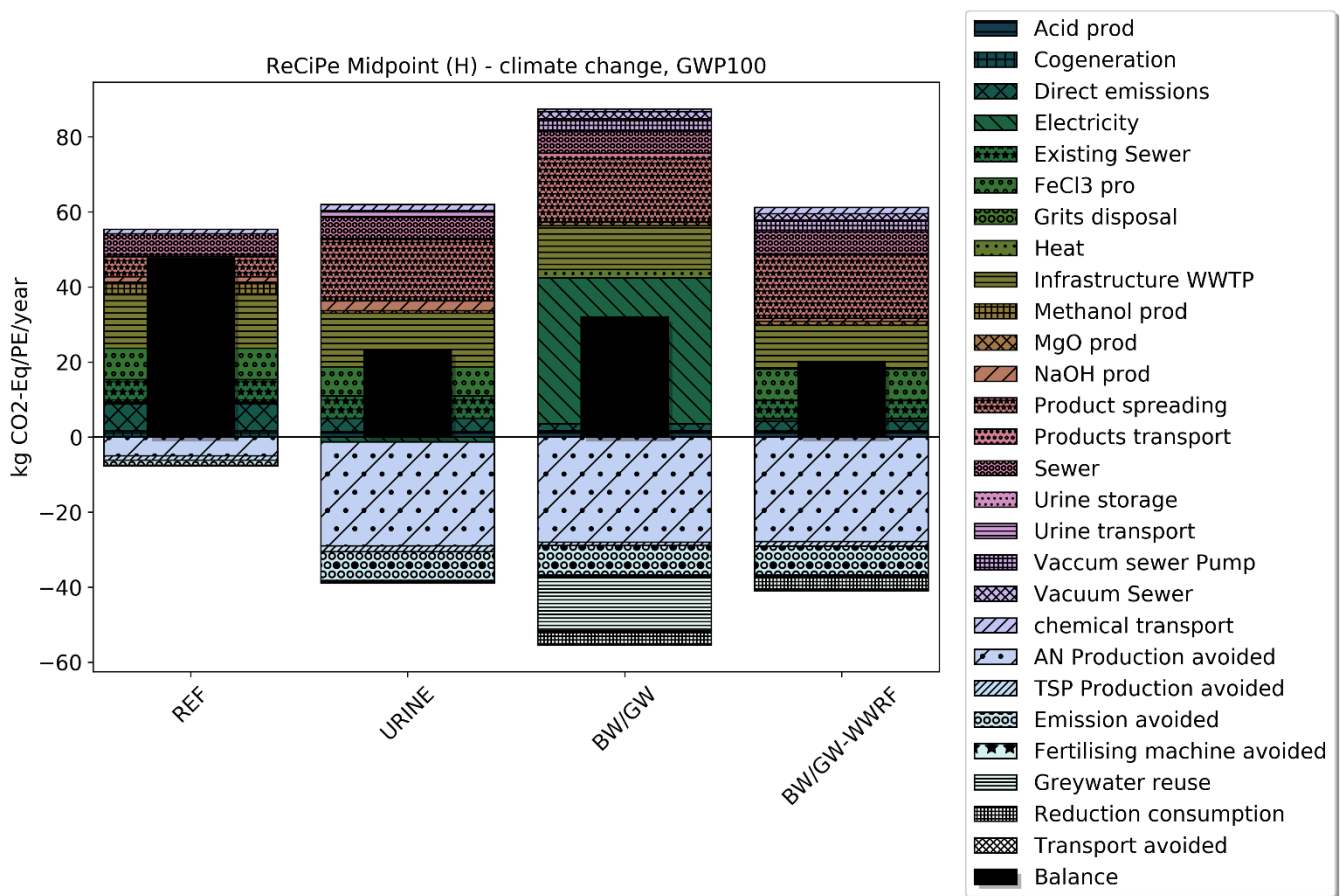


Figure 3 Comparison of the four scenarios on climate change impact (ReCiPe Midpoint H)