# Wastewater-based epidemiology: surveillance of illicit drugs and novel psychoactive substances

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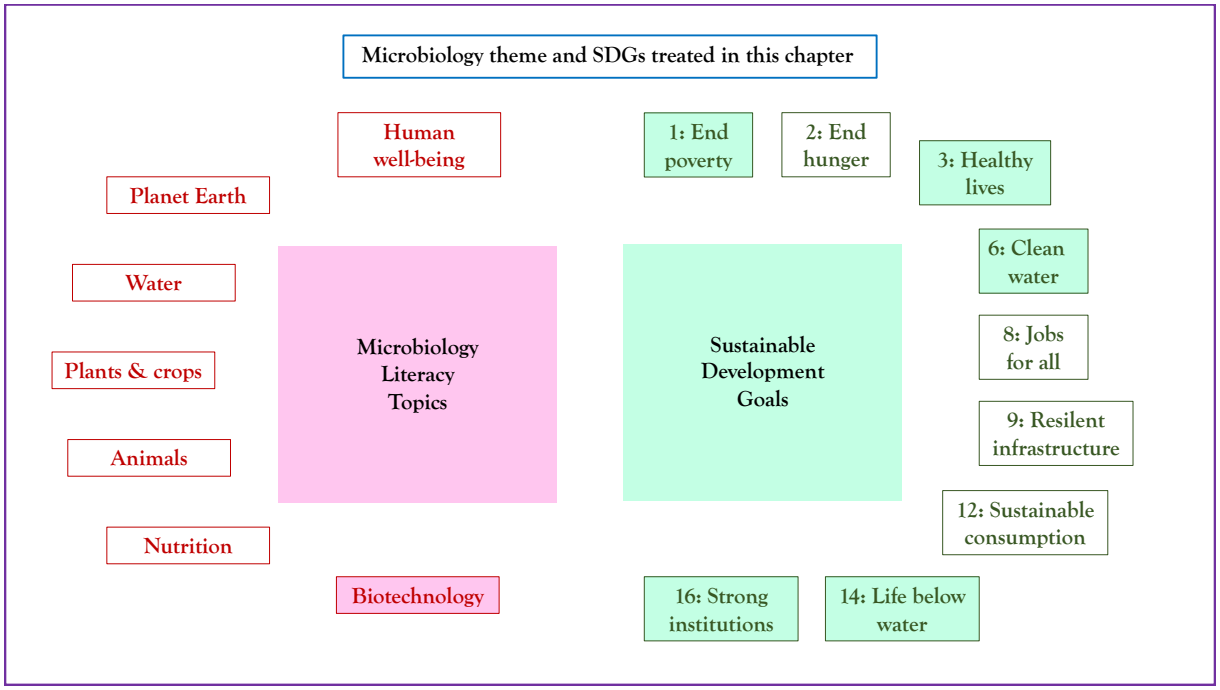
# Illicit drugs in wastewater

## Storyline

Since time immemorial, humans have sought substances that can help them to cope with physical and emotional challenges. Substances that can alter brain processes are termed psychoactive and can either be found in the natural world (e.g., in plants) or synthesized in laboratories. Many psychoactive substances are used as medicines to treat diseases. However, there is also a bad side to this story. Some people use excessive quantities of legal psychoactive drugs or prohibited (illicit) substances (often combined with other drugs and/or alcoholic beverages). The abuse of drugs can lead to acute and chronic health conditions and problematic addictions. In addition, drug use can foster social problems, violence due to drug trafficking, and result in pollution of the environment. The correct clinical use of medicines and combatting of drug abuse are important aims of the Sustainable Development Goals (SDG) related to "Good Health and Wellbeing", "Peace, Justice and Strong Institutions" and "No poverty". Although the impact is not yet fully understood, drugs that contaminate sewage and water may affect or be affected by environmental microorganisms. Thus, to achieve the SDGs "Clean Water" and to protect "Life below water", we also have to keep in mind the abuse of drugs.

## The Microbiology and Societal Context

*The microbiology:* microbial communities that live in rivers, lakes and oceans; interactions of microorganisms with drugs. *To complete the storyline:* drug abuse and addiction is a massive societal problem associated with human suffering, family and societal fragmentation, poverty, and drug trafficking. *Sustainability issues:* health; environmental pollution.



## Illicit drugs in wastewater: the Microbiology

1. ***Illicit drugs and psychoactive substances***. Psychoactive substances can affect the mind and the body of a person. Some drugs, which can be medicines or substances that have no medical use, are psychoactive substances. People can use drugs for several reasons: to enjoy the effects the drug causes in their body, to feel socially accepted in a group, to feel better or because they developed a dependence on the drug. A drug can be either a substance that is used in medicine, or substances legally or illegally used for recreational purposes. Some drugs are controlled, and their use is acceptable only if prescribed by a doctor. Legal drugs used for recreational purposes include ethanol (popularly known as "alcohol", present in beers and other drinks) and nicotine (present in cigarettes). Illegal or illicit substances, such as heroin, have no safe or accepted use. Some illicit substances can cause severe adverse effects on the body and may lead to dependence. Drug abuse is the use of illicit substances or the use of licit or controlled substances in excess and/or more frequently than normally prescribed.

2. ***The illegal trade in drugs.*** The sale of prescription drugs without prescription, and of illicit drugs, is prohibited by law, and thus is a criminal activity. Countries across the globe have drug policies to deal with and control the problem of drug trafficking, which is the way that criminals transport, trade and sell illicit drugs. Police activity to combat illegal drug trafficking requires sensitive and specific methods to detect the drugs in question: this is the job of the forensic scientist.

3. ***Drug detection.*** Forensic scientists usually detect these drugs in materials that are found in crime scenes or in the possession of an individual; forensic scientists also search these drugs in samples collected from individuals (such as blood or urine).

4. ***Drug metabolism.*** When people use drugs, the drug will enter the body and undergo chemical processes, which is called "metabolism". Metabolism is a set of chemical reactions that take place in the human body (mainly mediated by enzymes), leading to the transformation of a given substance into different forms, the so-called metabolites. Some substances will be almost completely transformed into their metabolites whereas others will not. Both the drug in its original form (if still available in the body) and/or its metabolites will ultimately be eliminated from the body. This can occur via faeces or urine.

5. ***Wastewater and wastewater treatment.*** When people eliminate their urine and faeces in the bathroom, these materials will reach the sewer network and subsequently the wastewater treatment plant. But why are wastewater plants so important? Because human excretions, domestic products and industrial residues are real or potential environmental pollutants that, if allowed to enter the environment, would rapidly poison vital ecosystem functions, wildlife and humans. The wastewater plant is a crucial barrier against pollutants entering the environment. But the barrier is not complete, and some compounds in wastewater may pass through it unchanged or as metabolites.

6. ***The importance of wastewater for forensics.*** Can you imagine how complex a wastewater sample is? Basically, anything that reaches the sewer will be in the wastewater. In addition, wastewater is composed of a huge number of small organisms: the microorganisms, which display an enormous diversity in terms of species and metabolic activities.

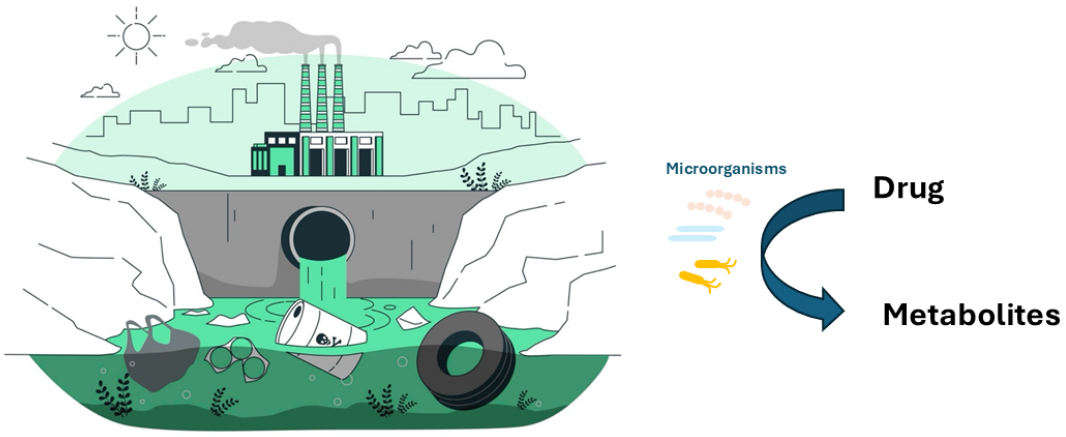
Although the primary purpose of wastewater treatment is to remove waste products and pathogens, wastewater represents the entirety of the waste products of a specific community and hence a valuable source of information about the products used and made in that particular community. That is, wastewater is a unique source material for forensic analysis. Therefore, another drug forensic strategy that is being adopted is to search for drugs in wastewater. Although wastewater is not usually received and tested by forensic laboratories, research laboratories have been investigating the analysis of drugs in wastewater. If drugs are found in wastewater samples, one of the possibilities is that these substances could have been consumed by people in the community delivering the wastewater. This can help public health and safety professionals to develop strategies to combat the drug problem in a country or region.

***7. Microbial metabolism of drugs.*** One big challenge in analysing drugs in wastewater is that they may be affected by the microorganisms present there, which may transform these drugs into other compounds. Do you remember about the metabolism in the human body? This can also happen in the microorganisms: they might be able to take the drug and convert it into another form. If a drug is transformed by the wastewater microorganisms, it might "disappear" from the wastewater and thus the scientists will not be able to find it when they analyse the samples. For this reason, research has been done in laboratories to investigate the potential of microorganisms to transform drugs in wastewater. This information can help scientists in understanding their fate in wastewater.

Illicit drugs can be viewed as xenobiotics, i.e. compounds that were not produced by an organism or are foreign to an ecological ecosystem. They enter into contact with the autochthonous microbiota – the usual microbial inhabitants – of an environment as unchanged molecules or as metabolites of them. Until now, little is known about the metabolism of illicit drugs by microorganisms, but it can result from three types of activity:

- use of a drug as microbial food, i.e. as a carbon or energy source for growth and reproduction,
- detoxification, by degradation or modification of its structure, in the case of a drug that is toxic for a microbe,
- fortuitous-accidental metabolism by enzymes produced for an entirely different function, in the case where the drug is similar enough in structure to a molecule whose metabolism is part of the normal spectrum of activities of the microbe.

***8. Microbial community composition and its perturbation.*** Most compounds, including drugs and their metabolites, introduced into a natural microbial community will lead to changes in its composition. The drug consumed by a person may be metabolized and the drug or its metabolites may reach the sewage and be delivered to the wastewater plant. In wastewater, drugs may interact with microorganisms living there. Similarly, these drugs may reach the microbiota in the river, after the wastewater treatment. In many cases, if the drug concentration is high enough, it might induce a change in microbial community composition. The shifts caused by such human interventions may serve as potential microbial markers to detect points of drug manufacturing and consumption. This is because the natural microbiota may be replaced by other, better adapted microorganisms, which may in turn be useful for scientists to propose new analytical methods to identify these drugs




Schematic representation of the possible contamination of wastewater by illicit drugs and their interaction with microbes in the environment. Drugs can either be degraded by human or microbial enzymes, which are special proteins that speed up the ratio of chemical reactions. (**Credits:** The figure was prepared by the authors, using an image free of royalties and taken from https://www.freepik.com/free-vector/water-pollution-concept-illustration_14205327.htm)

***9. Possible impacts of illicit drugs on wildlife and biodiversity.*** If illicit drug use exists in a population, traces of such compounds will spread into river ecosystems, entering in contact with the local wildlife and microbiota. The same is true of clandestine laboratories that produce illicit drugs: their wastes and residues may be delivered to the adjacent natural ecosystems, impact local wildlife, and cause shifts in microbial composition. These impacts may result in species extinctions. Microbes provide key ecosystem functions, but microbial extinctions are very difficult to determine.

***10. Drugs in the environment and sustainability.*** When we discuss sustainability, the first thing that may come into our minds is the most effective use of currently available natural resources in the context of an ecological perspective of human interaction with the surrounding environment. It is an important concept which has been discussed worldwide to plan several public policies to circumvent the detrimental effects of human impacts on nature, such as global warming, pollution, loss of biodiversity, loss of agricultural lands and deforestation. It is well documented that overexploitation caused by anthropogenic activities damage the environment, directly impacting biodiversity, which is essential to provide ecological services to everyone, but especially ethnic and traditional populations, and to maintain the fine-tuned dynamic equilibrium in ecosystems. A lot is propagated in the media about the harmful effects of pollution and deforestation to the biosphere. However, little concern is expressed about the impacts of human activities on microbial communities in terrestrial, aerial, marine and river environments.

***11. The need for societal debate concerning the use of drugs and environmental impact.*** Society urgently needs to discuss and answer a number of questions, such as

- Is drug consumption harmful not only to a subject but also to the environment?
- To what extent do drugs or their metabolites that are released into the environment cause shifts in microbial communities?
- Are such shifts transient or persistent?
- Do such shifts result in any loss of ecosystem services?

These questions are important to scientists, especially considering that ca. 99.8% of bacteria are not culturable in lab conditions, which means that most of the bacterial diversity in the world

is unknown. Therefore, assessing the environmental impacts caused by drug consumption is crucial and shows the importance of this matter not only for forensic science but also for environmental sustainability.

## Potential Implications for Decisions

1. ***Individual***
    a. Illicit drugs can cause several types of harm and lead to many health problems, so their use must be strictly avoided.
    b. Some drugs have therapeutic benefits but should be used only under medical supervision.
    c. If you know anybody using drugs, remind them about the dangers of drug use and advise them to seek help from someone caring and trustful, to be guided to search for medical help.

2. ***Community***
    a. The use of drugs may also impact the environment, and drugs reaching water bodies (such as wastewater, rivers, lakes and sea) might have an impact on the organisms and microorganisms living there, with consequences still unknown for the global ecosystem.

3. ***National policies relating to illicit drug use***
    a. Drug use can lead to public health problems.
    b. Drug use can also be associated with criminal activities (such as drug trafficking and violent crimes).

## Pupil Participation

1. ***Class discussion of the issues associated with drug use.***
    a. Why is drug abuse dangerous?

2. ***Class discussion about the role of analyzing the wastewater to detect drugs.***
    a. What have scientists been exploring in wastewater regarding abuse of drugs and why?
    b. Why is it important to understand what happens to a drug in wastewater?

## The Evidence Base, Further Reading and Teaching Aids

For lesson preparation, this content can be covered in three main topics:

- The concept of drugs and drug abuse, and the risks of drug use:

National Institute on Drug Abuse (NIDA). Drug Drugs, Brains, and Behavior: The Science of Addiction - Drug Misuse and Addiction Available at: https://www.drugabuse.gov/publications/drugs-brains-behavior-science-addiction/drug-misuse-addiction.
World Health Organization (WHO). Drugs (psychoactive). Available at: https://www.who.int/health-topics/drugs-psychoactive#tab=tab_1
Australian Government Department of Health. What are drugs? Available at: https://www.health.gov.au/health-topics/drugs/about-drugs/what-are-drugs

- Wastewater analysis and the importance of analyzing drugs in wastewater in a forensic context, and
- Microbial diversity in wastewater and the potential impact in in-sewer transformation of drugs.

De Campos, E. G.; De Martinis, E. C. P.; De Martinis, B. S. Forensic Analysis of Illicit Drugs and Novel Psychoactive Substances in Wastewater: A review of toxicological, chemical and microbiological aspects. Brazilian Journal of Analytical Chemistry, 2022. Available at https://brjac.com.br/artigos/2021-V8-NX2/brjac-19-2021.pdf.

**Although this paper has a technical, specialized approach, the text provides general information that can be used in the preparation of this lesson.*

Additional information can also be found in the following materials:
ESR. Drugs in wastewater. Available at https://www.esr.cri.nz/home/about-esr/our-science-in-action/drugs-in-wastewater/ (Page about drugs in wastewater elaborated by the New Zealand's Crown Research Institute ESR).
European Monitoring Centre for Drugs and Drug Addiction (EMCDDA). Wastewater-based epidemiology and drugs topic page (Page about wastewater analysis and the initiatives developed in Europe by the EMCDDA).

There are also news reports available online that can be helpful to demonstrate the applications to the students.