NOTE RAPIDE
L'INSTITUT PARIS REGION #41

Joskin

ENVIRONMENT
December 2020 • www.institutparisregion.fr/en

RECOVERING NITROGEN AND PHOSPHORUS FROM URINE TO IMPROVE ECOLOGICAL AND FOOD SECURITY

29 million
NUMBER OF BAGUETTES THAT COULD BE PRODUCED DAILY FROM WHEAT FERTILISED USING URINE FROM THE 12.1 MILLION PEOPLE IN THE PARIS REGION: EQUIVALENT TO TEN TIMES DAILY CONSUMPTION

703 tons
AMOUNT OF NITROGEN CONTAINED IN SYNTHETIC INDUSTRIAL FERTILISERS USED EVERY DAY TO FEED PEOPLE IN THE PARIS REGION (INCLUDING IMPORTS)

NITROGEN AND PHOSPHORUS, WHICH ARE VITAL TO AGRICULTURE, CURRENTLY DEPEND TO AN ALARMING DEGREE ON MASSIVELY IMPORTED FOSSIL RESOURCES. BEYOND ITS IMPACTS ON AQUATIC ENVIRONMENTS AND THE CLIMATE, THIS REALITY POSES A HUGE UNRECOGNISED THREAT TO THE SUSTAINABILITY OF OUR FOOD. THE SEPARATE COLLECTION AND RECYCLING OF URINE TO MAKE FERTILISER MAY BE PART OF A SOLUTION, PROVIDED SIGNIFICANT CHANGES ARE MADE TO FOOD AND SANITATION SYSTEMS. SOCIAL ACCEPTABILITY IS ALSO AN ISSUE. THIS PERSPECTIVE INVOLVES REDESIGNING URBAN SANITATION SYSTEMS AND CHANGING THE WAY THEY CONNECT TO THE RURAL ENVIRONMENT. ACROSS THE WORLD, IN FRANCE, AND NOW IN THE PARIS REGION, KEY ACTORS ARE MOVING IN THIS DIRECTION.

The fact that planetary boundaries have been, or are being, transgressed in areas such as the collapse of biodiversity, land artificialisation or climate change is high on the list of concerns relating to the future of our societies. The mechanisms which, until now, allowed populations and purchasing power to grow in developed and emerging countries seem to be reaching their limits[1]. As we seek renewable resources, nitrogen and phosphorus, although essential to the human metabolism, tend to pass under the radar. The predictable scarcity of these resources seems to be overshadowed, in the minds of the general public and political decision-makers, by other subjects relating to the circular economy and frugality (energy, construction materials, and so on) for which the solutions seem less taboo than the conversion of human excreta (see glossary) into fertiliser. And yet the climate change adaptation strategy for the Seine-Normandy Basin[2] and the regional circular economy plan forming part of the regional waste prevention and management plan for the Paris region both explicitly mention the subject[3]. It thus seems relevant to assess the real or imagined challenges, obstacles and benefits relating to this subject in the Paris region.

L'INSTITUT PARIS REGION
OCAPI

On the cover
After treatment, urine can be applied onto fields as a natural fertiliser. Its efficiency is similar to that of nitrogenous synthetic fertilisers, as long as landspreading limits ammonia volatilisation loss. Drop nozzles, for example, make it possible to prevent volatilisation because they touch the ground during application.

1. NEST building, Empa/Eawag campus.

2. Aurin reactor.

THE CURRENT NUTRITION/EXCRETION SYSTEM IS LINEAR, WASTEFUL AND POLLUTING

Most people are unaware that the production of conventional foodstuffs makes use of nitrogen-based fertilisers industrially synthesised using the Haber-Bosch process, or at least do not make the connection between this process and its dependence on petroleum products. To feed the Paris region, over half of the nitrogen comes from synthetic fertilisers (see central diagram). Producing them consumes fossil natural gas, requires a lot of energy and emits large amounts of greenhouse gases. Phosphorus and most other nutrients are extracted from fossil mines, most of them located abroad. Like fossil fuels, this resource will, potentially in the near future, reach a global production peak before declining[4] unless new practices are introduced.

Throughout the production and distribution chain for foodstuffs, discharging large quantities of nitrogen and phosphorus contributes to the eutrophication (see glossary) of aquatic environments, makes water unfit for certain purposes (including human consumption) and pollutes the atmosphere (with ammonia, nitrous oxide, etc.).

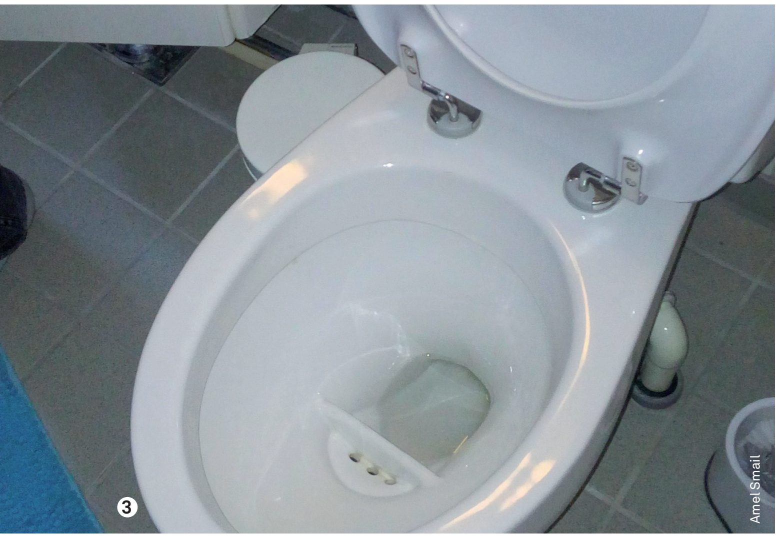
The increasingly widespread use of mains sewage, which accompanied the exponential development of urbanisation in the twentieth century, shifted the management of human excreta towards linear systems that generate environmental impacts. Our sewage system, based on the trio “flush toilet + sewer + sewage treatment plant”, produces some 150 litres of domestic sewage per inhabitant per day, made up of urine and faeces diluted in about 30 litres of toilet flush water mixed with domestic wastewater.

The necessity to protect aquatic environments led to the construction of sewage plants to extract or destroy certain components of sewage before returning it to the natural environment: organic matter, nitrogen, phosphorus, micro-organisms, etc. However, the systems used are costly in terms of facilities, chemical reagents and energy, emit nitrous oxide (a greenhouse gas), and are only partly effective in protecting aquatic environments.

In the Paris region, despite treatment methods and the fact that since 2005 the entire region has been classified as an area sensitive to eutrophication (see glossary), making it possible to require enhanced nitrogen and phosphorus abatement performance from sewage farms, one third of the nitrogen is still being discharged into the Seine: the equivalent of urinary nitrogen produced by four million inhabitants (see central diagram). Water quality is substandard in the downstream sector of Paris. Climate change and the resulting reduction in the river’s rate of flow, combined with population increase forecasts, cause a pincer effect: there is more effluent to be treated and less water to dilute it. This means that the ecological state of the Seine will inevitably deteriorate in the medium term unless increased use is made of treatment procedures whose cost would be disproportionate and which would have environmental side effects.

The current sewage system also makes the recovery and use of components (nutrients, organic matter, water, etc.) more complex. In the Paris region today, only 4% of the nitrogen and 41% of the phosphorus from human excreta are used in farming, via sewage sludge that is either sprayed or composted, though there is increasing reluctance regarding this. The rate is zero for towns that incinerate their sludge.

This state of affairs is the result of a long historic process that has led to the devaluation of human excreta and the uncoupling of urban and rural areas to the detriment of circularity. This was not always the case: in the early twentieth century, agricultural recycling rates for nitrogen and phosphorus from human excreta in Paris were 50% and 70% respectively. However, mixing excreta with domestic and industrial wastewater and rainwater ultimately led to the persistent chemical contamination (from industrial waste) and the temporary biological contamination (from faeces) of drainfields.



3. Wostman separating toilets, used in the agenda 21 operation in the Hyldespjaeldet district in Denmark.

4. "Marcelle" women's urinal allowing urine collection in the Grands-Voisins development (Paris 14th *arrondissement*).

SOURCE SEPARATION: A PROMISING, LESS POLLUTING AND MORE HYGIENIC PARADIGM

Source separation is an alternative approach to sewage treatment that involves separately collecting different flows (urine, faeces and/or grey water) to facilitate treatment and recycling. This practice can allow the recycling of nutrients, the majority of which, once ingested and excreted by the human body, are concentrated in urine: 85% for nitrogen and 65% for phosphorus. Unlike faeces, urine presents a very low and easily controllable risk of pathogen transmission, and offers opportunities to filter out pharmaceutical residues. Collection involves the use of dry urinals or separation toilets that use little or no water. The urine can be treated in different ways, from simply storing it for local use to transforming or even purifying it via a more complex industrial process in order to obtain different usable products, for example deodorised dry fertiliser that can be made commercially available.

Separate urine collection responds to a range of different challenges. As regards sanitation, it saves water, energy and reagents and helps to protect the environment, in particular the aquatic environment. From an agricultural point of view, using collected urine limits the use of other fertilisers, saves fossil resources, and reduces associated energy and environmental footprints. Moreover, such a circular economy for nutrients may help to create connections and a sense of reciprocity between town and countryside: towns produce fertiliser while the countryside provides food.

EXAMPLES OF COLLECTION AND RECYCLING EXPERIMENTS

Since the 1990s, projects involving source separation of excreta have been carried out in Western Europe, mainly Scandinavia and German-speaking countries. For a long time France kept its distance from the movement, restricting itself to initiatives at the level of individual households, mainly in rural settings, on isolated sites or in the field of events management (e.g. festivals). In recent years, a new dynamic has emerged. Research projects and concrete applications have appeared, notably in urban settings and in the Paris region.

Separate urine collection in Swedish eco-villages

Sweden has pioneered urine source separation, implementing the process in several eco-villages and eco-districts as far back as the 1990s. For example, in Understenshöjden, Stockholm's first eco-village, 44 houses are equipped with separating toilets. The urine is collected via a separate network, drained into storage tanks, and then sprayed onto neighbouring fields by a farmer.

In Switzerland, urine from a research centre is being used to produce concentrated fertiliser

On the Empa/Eawag campus in Dübendorf, an administrative and scientific building in use since 2006 has been equipped with dry urinals and separating toilets. The urine is treated on site using a process that makes it possible to concentrate nutrients and drastically reduce the presence of pharmaceutical residues using filters. After an experimental phase in 2015-2018, Aurin became the first fertiliser in the world made of concentrated urine to be officially approved. According to Eawag (the Swiss federal institute of water science and technology), 100 litres of concentrated liquid fertiliser can be made from about 1,000 litres of urine. Aurin is now sold by the Vuna company.

A growing number of projects in France

Several pioneering source separation initiatives in collective buildings have emerged over the past ten years or so in France. They concern different types of locale, including a primary school in Saint-Germé in the Gers département, which is the first state school in France to be equipped with dry separating toilets and dry urinals (installed in 2012). In Dol-de-Bretagne in the Ille-et-Vilaine département, an affordable housing development using a similar system is under construction.

Pilot projects have also recently been emerging in the Paris region. In Achères, the Syndicat interdépartemental pour l'assainissement de l'agglomération parisienne (Siaap) has equipped one of its buildings with dry urinals. The head offices of the European Space Agency in Paris should soon be fitted with separating toilets. The eco-district project on the Saint-Vincent-de-Paul site in the 14th *arrondissement* run by Paris & Métropole Aménagement also includes a urine recovery system on the scale of the district and is already applying it to public toilets on the site.

These initiatives also encourage property developers to include separate urine collection in their projects.

ASSETS FACILITATING TRANSITION: SIGNIFICANT RESOURCES IN THE PARIS REGION

Greater Paris is densely populated and the collection and agricultural use of the urine it produces could help the region's ecological transition. Looking further forward, changes in both agricultural practices and diet coupled with the use of urine-based fertiliser could make it possible to abandon nitrogenous chemical fertiliser to supply food to Greater Paris by 2050 [Esculier, 2018]. Urine collection and recycling could avoid the emission of about 500,000 tons of CO_2 equivalent annually in the Paris region (from sewage farms and synthetic fertiliser factories): this is equivalent to almost 1% of its total emissions.

However promising it may be, the large-scale implementation of source separation raises a number of challenges: technical, economic and cultural issues, adaptation to different urban settings, future development and the creation of new approaches to the collection, management and agricultural use of recovered nitrogen, etc. Launched in 2014, the Ocapi research and action programme aims to study these challenges and identify what helps and hinders the socio-ecological transition of current urban nutrition/excretion systems. Its aim is also to provide support for people setting up source separation projects in the Paris region.

In the framework of the "Eau et Climat 2019-2024" programme, the Seine-Normandie water authority now subsidises up to 80% of the costs of collective projects for the source separation of urine, which should create an economic leverage effect.

WHERE TO START? AN AUSPICIOUS CONTEXT, PRIORITY TARGETS

The Paris region (Île-de-France) is the country's most dynamic region in terms of urban development, and source separation techniques for urine and faeces can de developed most easily in new real estate projects. The production of urban spaces mainly takes two forms: extension, with the creation of new services and networks, including sanitation, which can then be more easily adapted; and renewal, with or without a change of use for the land, which is often accompanied by urban consolidation that requires updating existing utilities.

Since the early 2000s, almost 30,000 units in apartment buildings and 9,000 individual homes are built on average every year[5]. This dynamic is on the rise, driven for example by the objectives of the Sdrif [regional master plan] adopted in 2013, the construction of the Grand Paris Express, etc. Over 80% of new constructions are concentrated in the Paris metropolitan area, mostly in the form of flats (over 70% of homes built). Office developments also offer potential for developing source separation techniques for excreta. Every year, on average, more than 600,000 sq.m. of new or renovated office space has been created in the Paris region[6] since the 2000s, although this has slowed more recently (300,000 – 400,000 sq.m./year) [Roger, 2017]. A key arena for the development of innovations, office real estate is identified as a priority target.

The alternative management of human excreta is also of value in emblematic public locales (concert venues, stations, etc.), whose footfall and visibility can help raise awareness among decision-makers and the general public and disseminate knowledge of such innovative processes. Educational institutions are also a priority target, with 2,400,000 pupils and 790,000 students and apprentices in 2018[7]. The recent dynamic around "third places" (of which there are over 600 today, with over 1,000 planned in 2021) is also attracting the attention of project leaders. The fact that they are intended to be places of social and environmental innovation [Camors & Blein, 2017] makes it possible to imagine experimenting with source separation techniques with the telecommuters and users of these spaces.

Older real estate can also contribute to more effective management of the nitrogen cycle. The case of the Paris region, with its 5.6 million homes of which 4 million are in apartment buildings (Insee, RP 2015), is emblematic of how important it is to plan source separation initiatives in existing urban areas. Moreover, over half the homes were built before the 1970s and require renovation and rehabilitation in order to contribute to energy transition. This is an opportunity to roll out alternative waste separation techniques. The region's 54,000,000 square metres of office space is also concerned by the challenges of renovation and transformation.

TOWARDS THE MASS DEPLOYMENT OF URINE SEPARATION?

Moving from an old model of sanitation that is the legacy of hygienism to a model that combines advances in sanitation with a circular, eco-friendly system will require the mobilisation of public and private actors involved in the construction, renovation and rehabilitation of buildings. The initiatives presented in this summary demonstrate that solutions adapted to different urban forms do exist.

From an agronomic point of view, a spraying trial on a field of bread wheat on the Saclay Plateau, carried out in 2019 by the Ocapi programme and the INRAe,

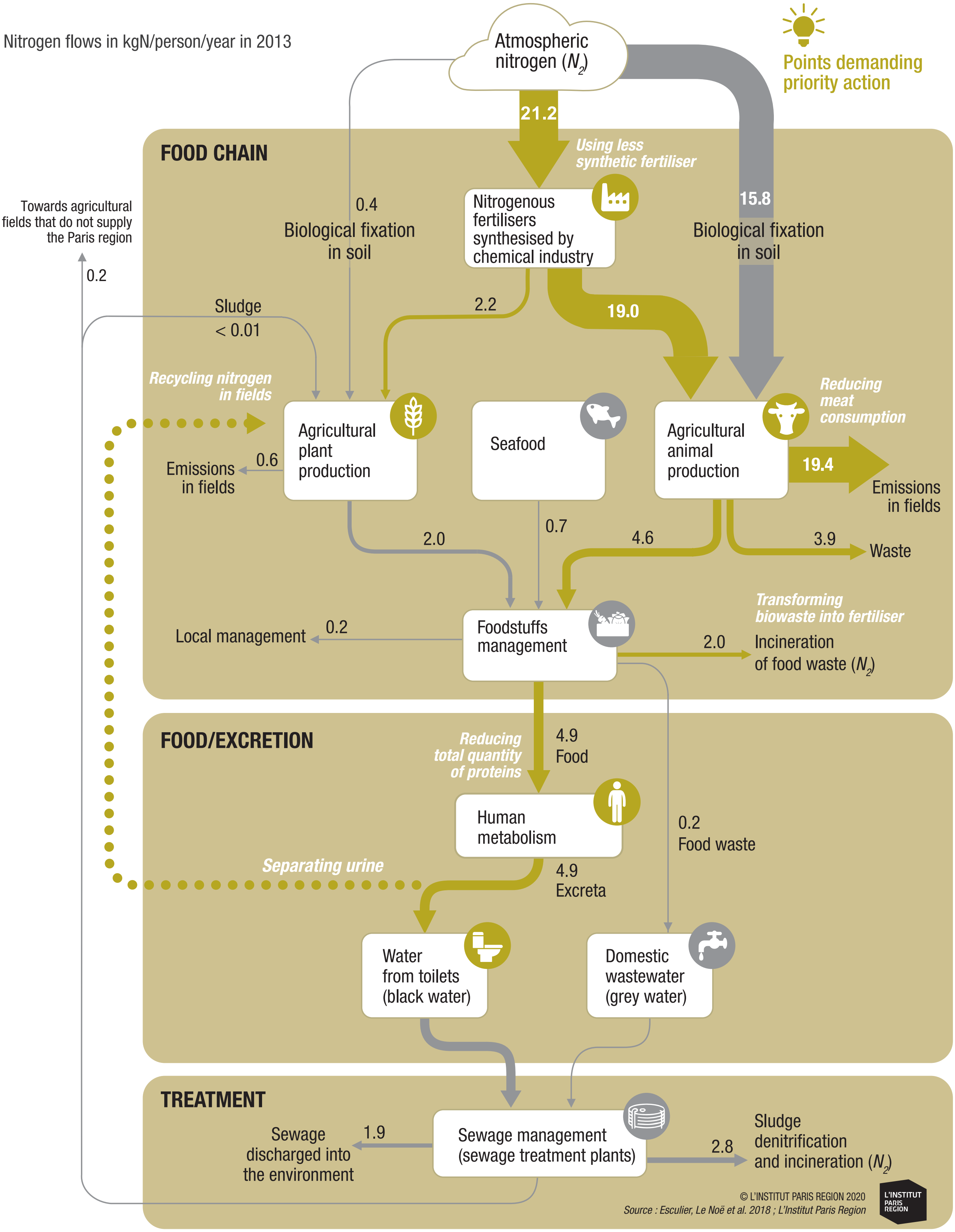
THE IMPORTANCE OF UPGRADING HOMES

The question of the pace of change is important. If 3% of homes were equipped with urine source separation systems every year, almost a third of all homes would be equipped by 2030.

On the other hand, since 2008 old housing has only been replaced at a rate of 1% per year for individual homes and 3% for flats. Relying on fitting new homes with the solution would only make it possible to equip 13% of homes by 2030, based on the Sdrif's hypothesis that 70,000 homes will be built annually. These figures should be compared to the 15 years it took to connect homes to mains sewage between 1895 and 1910 in Paris.

Essential engagement in rapid ecological transition thus involves working on both new builds and existing buildings.

NITROGEN FLOWS IN THE PARIS REGION: HIGH CIRCULARISATION POTENTIAL



Source : Esculier, Le Noë et al. 2018 ; L'Institut Paris Region showed that natural urine-based fertiliser has similar fertilizing potential to synthetic fertilisers. A true paradigm shift, the use of nutrients extracted from urine thus has many benefits that would help to attenuate a global synthetic fertiliser crisis and, consequently, a food crisis. The production of synthetic fertilisers, which mainly takes place outside Europe and relies on petroleum for nitrogen and mining for phosphate, can no longer continue in this way. The goal is also to reduce water consumption, the eutrophication of aquatic environments, and the financial and environmental costs of sanitation. While adapting to climate change plays a growing role in public policy, the utilisation of urine-sourced nitrogen and phosphorus is emerging as a promising way of helping France to achieve its "zero net emissions" goal by 2050. ■

Manuel Pruvost-Bouvattier, agronomist, research analyst (water and natural environments), and **Martial Vialleix,** research analyst (urban ecology), doctoral student,
Environment department *(director: Christian Thibault)*
Aurélie Joveniaux, research associate, Ocapi programme at Leesu,
and **Fabien Esculier,** researcher and coordinator of the Ocapi research and action programme at Leesu, École des Ponts ParisTech (ENPC)

RESOURCES

- Fabien Esculier, 2018. Le système alimentation/excrétion des territoires urbains : régimes et transitions socio-écologiques. Thèse de doctorat en sciences et techniques de l'environnement, Université Paris-Est.
- Adam et al., 2019. L'Institut Paris Region. *Note rapide* n° 812. Comment le MOS vous aide à comprendre votre territoire.
- Roger, 2017. L'Institut Paris Region. *Note rapide* n° 760. L'immobilier de bureau dans un nouveau cycle de production.
- Camors, 2017. L'Institut Paris Region. *Note rapide* n° 755. Les tiers lieux : de nouveaux espaces pour travailler autrement.
- *Les Cahiers* de L'Institut Paris Region n° 173, 2017. Une métropole à ma table. L'Île-de-France face aux défis alimentaires.
- W. Steffen et al. 2015. Science. Planetary boundaries : Guiding human development on a changing planet.
- PIREN-Seine, 2018. La séparation à la source de l'urine. Fiche 4 pages.
- PIREN-Seine, 2019. L'azote dans le système alimentation-excrétion des Franciliens. Poster.
- Billen, Esculier, Garnier, Le Noë, 2020. The Conversation. Nourrir Paris en temps de crise… et après ?

Sites institutionnels utiles

- www.leesu.fr/ocapi
- www.eau-seine-normandie.fr
- www.siaap.fr
- www.arceau-idf.fr/gtt6
- www.reseau-assainissement-ecologique.org

GLOSSARY

Eutrophication: accumulation of nutrients that upsets the balance of a natural environment. Aquatic eutrophication results in excessive proliferation of algae and plants which, when they decompose, leads to massive oxygen consumption, asphyxiating the environment and its living organisms.
Excreta: body waste mainly resulting from nutrition and the metabolism (faeces, urine, sweat, sebaceous matter, $C0_2$, etc.).
Grey water: wastewater generated in households or office buildings from streams without fecal contamination (sinks, showers, baths, washing machines or dishwashers), i.e. all streams except for the wastewater from toilets.
Nutrients: nutritious organic or mineral substances the body needs to stay alive.
Ocapi programme: a research and action programme focusing on urban food and excretion systems and the source separation of sewage.

---

1. Among the major limits, apart from voluntarily abandoning petroleum, a step that is necessary to limit global warming, the European Union is likely to suffer oil supply constraints between now and 2030, according to the prospective analysis carried out by the Shift Project think tank published in June 2020.
2. The strategy unanimously adopted by the Comité de bassin Seine-Normandie on 8 December 2016 mentions "developing alternative solutions with respect to eco-friendly sanitation, such as separate management of urine or dry toilets".
3. The regional circular economy plan included in the regional waste prevention and management plan mentions "the challenge of improving knowledge of nitrogen and phosphorus cycles in the Paris region and seeking relevant solutions".
4. Since 2014 phosphorus has been classified as a critical raw material for the European Union.
5. Source: homes under construction recorded in the Sitadel database produced by the Service de la Donnée et des Etudes Statistiques (SDES). See https://www.data.gouv.fr/fr/datasets/statistiques-sur-les-permis-de-construire-pc-permis-da-menager-pa-et-declaration-prealable-dp-base-sitadel/#_
6. Source: database of the Observatoire Régional de l'Immobilier d'Entreprise en Île-de-France, annual estimation of office space in the Paris region. See http://www.orie.asso.fr/publications/donnees-statistiques.
7. Source: Evaluation, forecasting and performance department, Ministry of Education and Research.

PUBLISHER
Fouad Awada
HEAD OF COMMUNICATION
Sophie Roquelle
LAYOUT DESIGN
Jean-Eudes Tilloy
GRAPHICS/CARTOGRAPHY
Laurie Gobled, Laetitia Pigato
PRODUCTION
Sylvie Coulomb

TRANSLATION
Martyn Back
MEDIA LIBRARY/PHOTO LIBRARY
Inès Le Meledo, Julie Sarris
MEDIA RELATIONS
Sandrine Kocki
33 (0)1 77 49 75 78

L'Institut Paris Region
15, rue Falguière
75740 Paris cedex 15
33 (0)1 77 49 77 49

ISSN 2555-7165
ISSN online
2497-126X

www
institutparisregion.fr/en

L'INSTITUT PARIS REGION