



HAL
open science

The emergence of systems for the source separation and valorization of human waste in greater Paris : from necessity to implementation.

Marine Legrand, Aurélie Joveniaux, Alessandro Arbarotti, Bernard de Gouvello, Fabien Esculier, Jean-Pierre Tabuchi

► To cite this version:

Marine Legrand, Aurélie Joveniaux, Alessandro Arbarotti, Bernard de Gouvello, Fabien Esculier, et al.. The emergence of systems for the source separation and valorization of human waste in greater Paris : from necessity to implementation.. Pré-conférence internationale Eau, mégapoles et changement global (EAUMEGA), Dec 2020, Paris, France. hal-03703680

HAL Id: hal-03703680

<https://enpc.hal.science/hal-03703680v1>

Submitted on 24 Jun 2022

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.

THE EMERGENCE OF SYSTEMS FOR THE SOURCE SEPARATION AND VALORIZATION OF HUMAN WASTE IN GREATER PARIS: FROM NECESSITY TO IMPLEMENTATION

Legrand Marine¹, Jovéniaux Aurélie¹, Arbarotti Alessandro¹, de Gouvello Bernard^{1,2}, Esculier Fabien^{1,3}, Tabuchi Jean-Pierre⁴

KEYWORDS: Sanitation, source separation, human excreta valorization, dry toilets, urine, territorial configuration, Paris.

ABSTRACT

The use of sewers to transport human excreta away from inhabited zones now causes particularly acute problems in megacities. Given the major global changes faced by wastewater management systems, these huge population centres highlight the limitations of the traditional sanitation management model. Apart from the frequent overloads on centralised wastewater management systems, there is their deep footprint in terms of energy expenditure, greenhouse gas emissions and continuing frequent pollution of aquatic environments. Yet managed separately, these excreta could be used as fertiliser: their agricultural application would represent a move away from the waste remediation model and an opportunity for mutual benefit between urban and agricultural zones, supplying the latter with lasting, local and nonfossil fertilising materials.

Focusing on the case of the Paris conurbation, we provide a crosscutting analysis of the current opportunities for implementing source separation systems in a highly concentrated population centre. More specifically, we examine the technical, organisational and economic obstacles and drivers around the production of fertilisers from human excreta, in particular from urine, under good sanitary and agronomic conditions.

We show the buildup of evidence about the incoherence of the current wastewater management system and the need for a paradigm shift. Nonetheless, pilot projects remain difficult to implement (due to political, sociocultural, economic, regulatory and technical obstacles, which are particularly tough in the case of a megacity). Despite this, there has been a recent shift in the dynamics, with projects emerging on the margins of urban planning. A key factor in their success is adaptation to different territorial configurations. Backed by individuals and groups with specific priorities, these projects offer a glimpse of the possibility of devising new sociotechnical systems for managing human waste.

1 INTRODUCTION

France's metropolitan capital region, Île-de-France, experienced steady urbanisation over the 20th century that continues today. "Grand Paris" (Greater Paris) has become a megacity. From the point of view of spatial planning, what we see here is a combination of a tradition of centralisation specific to France, and a more global urban dynamic, characterised by the constant and intense growth of the big urban hubs, linked with ever greater competition between the strongholds of the globalised market economy. Paris has historically been the single economic, cultural, political, intellectual and logistical centre of the country, which is organised in a radial pattern around its capital. Today, the city is in competition with New York, London, Beijing, Lagos, Mexico City, São Paulo, Tokyo, as a global pole of attraction. It is as if the whole planet were now structured around conurbations, as if distances had ceased to exist, thanks to the fluidity of air travel, the spread of digital communication and the low cost of freight transport (Thisse and van Ypersele, 1999).

However, despite this apparent seamlessness, all the big conurbations, in particular megacities, are experiencing problems in access to water and food, but also in human wastewater management, because of the high population concentrations they create. The crossing of environmental boundaries, now a reality across the world, especially with respect to the biogeochemical nitrogen and phosphorus cycles (Steffen et al. 2015), is exacerbated at local level in these unprecedentedly vast global cities. The further planned expansion of the megacity of Paris in the 21st century raises the question of whether it

¹ LEESU, ²CSTB, ³METIS, ⁴SIAAP.

is materially possible to fulfil all the functions necessary to the construction and operation of such an entity:¹ transport of people, transport of goods (food, construction materials, etc.), energy supply... The need to place drastic limits on the environmental impact of this territory makes the task even tougher. The management of Greater Paris's wastewater in particular suffers from many limitations, exacerbated by the fact that the flow rate of the River Seine is fairly low relative to the city's population.²

This article draws on the case of Greater Paris to examine the future of excreta management in dense urban conditions. We will start with a material fact, i.e. the limitations of the megacity's sanitation system, which is central to the relations between soil, water and food. We will then look at the interplay of actors, the standards and the infrastructures on which the possibilities for the implementation of more virtuous methods of managing urine and faecal matter now depend. What can be done to organise the collection, treatment and transport of human waste outside sewers? After exploring the normative/legal framework that might be conducive to such a paradigm reversal, we will discuss the territorial web into which these innovations will need to be fitted at regional and local scale. Finally, we will consider the conditions that favour the emergence of pilot projects in the interstices of urban production, such as participatory housing and eco-neighbourhoods.

This analysis draws on research conducted under the OCAPI programme³: (1) a territorial ecology approach applied to the management of food supply and excretion in the greater Paris region; (2) a historical and regulatory analysis of the sociotechnical gridlock around the mains drainage approach; (3) tracking of case studies on the outcome of urban project scale pilot experiments conducted in different urban configurations ; tracking of demonstrations conducted at the scale of individual buildings; (4) interviews conducted with members of the *Arceau Île-de-France* taskforce working on the "source separation of domestic wastewater". This task force, jointly headed by SIAAP⁴ and the OCAPI programme, consists of some 60 academic research actors from public institutions in Île-de-France, together with practitioners working in the human wastewater management sector.

2 HOW TO MANAGE A MEGACITY'S HUMAN WASTE WHILE RESPECTING PLANETARY BOUNDARIES? THE CASE OF GREATER PARIS

The many constraints associated with the current growth of the Paris urban region have encouraged new thinking by many different actors on the role of human excreta in sanitation. Sanitation encompasses multiple issues: rainwater, domestic uses of water (hygiene, washing, cooking,...), the management of human waste, etc. An analysis of the material flows involved shows that the main pressure on Paris's wastewater management system with respect to the quality of the Seine comes ultimately from human waste, which at present is diluted in wastewater then processed in a water treatment plant before being discharged into the environment (Esculier et al., 2015). Following a territorial ecology approach, it ultimately becomes clear that there is ultimately little intrinsic connection between human excreta and water management within a territory, for which they constitute a form of pollution, and that they can be reanalysed as a resource, an integral part of a system comprising agricultural production, dietary patterns and human excretion – a territory's "nutrition/excretion system" (Esculier, 2018).

2.1. The unrecognised limitations of the existing nutrition/excretion system: linear, wasteful and polluting

Conventional food production makes large-scale use of industrial fertiliser produced by petrochemical synthesis (ammonium nitrate fertiliser) or from mineral extraction (phosphorus, potassium, etc.). Manufacturing them entails large quantities of energy, high greenhouse gas emissions and the use of fossil resources. Throughout the food production and distribution chain, the discharge of large quantities of nitrates and phosphates contributes to the eutrophication of aquatic environments, makes water unsuitable for numerous purposes, including human consumption, and generates atmospheric pollution.

Moreover, the generalisation of mains sewage systems in western cities, which accompanied exponential urban growth in the 20th century, heavily tilted the management of human waste towards linear systems that generate environmental impacts. The typical wastewater management system in western cities, based on the trio of "flush toilets – mains sewer – treatment plant", mixes and dilutes urine and faecal matter into the 150 litres of domestic wastewater (about 20% of it from flush toilets) discharged by every inhabitant each day (Esculier et al., 2018). In a large proportion of cities, especially in the Global South, sanitation systems are rarely centralised, and in many cases completely absent. In

these circumstances, the obstacles to the development of frugal models for the management of urine and faecal matter are somewhat different (WHO, 2019).

In Europe, the imperative to protect aquatic environments has led to the construction of treatment plants to remove or eliminate certain substances in wastewater before the purified water is discharged into the environment. However, the solutions employed are costly in infrastructures, chemical reagents and energy, emit greenhouse gases (especially N₂O), and are only partially effective in protecting aquatic environments. In Paris, with climate change, the expected fall in the flow of the Seine combined with the anticipated increase in population, will have a self-reinforcing impact: more effluents to treat and less water to dilute them. A deterioration in the state of the Seine will be hard to avoid, without treatments that are very costly to implement and by no means guaranteed to work.

In addition, nutrient recovery is very deficient in conventional wastewater management. In Paris, at present, only 4% of the nitrogen and 41% of the phosphorus from human excreta is recovered for agricultural purposes, through the spreading or composting of treatment sludges (Esculier et al., 2018). This was not always the case: in the early 20th century, the rate of agricultural recycling of nitrogen and phosphorus from human excreta from the city of Paris was respectively around 50% and 70%, at a time when the city's population was already more than 3 million (Esculier & Barles, 2019). The need for an ecological transition in our methods of managing human excreta is therefore an invitation to consider alternatives to the current sanitation system and to reopen the debate over mains sewerage systems a century on.

2.2. Source separation: a promising, frugal, less polluting and more hygienic paradigm

Source separation is an alternative approach to sanitation, in which different flows (urine, faecal matter, domestic water, rainwater, etc.) are collected separately to make treatment and recovery easier, particularly the recycling of the nutrients contained in them. Most of the nutrients ingested then excreted by the human body are concentrated in urine (85% of the nitrogen and 65% of the phosphorus) in small volumes. The selective collection of urine would therefore seem to be an appropriate way to improve the rate of nutrient recycling and limit discharge into rivers. It can be collected from dry urinals or from urine diversion toilets, using very little or no water. Different treatments are possible, ranging from simple storage for local use, to more complex industrial processing, resulting in different recovery products and systems, for example an odour-free fertiliser for commercial distribution.

In sanitation terms, separation at source generates savings of water, energy and reagents, and helps to protect the environment, in particular aquatic environments. From an agricultural perspective, it obviates the need to produce chemical fertilisers, saves fossil resources and reduces the associated energy and environmental footprint. And finally, it offers a way to incorporate the management of human waste (urine and/or faecal materials) into the territory's food system, by returning ingested nutrients to agricultural land in the form of fertilising materials.

The interest in source separation, and more specifically in the recovery of nutrients that are primarily contained in urine, re-emerged in Europe in the early 1990s, after a century of "blindness" to the richness of this resource (Drangert, 1998). Numerous community projects have emerged in Sweden and more broadly in Scandinavia, in eco-villages where urine is collected and recycled on nearby farmland. The German-speaking countries have also taken up the issue, with an approach more focused on academic research into the development of processes for converting urine into urino-fertiliser and on vacuum toilets (Larsen et al. 2013 - Part IV).

In France, as well as the community dynamic already underway, pressures on wastewater management in the Paris conurbation have sparked local interest in the source separation of urine in the last five years, marked among other things by the involvement of SIAAP and the Agence de l'Eau Seine Normandie (AESN) in the OCAP action-research programme since 2015. These two bodies have incorporated the source separation of urine into their strategic plans (SIAAP 2030 for SIAAP; Seine basin climate change adaptation strategy and Planning and Water Management Masterplan for AESN). Since 2018, AESN has fully integrated source separation into its operational programme and plans to provide subsidies of up to 80% for source separation implementation projects. Political tools are thus being introduced to support the development of source separation. Nonetheless, there exists no legal framework dedicated to the approach, by contrast with the 19th century, when this practice was the norm.

2.3. Does source separated urine fall within wastewater legislation? The legacy of misdirected legal framework

The first Parisian sewers were built to collect rainwater and to discharge water and street sludge outside the city. In the 19th century, discharging urine and faecal matter into the sewer was forbidden, as they were stored in cesspools and collected separately for fertiliser production. When domestic water systems were installed in Paris buildings, people began using flush toilets and the contents of cesspools became more and more diluted, with the result that it was increasingly uneconomical for cesspool emptiers to collect them. Resistance to these resources being discharged into the sewers was nevertheless strong enough to stop it happening for decades: initially only rainwater could be collected in the sewers, followed after 1852 by greywater. Once the Paris authorities had tested and approved sewage farms and the direct spreading of wastewater on farmland, the situation changed completely, and the discharge of urine and faecal matter into the sewers became compulsory in 1894. However, this circular scheme did not survive the expansion of the city and the competition with chemical fertilisers. Circular management of urine and faecal matter peaked in the 1910s and direct discharge into the river became the primary means of disposal of human excreta soon afterwards. From the 1970s onward, most human waste was processed in wastewater treatment plants, with limited nutrient recycling through the spreading of sewage sludge (Esculier & Barles, 2019).

The Parisian model of sewer collection of urine and faecal matter gradually extended to other French cities, but only became the norm after WWII. In rural areas, the introduction of the flush toilet and domestic water supply was gradual. Septic tanks were the norm for the management of human waste where the population was small – defined as fewer than 150 people in the 1969 ministerial order.⁵ Today, French law distinguishes between collective sanitation and non-collective sanitation for the management of wastewater (and hence human excreta). The existence of a public sewer is the main factor that distinguishes between these two forms of sanitation: in collective sanitation, wastewater (and human waste) are collected in a publicly owned sewer; in non-collective sanitation, there may be a privately owned autonomous wastewater treatment system or a privately owned sewer (and wastewater treatment). Where a public sewer exists, household connection is compulsory.

Where does the separate collection of urine and faecal matter fit into this conceptual framework? Before 2009, dry collection of human excreta was not covered by legislation. It was introduced in the 2009 Order, which refers to non-collective sanitation as a “specific case”,⁶ but with very restrictive conditions, notably the obligation to manage it *in situ*. This obligation is conceptually problematic since it precludes the possibility of recirculating nutrients to agricultural land. Nevertheless, it shows that the use of domestic dry toilets was becoming sufficiently widespread to require legislators to provide a framework for this “new” way of managing human waste. However, though human excreta can now be managed separately, their status is not clearly defined (Brun et al., 2020).

In 2010, a question was addressed to the Ministry in charge of sanitation on the possibility of installing dry toilets in a collective sanitation zone (question No.73941 of 03/16/2010). The answer was that connection to the public sewer is compulsory but that installation of dry toilets is possible, i.e. the discharge of excreta into the sewer is not compulsory. These dry toilets would thus fall under the legislation on non-collective sanitation, despite being located in a collective sanitation zone. But what if human excreta were to be collectively managed outside the sewer? Source separation clearly emerges as a hybrid system that is not properly taken into account in French law. Moreover, practitioners lack sufficient knowledge of this new paradigm to be able to incorporate it easily into their activities. Source separation falls within a legal vacuum that leads into two different paths:

- in many cases, it leads to the rejection of source separation, either because the legal vacuum is interpreted as a proscription, or because the legal risks are perceived as too great;

- in some cases, it creates space for innovation. A legal framework necessarily develops after the emergence of new practices, not in anticipation. In the meantime, other legislative frameworks can be applied to give legal security to source separation projects (such as the spreading of septic tank sludge or the standardisation of fertilisers). The sections that follow show that the ability of the actors to get to grips with source separation will depend on the sociotechnical configuration in which they operate.

3 MATERIAL AND ORGANISATIONAL CONSTRAINTS: EVIDENCE FROM THE PROJECTS EMERGING IN DENSE URBAN ENVIRONMENTS

3.1. Organising collection, treatment, agricultural recycling

Dense urban environments are favourable to source separation because of the quantity of nutrients that can be recovered. However, these conditions impose specific spatial, technical and logistical constraints, which have to be accommodated by those running human waste collection and recovery projects. This was the case for the three projects discussed below.

The « ZAC de Saint-Vincent-de-Paul » (Paris 14th) is an urban development zone situated on a former hospital site designated for an eco-neighbourhood conversion project. The plan here is to test separate urine collection across the site, with the goal of treating urine *in situ* through a nitrification-distillation process capable of producing a fertiliser that concentrates the nutrients in 5% of the initial volume. The project's backers, the City of Paris and Paris & Métropole Aménagement (PMA), are considering this type of treatment especially in the light of the city's spatial and logistical constraints, since it reduces the volumes that need to be transported off the site for recovery purposes: "*Saint-Vincent-de-Paul is something of an enclave in inner-city Paris [...] and bringing lorries into an enclave isn't great... So the option we are looking at [...] [is to] process, reduce and concentrate the volumes in situ*" (Ghislain Mercier, Sustainable Cities Manager at PMA).

In Grenoble (Isère), an apartment building, Au Clair du Quartier, completed in 2017, is fitted with urine diversion dry toilets; faecal matter is collected and composted *in situ*, whereas urine goes into the public sewer. The choices made (separation toilets, collection and recovery of faeces only), which lead to a tenfold reduction in the volumes needing to be stored and managed in the building, compared with the collection of both urine and faecal matter, were prompted by spatial and logistical constraints. The residents have limited space in their urban building, which has no cellar and a small attached 200 m² garden, to store, compost and spread the material. Moreover, the three-storey building has no lift, and the materials have to be carried by hand in buckets. Urine collection by pipe was not considered, and the collection of both faeces and urine in buckets would have entailed more frequent emptying and/or heavier buckets, a logistical task that the residents considered too burdensome.

In Bordeaux (Gironde), a community organisation called La Fumainerie (The human manure factory) was set up in 2019 to assist residents who would like dry toilets in their homes, but lack a garden or space to store and recycle materials *in situ*, raising the question of their collection and transport for recycling elsewhere. In 2020, the organisation started an experiment to install dry toilets in city-centre homes, and to have the materials collected by delivery scooters for recycling by partner enterprises. La Fumainerie opted for the urine diversion dry toilets as the solution to facilitate human waste recycling: the plan is to compost the faeces and to use the urine to produce agricultural biostimulants. This choice is also prompted by logistical factors: separate collection makes it easier for the emptier to handle and transport the materials (lighter and more manageable containers). In addition, separation reduces the volume of wood shavings needed to cover the faeces and therefore the frequency of collection, as well as limiting odours. It should be noted that the La Fumainerie project also raises legal questions, since it entails installing dry toilets in the city centre, in a collective sanitation zone, a situation not currently covered by the regulatory framework (see 1.3).

These examples highlight the fact that city-based source separation projects require accommodations with restrictions and issues that are specific to dense urban environments (shortage of space; the issue of the evacuation and transport of materials, which often cannot be treated and recycled locally because of a lack of space and the absence of nearby gardens and agricultural green areas...), but are also specific to each site. While the context partly guides the projects and choices, the range of possibilities remains very wide. The three cases cited illustrate the variety of possible options (collection of urine and/or faeces, recycling of materials *in situ* or off-site in the form of compost, urine-based fertiliser, biostimulant...).

3.2. Territorial tiers and complex interplay of actors

Beyond the technical and logistical questions specific to dense urban environments, there is the complexity of the interplay of actors nowadays involved in the governance of sanitation at the scale of a city of this size.

- The regional scale

The metropolis of Paris occupies a special position in a country with highly centralised functions. Nonetheless, a distinction needs to be made between, Paris as a city (2.2 million inhabitants) and the Greater Paris Metropolis (7 million inhabitants), on one hand, and on the other hand the collection of municipal entities that together constitute the urban region (10.7 million inhabitants). The City of Paris has shown a clear commitment to environmental issues under recent municipal administrations. It is

part of the C40 Climate Group⁷. Its mayor, Anne Hidalgo (Socialist Party, historical social-liberal tendency) was re-elected in 2020 with the support of the French ecologist party (Europe Ecologie les Verts, liberal ecology tendency). At regional level, conversely, Île-de-France as a region is currently headed by a conservative liberal party (Les Républicains) with very little interest in environmental issues, and it is this same political current that heads the majority of municipalities in the region.

In addition, the “Greater Paris” metropolis is itself the product of a territorial *mille-feuille*. At its creation, completed in 2015, it was superimposed on the existing local authorities. Today, it is the municipal groupings, the “Etablissements publics territoriaux” (EPT), which are in charge of sanitation, except in the case of Paris, where the city itself is directly responsible. While wastewater collection is generally done by the municipalities or the EPT, in the inner suburbs of Paris there is also the tier of *départements*, which are in charge of transport. Finally, waste treatment is delegated to a higher level. In the Paris region, it is SIAAP, the Syndicat Interdépartemental pour l’Assainissement de l’Agglomération Parisienne, the country’s largest institution, which is responsible for the interdepartmental transport and treatment of wastewater for all the municipalities in the metropolis, as well as for many neighbouring municipalities located in the region, serving a total of more than 8 million inhabitants and treating a total daily volume of 3 million cubic metres of wastewater in six treatment plants. SIAAP is run by a management and a Board of Directors that includes representatives of the local authorities.

The toilet flush and the sewer introduce a distance between inhabitants and the question of wastewater that is not just material, but also symbolic, as noted by Gay Hawkins, (2004). In Paris, moreover, wastewater management is carried out within a complex system of governance in which decision-making involves multiple territorial levels and is interwoven with regional and national political issues. This situation also helps to maintain a wide gap between citizens who live in the region and choices about the technical systems employed for the handling of wastewater. As long as they largely perceive these systems as a black box, how can citizens get involved in future choices about the handling of their own bodily waste?

- Large local authority scale

Source separation projects make it necessary to design and manage new systems for collecting, treating and recycling human excreta, often at local scale. This raises the question of the governance of these new systems and the sharing of roles and responsibilities between public and private actors in multiple sectors: urbanism and housing, water, waste management, agriculture, etc. As noted by McConville et al. (2017), one of the challenges of source separation is the crosscutting nature of the issues raised and the sectors concerned; a shared vision, coordinated action and a clear division of roles and responsibilities between the different stakeholders are needed for the projects to work. The case of Saint-Vincent-de-Paul (see inset) illustrates the complexity of both the technical and the governance choices that need to be made. The plan for separate urine collection across the future eco-neighbourhood raises a number of questions. Where to put the different components of the proposed system: storage tanks, separate collection network, local urine treatment unit? In a public space, a private space? Managed by whom? There was extensive debate on these questions. The existing sanitation players might be reluctant to commit to experimental projects that differ from the conventional sanitation management system, and entail new powers and responsibilities, as well as a degree of uncertainty and risk. In the end, the decision was taken that the Saint-Vincent-de-Paul urine collection and treatment project would be managed publicly, by the City of Paris. Different choices have been made in other experiments: in 2010, for example, with regard to the first wastewater heat recovery projects, the City of Paris eventually outsourced the running of the sections of the public system concerned to a private company.

So while the territorial governance of sanitation management looks to be reliant on a complex and multitiered set of actors, certain specific spaces are nevertheless opening the way to the emergence of opportunities for source separation. These initiatives can also benefit from the concentration of skills present in the territory.

4 TOWARDS THE INTEGRATION OF SOURCE SEPARATION INTO URBAN PRODUCTION?

Until 2010, the quest for frugal and circular handling of human waste was mainly driven in France by civil society organisations and small enterprises, allied in their vision of ecological sanitation,

focusing on local action and largely confined to the rural world. In low-density areas (where materials can be recycled locally), initiatives are becoming more numerous and the techniques applied are largely settled. This is far from the case in urban territories. The creation of several academic research programmes around the issue in the last decade in France, including the OCAPAPI programme, is helping to open up the city to these ideas. These academic institutions are familiar with dense urban conditions, where the largest volumes are generated (Legrand, 2020). In the urban environment, source separation is currently in the experimental phase, and has not yet reached a stage of application with stable and robust methods that can be applied routinely by urban planning professionals and local authorities. At the same time, the emerging interest in the industrial sector and in the big wastewater management corporations, while worth noting, has so far produced few results, for at least two reasons. First, they seem to be waiting for a viable business model, and second, their standpoints favour “end of pipe” solutions that do not challenge the supremacy of wastewater treatment plants, which are central to their activities and to their business model. Under these circumstances, the path from research to the implementation of pilot projects is laborious: how to make the transition from the demonstration phase to the upscaling phase?

4.1.- On the “margins” of urban production

While there are a handful of buildings fitted with dry toilets on the initiative of their owners in the city of Paris, initiatives are primarily implemented on the “margins” of urban production, i.e. first on the margins of the built environment (temporary urbanism) and second outside the framework of conventional real estate development.

- Public space & temporary urbanism

At present, experiments in the source separation of urine and faecal matter in the Paris region are taking place primarily in the interstices of the urban matrix, i.e. in spaces that require no intervention on the built fabric. Quantitatively, they mainly involve event spaces (dry toilets at festivals that partly replace chemical toilets). Festivals (e.g. We Love Green; Fête de l’Humanité) are large-scale but temporary events that generate exceptional flows of waste materials. Managing those materials off the grid, without water, is a way to absorb and divert this surplus, which is already recycled via ad hoc systems at regional scale by dry toilet hire companies operating in the Paris region. To a lesser but growing extent, these solutions are also moving onto construction sites: they provide a service to workers in the construction sector, including those working on the underground sites for the city’s new rail line, the Grand Paris Express.

A second context where source separation is active, still on an ad hoc basis, is public space (Bourcier, 2019). In the last few years, waterless urinals designed to collect and recover liquid excreta have been installed in the streets of the capital, together with a recycling plan whose logistics have not yet been consolidated. These urinals have added to the different models currently available in public space (which are either emptied regularly or directly connected to the sewer system). At present exclusively male, these urinals are a complement to the stock of self-cleaning toilets, which is deemed inadequate, along with the temporary chemical toilets installed in places characterised by high seasonal traffic (riverbanks, parks).

A third context is sites associated with “temporary urbanism”, i.e. places designated for refurbishment where local authorities and civil society organisations collaborate to reduce the risk of squatting and to prepare the ground for future uses. In these conditions, the forms of occupancy and the infrastructures, which are often light and temporary and partly peripheral to urban planning norms, open the way for new flow management initiatives. “La Cité fertile” in Pantin (93), for example, a brownfield site that has been converted to a place of recreation and consumption around the theme of urban farming, is equipped with 10 dry toilet cabins (urine goes into the sewers, faeces are composted *in situ*; Les Grands Voisins in the 14th arrondissement of Paris (future site of the Saint-Vincent-de-Paul eco-neighbourhood) has a demonstration model of a women’s urinal with collection (see below). Some attempts to install dry toilets for public use have nevertheless ended in failure, as a result of logistical and practical constraints and difficulties in educating users. At first sight, these failures can be attributed to a lack of commitment on the part of the actors concerned, given that in physical terms the sites had enough space to handle and recycle the materials *in situ*. One iconic example of such a failure was the COP21 in Le Bourget.

A final, even more marginal case of the development of initiatives for the source management of human waste is urban housing areas situated in collective sanitation zones but not linked to the mains

system, such as floating housing (houseboats), which are highly specific ; and finally slums, which are home to several thousand people in the Paris region. These forms of housing, though treated as invisible and not included in sanitation schemes, nevertheless constitute particular urban configurations, and in certain cases their informal dimension, notably the lack of sanitation, offers an opportunity for new solutions to emerge (e.g. 6B in Saint Denis where *Arbor Loos* have been installed).

- “Inclusive” urbanism based on the example of participatory housing

Participatory housing (PH) can also be a favourable environment for experiments in source separation. Some PH houses or apartment buildings – mostly in the countryside, but also sometimes in cities – are fitted with dry toilets. The few urban apartment buildings in France, whether completed or under construction, with homes fully equipped with urine diversion dry toilets are currently PH buildings. This is the case for the Au Clair du Quartier apartment building in Grenoble, built in 2017 (see 2.1), but also for a PH Ecoravie building in Dieulefit (Drôme), constructed in 2016. Currently under construction, the L'Ôdôberge PH project in Dol-de-Bretagne (Ille-et-Vilaine) also includes a plan for 24 apartments across three buildings to be fitted with urine diversion dry toilets that will recycle both urine and faeces. So a new dynamic in favour of source separation in urban PH apartment buildings seems to be emerging. PH might be a favourable terrain for experiments with such projects, for different reasons.

They generally involve individuals who are sensitive to environmental issues and open to alternative approaches. Moreover, the desire of PH groups to be agents of their own housing, with individual participation in the design and management of homes, may also be seen as factors that are favourable to the implementation of source separation. Projects of this kind need to be discussed and accepted by the different residents concerned, and require their participation to work. While PH would seem to be favourable terrain for the development of alternative sanitation projects, such projects are nevertheless a matter of debate within PH groups, are not always accepted and are sometimes abandoned or reshaped over time. Cooperation in the design of these projects by the different residents concerned, and their adaptation to the conditions and to the needs and constraints of the group, are key factors in their success. Projects like Au Clair du Quartier and L'Ôdôberge challenge the conventional sanitation system in its governance. They suggest a third way between non-collective (individual) and collective (public) sanitation: collective management of their excreta by a group of residents at the scale of individual buildings, with partial treatment and recycling *in situ*. This third way reshapes the relations between the individual and the public sphere, with the appearance of a new tier of decision-making, management and responsibility: the resident collective (Joveniaux, de Gouvello and Legrand, 2020).

Pilot projects are thus emerging, but they nevertheless remain at the margins of urban production. While the scale of these operations remains too small to demonstrate their legitimacy in a more conventional context, they are nevertheless beginning to build up a fund of experience that could favour the upscaling of new initiatives.

4.2. Eco-neighbourhoods as a favourable demonstration context?

Inset: description of the two eco-neighbourhood projects containing demonstrators

The LaVallée eco-neighbourhood project

Situated in Hauts-de-Seine (92) on the former École Centrale site, the LaVallée eco-neighbourhood covers an area of more than 20 ha, standing between Châtenay-Malabry town centre, the green corridor and parc de Sceaux. Construction work on this eco-neighbourhood, intended to house more than 4500 people, began in 2018. Included in the plan are amenities such as a school complex, a secondary school, a crèche, a sports area, an aquatic centre, a strolling area, an urban farm, a third place, offices and co-working spaces, cafés and restaurants, shops. The project was marked by an unusual partnership between the firm Eiffage Aménagement and an academic institution, i-Site Future. Working with Eiffage's professionals in the E3S (“Smart, sober and safe eco-neighbourhood”) programme, almost 60 researchers from different disciplines joined forces to support urban innovation around four central themes: low carbon, the circular economy, nature in the city and new uses. This included the introduction of a demonstration model for a new relationship to water and nutrients, including a rainwater recovery system and male and female urinals designed to collect urine for use in fertilising the green spaces.

The Saint-Vincent-de-Paul (SVP) project

In 2016, a ZAC (Zone d'Aménagement Concertée –Urban Development Zone) was created on the former SVP hospital site, located in the 14th arrondissement of Paris. This 3.4 ha plot is the site of a conversion project to develop a primarily mixed residential eco-neighbourhood with 600 dwellings, but also shops, a school, etc.

Construction work on the eco-neighbourhood began in 2018, and should be completed in 2024. The City of Paris would like to make SVP a pilot site for the city's energy and ecological transition policies. On this basis, Paris & Métropole Aménagement, a public company that it commissioned to develop the ZAC, designed a strategy for SVP founded on the commitment to a "Triple Zero": zero carbon, zero waste, zero discharge. It was within the context of this global environmental approach that the plan for separate urine management emerged in SVP. This project, which reflects the political aspirations of the City of Paris, is in the final phase of design and its principle and procedures should be approved in 2020.

While eco-neighbourhoods might also seem to be favourable contexts for the demonstration of source separation in cities, no projects of this kind have so far been completed in France. However, two eco-neighbourhoods currently under construction intend to test the process: Saint-Vincent-de-Paul (SVP) in Paris and LaVallée in Hauts-de-Seine (see inset). It should be noted that these two eco-neighbourhoods operate in different institutional frameworks: in SVP, the project is backed by public actors, the City of Paris and the local public company Paris & Métropole Aménagement (PMA), whereas LaVallée is run by a public-private partnership between Chatenay municipality and the Eiffage Group⁸.

In both cases, before the establishment of a large-scale project for the separation of urine at source (for a district in the case of SVP, for a third place in LaVallée), the goal is to begin with a small scale demonstration project. In the case of SVP, this is happening as part of a temporary urbanism experiment, in areas still not affected by the construction work on the eco-neighbourhood. Women's urinals have been installed in a yard adjacent to a meeting and social centre adjoining a bar and snack area ("Les Grands Voisins" site). At LaVallée, the aim of the the E3S research partnership is to set up a project scale demonstrator in the office premises allocated to the Eiffage teams working on the site. The target users are therefore different. In SVP, they are people who attend the events organised by Les Grands Voisins and the bar, which means that the test population's profile is very varied. At LaVallée, the only users are Eiffage employees.

The experimental status is also different. At Les Grands Voisins, it is associated with a piece of temporary urbanism, which permits a degree of operational flexibility. Although supported by PMA, the design of the women's urinals is the brainchild of a female designer and it was built through an appeal to the site's local users. In Chatenay-Malabry, the construction of the demonstrator, although a product of the E3S partnership, has to fit in with the pre-existing formal procedures for the construction of the neighbourhood, decided by Eiffage. The researchers who designed the demonstrator have no control over its construction and have had to accept a reinterpretation of the purpose of the system. This reinterpretation comes from the corporate actors, who are governed by other priorities and constraints (in particular time constraints) linked with the building of the neighbourhood itself.

Trying to build the city in a different way, but with conventional actors, is not easy, because of the influence of highly codified operational frameworks and procedural systems, which can compromise the possibilities for experiment. Overcoming this difficulty will require the operational actors to be prepared to take certain liberties with these frameworks.

Conclusions

The need for a change to the paradigm of centralised sanitation and human waste management in the urban environment arises first from a material fact about the relations between water management, energy saving and food production. Given this reality, how can the territorial players organise themselves to initiate change at the scale of a megacity? How can they make the transition from the recognition of disaster to the implementation of action strategies?

As things stand, the approach applied in PH or in eco-neighbourhoods cannot be upscaled has a formalised methodology. Indeed, translation into action is not simply about favourable conditions: behind, there are men and women with their history, their knowledge and their capacity to tackle this specific subject from a perspective of practical action. While these marginal contexts (e.g. PH, temporary urbanism) offer potential frameworks for implementation, the implementation of Source separation in these contexts cannot be taken for granted, let alone be guaranteed outside, i.e. in a more conventional approach to the production of the city. Nonetheless, early signs of broader interest are emerging in France, such as the fairly radical conclusions of the citizen convention on climate which brought together 150 citizens drawn by lot, or else the ecologist breakthrough in the 2020 municipal elections in several of France's big cities and metropolises (Bordeaux, Grenoble, Lyon, Besançon and Paris).

The limitations of the current sanitation system have now been clearly demonstrated, and these limitations become more extreme in the context of a megacity. The case for a paradigm shift no longer needs to be made, but in France the transition to action is still in its infancy. For these innovative practices to be upscaled and transposed to the production of the city, much still needs to be done: (1) to convince, but above all to support, the actors involved in managing urban flows and in the agricultural world; (2) to argue for an extension of the scope of participatory urbanism, while educating inhabitants about the sustainability issues around water and human waste management; (3) to emphasise spatial planning scenarios other than the ever increasing expansion of urban hubs and the relentless international competition between them, with the objective of establishing sustainable nutrition/excretion systems. This roadmap needs to be part of a wider process of education on the importance of the organic and mineral cycles that pervade the Earth and make us what we are.

References

- Bourcier, S.** 2019. *Le « pipi sauvage » en ville ou l'insoutenable fluidité des êtres. Analyse ethnographique d'une pratique citadine et des conditions de sa régulation dans l'espace public parisien*. Master thesis, EHESM Marseille.
- Brun, F., Joncoux, S., de Gouvello, B., Esculier, F.,** 2020. Vers des filières de valorisation des urines humaines. Le regard des agriculteurs franciliens. *Etudes rurales* (in press)
- Drangert, J.-O.,** 1998. Urine blindness and the use of nutrients from human excreta in urban agriculture. *GeoJournal* 45: 201-208.
- Esculier, F. & Barles, S.** 2019. Past and future trajectories of human excreta management systems – the case of Paris XIXth-XXIst centuries. In: *The Seine River Basin*. Flipo, N., Labadie, P., Lestel, L. (Eds). The Handbook of Environmental Chemistry. Springer, Berlin, Heidelberg. DOI : 10.1007/698_2019_407_
- Esculier, F.** 2018. *Le système alimentation/excrétion des territoires urbains : régimes et transitions socio-écologiques*. Thèse de doctorat de l'Université Paris-Est. Sciences et Techniques de l'Environnement. <https://hal.archives-ouvertes.fr/tel-01787854>
- Esculier, F.,** Le Noë, J., Barles, S., Billen, G., Créno, B., Garnier, J., Lesavre, J., Petit L. et Tabuchi, J.-P. 2018. *The biogeochemical imprint of human metabolism in Paris Megacity: a regionalized analysis of a water-agro-food system*. Journal of Hydrology. DOI : 10.1016/j.jhydrol.2018.02.043.
- Esculier, F., Tabuchi, J.-P., Créno, B.** 2015. Nutrient and energy flows related to wastewater management in the Greater Paris: the potential of urine source separation under global change constraints. *International conference on Water, Megacities and global change*, Paris.
- Hawkins, G.** 2004. Shit in public. *Australian Humanities Review*, (31-32).
- Joveniaux, A., de Gouvello, B. & Legrand, M.,** 2020. L'habitat participatif comme producteur d'alternatives dans la gestion des flux et services collectifs urbains : le cas de l'assainissement écologique. *Flux*. (under review).
- Larsen, T.A.,** Udert, K. M., Lienert, J. (Ed), 2013. *Source Separation and Decentralization for Wastewater Management*. IWA Publishing.
- Legrand, M.** 2020. Digestions fertiles, le retour au sol des excréments humains. *Revue d'Anthropologie des Connaissances* (in press).
- Mc Conville, J.,** Kvarnström, E., Jönsson H., Kärman E., Johansson M., 2017. Source separation: Challenges & opportunities for transition in the Swedish wastewater sector. *Resource, Conservation and Recycling*, 120: 144-156.
- Steffen, W.,** Richardson, K., Rockstrom, J., Cornell, S.E., Fetzer, I., Bennett, E.M., Biggs, R., Carpenter, S.R., de Vries, W., de Wit, C.A., Folke, C., Gerten, D., Heinke, J., Mace, G.M., Persson, L.M., Ramanathan, V., Reyers, B., Sorlin, S., 2015. *Planetary boundaries: Guiding human development on a changing planet*. Science. doi:10.1126/science.1259855
- Thisse J.F. & Van Ypersele T.,** 1999. Métropoles et concurrence territoriale. *Economie et statistique*, n°326-327 : 19-30
- World Health Organization,** 2019. *Progress on household drinking water, sanitation and hygiene 2000-2017: special focus on inequalities*. Geneva.

¹ Since 2000, every year in Île-de-France, an average of 30,000 apartments, 9000 houses, and 600,000 m² of office space have been built every year, linked with the implementation of the Grand Paris Express, an additional transport line designed to improve connections between the city's different suburban areas.

² 650 L per person per day (monthly minimum flow with a 5-year return period).

³ Optimisation of urban Carbon, Nitrogen and Phosphorus cycles - www.leesu.fr/ocapi.

⁴ Syndicat Interdépartemental pour l'Assainissement de l'Agglomération Parisienne (Paris region interdepartmental wastewater management federation)

⁵ Order of 14 June 1969 on septic tanks and devices or systems for purifying the effluents from residential buildings.

⁶ Order of 7 September 2009 setting the technical requirements applicable to non-collective sanitation facilities that receive a gross quantity of organic pollution less than or equal to 1.2 kg per day BOD5

⁷ URL: <https://www.c40.org/cities/paris>

⁸ The operation is headed by a SEMOP (Single Operation Semipublic Company), 66% of which is owned by Eiffage Aménagement and 34% by Châtenay-Malabry municipality.