



Review and prospect of emerging contaminants in waste – Key issues and challenges linked to their presence in waste treatment schemes: General aspects and focus on nanoparticles



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ABSTRACT

The presence in waste of emerging pollutants (EPs), whose behaviours and effects are not well understood, may present unexpected health and environmental risks and risks for the treatment processes themselves. EP may include substances that are newly detected in the environment, substances already identified as risky and whose use in items is prohibited (but which may be present in old or imported product waste) or substances already known but whose recent use in products can cause problems during their future treatment as waste. Several scientific studies have been conducted to assess the presence of EP in waste, but they are mostly dedicated to a single category of substance or one particular waste treatment. In the absence of a comprehensive review focused on the impact of the presence of EP on waste treatment schemes, the authors present a review of the key issues associated with the treatment of waste containing emerging pollutants. This review presents the typologies of emerging pollutants that are potentially present in waste along with the major challenges for each treatment scheme (recycling, composting, digestion, incineration, landfilling and wastewater treatment). All conventional treatment processes are affected by these new pollutants, and they were almost never originally designed to consider these substances. In addition to these general aspects, a comprehensive review of available data, projects and future R&D needs related to the impact of nanoparticles on waste treatment is presented as a case study.

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1. Introduction

Evolution in the patterns of production and consumption has led to the presence in end-of-life products, and therefore in waste, of new substances that may engender sanitary and environmental risks and act differently from previously known substances. Indeed, the majority of monitoring programs are currently based on regulated substances that are either persistent, bioaccumulative and/or inherently toxic. Currently, questions exist about the potential impacts of emerging pollutants, which are substances that are not necessarily new to the market but are currently not regulated and may cause environmental hazards. These substances can be detected in the environment but are not yet included in monitoring programs, and their behaviour, fate and (eco) toxicological effects are not well understood. There is no overall definition of those emerging pollutants and no exhaustive list of compounds con-

tained within this term. Moreover, the notion of the emerging pollutant must be defined according to the target media. In the specific case of waste, current waste treatment schemes (recycling, anaerobic digestion, composting, landfilling, incineration and wastewater treatment) were not designed with prior intent to consider these substances. Consequently, such substances can present unexpected sanitary and environmental risks (risks to waste industry workers or risks of release to the environment) or risks to the treatment processes themselves (risks of inhibition or interference with the processes).

Considering this, the French Industry–University Cooperative Research Network on Waste (RECORD – www.record-net.org) decided to lead a detailed study on new pollutants that can be found in waste focusing on the various steps of their treatment or recovery (Fig. 1). The purpose of the study was to provide answers regarding the presence of new pollutants within waste, their impact on waste management and the risks that they may generate for human health and the environment.

The RECORD study was initially based on an analysis of previously documented situations; from a pre-established list of categories of substances, the researchers performed a literature review

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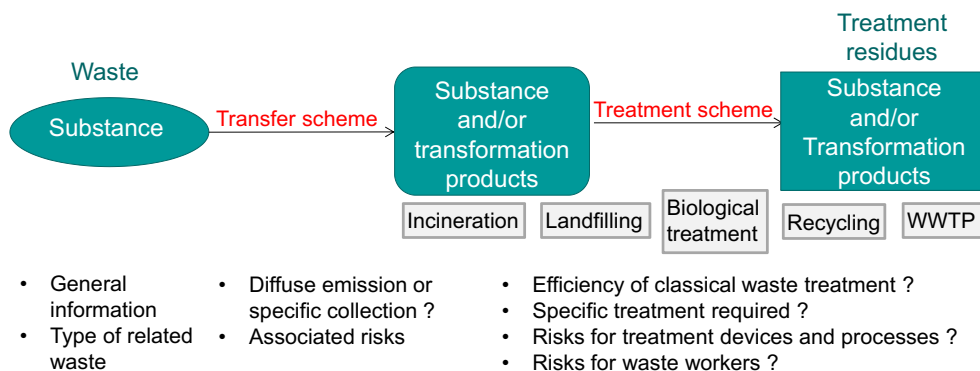


Fig. 1. Outcome of emerging pollutants in waste collection and treatment processes.

and interviewed experts to assess the available information and the level of knowledge about the presence of these new contaminants in waste. The approach of the study was based on a search by substance and not by type of waste or treatment process. Indeed, a search by waste type requires knowing the specific composition for each type of product (e.g., plastic materials, textile waste or household waste), but this information is not available (because of the great variety of products and industrial secrets). On the other hand, several studies concerning waste treatment processes have been published, but the efficiency of a specific treatment depends on the considered type of substance (Kümmerer, 2011). The sheer bibliographical exhaustiveness puts this approach out of reach due to the large number of emerging pollutants, but the substances with the widest range of use and the greatest susceptibility to being found in large quantities in waste were retained within the framework of the RECORD study and were classified into broad categories (nanomaterials, micropollutants and Genetically Modified Organisms – GMOs).

The second step of the RECORD study consisted of research into new substances that are scarcely documented but are susceptible to being found in waste; this phase was mainly based on interviews with various actors and targeted experts (such as researchers and industrial and association spokesmen) who belong to different fields of activity (waste treatment, environmental and sanitary risk management, toxicology and emerging pollutants) or work with specific substances (nanomaterials, pesticides, pharmaceutical residues and genetic material).

From the results of this RECORD study, several challenges linked to the presence of emerging pollutants in waste have been identified according to their pollutant category and appropriate waste treatment schemes.

In this review, Section 2 highlights the key issues associated with the treatment of waste containing emerging pollutants. This section presents the most debated and questionable issues, the typologies of emerging pollutants that are potentially present in waste and the major examples of challenges for each treatment scheme independent of the considered pollutants.

Section 3 presents a comprehensive review of available data, projects and future R&D needs related to the impact of nanoparticles on waste treatment as a case study.

2. Key issues and challenges linked to the presence of emerging pollutants in waste

2.1. Media and societal background

Prior to the RECORD study, a survey of environment-focused journalists and environmental and consumer protection associations was performed to estimate the media and societal context

of emerging pollutants in France. The first questions raised about the presence of new polluting substances in waste emerged from the scientific realm. However, as newspapers specialised in the environment took on the subject, it opened to a wider and more sensitive public. This greater interest in turn spurred on less-specialised media to feed the debate on this question and, therefore, engaged an ever wider section of the public to request information. While media play an important role in investigating societal issues, associations are predominantly the whistle-blowers. Furthermore, the implementation of new regulations that take into account new knowledge of substances or increasingly elaborate studies by safety sanitary agencies is useful to reopen the debate and gives structure to questions, but it may fuel the fears of citizens.

In most of the consulted articles in specialised publications, the themes discussed often deal with contamination of food (e.g., by residues of pesticides) or daily consumption items (e.g., additives in feeding bottles), which directly affect the users' health. However, it is the issue of drinking water quality that is predominant as it establishes a link between the use and fate of consumer products and the substances they contain. In particular, waste treatment (i.e., wastewater and landfill leachates) efficiency is questioned especially with regard to products having a dedicated waste treatment process as in the case of pharmaceutical residues or pesticides. Consequently, even if waste management is the responsibility of several actors (among them the users, who can take part in specific sorting), it appears that in the event of a failure, the public turns most easily on public authorities and/or companies in charge of the treatment, which are usually considered to be not vigilant enough.

All of this is to say that there is a great distrust with regard to the treatment of waste containing new substances still at an experimental stage (e.g., GMOs) or at an early stage of marketing (e.g., nanotechnologies). Indeed, the public perceives the value of these new technologies but is more and more aware of the fact that the disposal of these products can have fatal consequences for the environment (Grunwald, 2008) especially as the concept of a product's life cycle is better known and disclosed. For instance, during the recent French national debate on nanotechnologies, the issue of nanoproductions' life cycles was raised by the audience (CNDP, 2010). Finally, contrary to the United States where GMOs and nanotechnologies are better accepted, Europeans favour the application of the precautionary principle (moratoria and case by case limitations), which is considered a threat to the economy by Americans (Kirilenko et al., 2010).

2.2. Emerging contaminants potentially present in waste

Several new pollutants have been identified as potentially present in waste. It should be noted that these pollutants are men-

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