THE OPECST SUMMARIES

THE PARLIAMENTARY OFFICE FOR SCIENTIFIC AND TECHNOLOGICAL ASSESSMENT

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The Impact of Plastics on Human Health

The harmful effects of plastic pollution on the environment have been scientifically demonstrated and are now well known to the general public. Less research has been carried out into the impact of plastics on human health, although in recent years a growing number of scientific studies have highlighted the health risks they pose to the general public.

From 25 November to 1 December 2024, the final round of negotiations on the future international treaty to eliminate plastic pollution will be held in South Korea. Measures to reduce the toxicity of plastics are one of the issues still under discussion.

To contribute to the current debates and future decisions, the Office, which has already invested a lot in the subject of plastics, organised a public hearing in the form of two round tables to take stock of scientific knowledge on the impact of plastics on human health and issue recommendations to the negotiators.

Philippe Bolo,
Member of the National Assembly

Plastic production has grown exponentially over the last twenty years, and plastics are now everywhere in the environment

As plastics production has increased exponentially, so too has the amount of waste

➢ **Sharp growth in plastics production**

Plastics have only been on the market for a relatively short time, since the 1950s. Since then, **production has accelerated constantly: it has doubled over the last 20 years and is set to exceed 500 million tonnes by 2024**. If these 500 million tonnes were converted into plastic wrap, it would be enough to wrap the whole of France 50 times over!

According to OECD projections, plastics production is set to reach 750 million tonnes by 2040 and exceed one billion tonnes by 2050.

The packaging sector accounts for 32% of the plastics used (i.e. 139 million tonnes in 2020), making it the leading outlet for plastics production, and this share is set to remain stable over the next thirty years. **Plastic production is still largely influenced by single-use plastics**.

Textiles now account for 10% of plastic production (45.2 million tonnes in 2020), and their share is set to increase slightly by 2050 (11.2%).

➢ **Waste production is following the plastics production curve**

The **output of plastic waste is expected to rise from 360 million tonnes in 2020 to 617 million tonnes in 2040**.

Despite the rethoric about the circularity of the plastics life cycle, it remains linear, even in the most advanced countries in terms of waste collection, sorting and processing. In 2018, of the 3.6 million tonnes of plastic waste produced in France, only 0.6 million tonnes was actually recycled (i.e. 17%)!

Worldwide, less than 10% of plastic waste is recycled and, despite expected progress in waste collection, sorting and processing, on a business-as-usual basis, this rate is unlikely to exceed 14% in 2040, compared with 50% going into landfill and 17% for incineration.

In 2020, poorly managed plastic waste – i.e. waste that ends up in the environment – amounted to 81 million tonnes (22% of the total). By 2040, it is likely to account for 119 million tonnes (or 19%).

Plastics are now everywhere in the environment

➢ Plastic pollution is amplified by microplastics

Plastics are not inert. When exposed to environmental elements such as ultraviolet rays, water and oxygen, their surface erodes and **they break down to form microplastics and nanoplastics**.

Microplastics leak into the environment throughout the plastics life cycle: when they are produced, through losses of industrial granules, when they are used, such as when plastic microbeads were used in cosmetics (a practice now banned in Europe), and this still occurs through tyre wear and the washing of synthetic fabrics, and when they reach the end of their life, through the breakdown of macroplastics present in the environment.

➢ Plastics have invaded the whole of the environment

They can be found 10,000 metres deep in the ocean, in the glaciers of the Himalayas, and even in the clouds, in the form of microplastics.

The presence of microplastics far from their source of emission is linked to the strong increase in mismanaged plastic waste, as well as their small size, light weight and persistence. The results of research into the tropospheric dispersion of microplastics show that **particles contained in sea spray pass through the air and are carried over long distances**.

Plastics have become an integral part of the environment. For example, a new rock formation, known as plasticomerate, has been discovered, with plastics forming one of its main components.

Despite the methodological challenges in detecting and characterising plastics and the risks they pose to human health, the warning signs are multiplying

Analysing particulate plastics and the associated health risks is fraught with methodological difficulties

➢ The methodological challenges involved in characterising and quantifying particulate plastics

These are related to the wide variety of compositions, sizes and shapes of plastics.

Analyses of mineral water and tap water produce results that vary considerably from one study to another. However, work carried out by the French standardisation organization Afnor has produced a standard for characterising microplastics in water, setting an international benchmark that makes it easier to compare results.

Detecting and quantifying particulate plastic in human samples is fraught with similar problems. A study on the amount of microplastics ingested by humans caused a stir in 2019[1], estimating it at 5 grams per week, the equivalent of a credit card. Since then, several studies have shown considerably lower amounts, without reaching a consensus. In 2022, a scientific study[2] estimated that it would take 23,000 years to ingest the equivalent of a credit card. Another study[3] estimated plastic ingestion at 4 micrograms per week, a million times less. A very recent study[4] conducted in 109 countries, both industrialised and developing, showed high exposure of 500 milligrams per day in South-East Asian countries, mainly as a result of seafood consumption.

Analytical methods and processes need to be improved to avoid contaminating the samples being analysed, for example by the widespread use of plastic objects in laboratories. The proliferation of formulations for plastic materials also exacerbates the challenges of analytical work.

Given the difficulties involved in understanding plastics, **the quantity of microplastics and, especially, nanoplastics in the environment is certainly underestimated**.

➢ Nanoplastics detection remains in the early stages

A literature review in 2023 highlighted the presence of nanoplastics in certain foods, such as tea[5] and rice[6].

Similarly, a study[7] – yet to be confirmed – has concluded that plastic water bottles contain 250,000 particles per litre, 90% of which are nanoplastics.

However, these particles' small size and the diversity of the environments in which they are found pose a real methodological challenge in detecting and quantifying them. For example, there is currently no technique for detecting nanoparticles in the lungs. However, researchers are interested in nanoplastics because **they are likely to cross the intestinal barrier or the epithelium and enter the bloodstream to reach secondary organs**.

➢ The limits to laboratory models

Most studies are carried out on commercial particles, which are spherical and essentially made of polystyrene, which does not reflect what is actually found in the environment.

And yet plastic particles' toxicity depends on their physico-chemical characteristics and shape. Fibres of a certain length can disrupt phagocytosis, since macrophages are unable to ingest them fully when they are too long. This can cause persistent inflammation.

The doses used in the laboratory are often very high, and the long-term effects have been relatively under-researched, in particular because cohorts have not been established. Furthermore, studies are often carried out on healthy people, when they should be extended to those at risk. For example, patients suffering from chronic inflammatory bowel disease – Crohn's disease or ulcerative colitis – were found to have more microplastics in their faeces than healthy volunteers.

Beyond these methodological limitations, the warning signs of the risks that particulate plastics pose to human health are multiplying.

The warning signs of the risks that particulate plastics pose to human health are multiplying

➢ **Microplastics are present – and accumulating – in all human organs**

People are exposed to plastics in three ways: through food, breathing and the skin. Exposure can be direct, through the use of everyday products, but also through inhalation. In the Paris region, 3 to 10 tonnes of airborne plastics are deposited every year, mostly fibres, and we inhale up to 30 million plastic particles a year. As many microplastics are inhaled as ingested.

Exposure can also be indirect: micro- and nanoplastics are present in all ecosystems and affect the animal and plant species we consume – salt, beer, fruit and vegetables, tea, eggs, meat, etc.

The organs that absorb them are numerous – the lungs, the colon, the skin. It has been shown that **plastics can be transported by the blood and by the nerves and reach distant organs** such as the testicles, placenta, kidneys and brain. One study[8] estimated the concentration of plastic in the brain at 5 milligrams per gram: this would mean that **0.5% of the brain's mass is made up of plastic**.

Microplastics also accumulate in the organs. The quantity of plastics in the lungs increases with age, which suggests that these particles can persist in the body without being eliminated.

The accumulation of plastics in both the physical and living environments and their consequences for human health therefore raise legitimate concerns under the One Health principle, which identifies the links between animal health, human health and the quality of the environment.

➢ **Worrying correlations between the presence of plastics and the alteration of certain organs and their functions, and even the appearance of pathologies**

- *Plastics have an impact on the digestive system*

Exposure to plastics appears to change the composition of the intestinal microbiota. Bacteria appear in both adults and children, such as pathobionts, which can contribute to dysbiosis of the intestinal microbiota. In addition, a reduction in butyrate, a highly beneficial short-chain fatty acid (SCFA), has been observed in children.

Currently unpublished work on mice has shown that adding microplastics to their diet leads to a loss of beneficial bacteria and an increase in bacteria that are harmful to the intestinal microbiota when the rodents are fed a Western-style diet rich in fat and sugar.

Abrasive phenomena linked to the transit of large microplastics cannot be ruled out, particularly in areas not covered by mucus. This abrasion could lead to inflammation.

- *Inhaled plastics have an impact on health*

Depending on their size, plastic particles can penetrate deeply into the respiratory tract.

The largest particles, over 300 micrometres in diameter, cannot pass through the nasopharynx. Those between 2.5 and 10 micrometres can travel down into the bronchi. Only the finest inhalable particles, less than 2.5 micrometres in diameter, can enter the bronchi and reach the alveoli.

The respiratory system is equipped with elimination mechanisms such as mucociliary clearance and alveolar macrophages. **However, nanoparticles can bypass clearance mechanisms, cross the epithelium and enter the bloodstream to reach secondary organs**. Some nanoparticles can travel up nerves, such as the olfactory nerves, and reach the brain.

The toxicity of inhaled plastic particles was demonstrated in the 1970s in workers in the flocking industry. Some of them developed impaired lung function, breathlessness, inflammation, fibrosis and even lung cancer. The same symptoms have been observed in workers in the textile and PVC industries.

In addition to particulate plastics, additives, contaminants and monomers can also have an impact on health. In the polystyrene industry, for example, it is mainly the monomers (styrenes), which are known to be toxic and carcinogenic, that cause these diseases.

An increase in stomach cancer could also be due to swallowing inhaled particles.

Other studies have shown a **correlation between respiratory diseases and the presence of plastics in the lungs**. There are more particles and fibres present in tumours than in normal tissue.

There is also **a link between the presence of microplastics and impaired lung function**. There are more plastics in the bodies of people with allergic rhinitis. Blood parameters are also altered when plastics are detected in the lung.

- *The presence of microplastics in carotid artery plaque is correlated with an increased risk of myocardial infarction*

A recent study published in the New England Journal of Medicine[9] measured the quantity of microplastics removed from such plaque in over 300 patients who underwent surgery on their carotid artery. This study showed that **there was a 4.53 times greater risk of myocardial infarction, and potentially of stroke and even death, in people with the highest levels of micro and nanoplastics**.

Plastics are also dangerous because of the chemicals they contain, which impose exorbitant costs on society

Plastics are sources and vectors of worrying chemicals

➢ Plastics are sources of chemicals

Plastics production involves many chemicals at different stages in the manufacturing process. They can be **categorised into four groups**: starting substances, i.e. monomers and catalysts; **additives** added to these products to make them functional (plasticisers, anti-oxidants, flame retardants, colourants, etc.); **manufacturing aids** used to facilitate the production of plastic materials and products; **non-intentionally added substances** (NIAS), which are either impurities from other chemicals, byproducts formed during the manufacture of plastics, or byproducts of degradation that appear during their use or at the end of their life.

- *A very large number of chemicals, a quarter of which are dangerous*

More than 16,000 chemicals are listed in the PlastChem database[10].

Four criteria have been adopted to determine chemicals' hazard: their **persistence**, in order to identify chemicals that do not break down easily in the environment; their capacity for **bioaccumulation**, referring to chemicals that accumulate in the human body or in other organisms; their **mobility**, which targets chemicals that spread easily in the environment and in drinking water; and their **toxicity**, to assess their danger to human health.

More than 4,000 of the 16,000 chemicals listed, i.e. a quarter of them, can be classified as hazardous. Their toxicity to the environment, particularly the aquatic environment, as well as to human health, has been well documented scientifically. Numerous studies have shown that these chemicals are toxic to certain organs, such as the liver, and that they are carcinogenic, mutagenic or reprotoxic. Some chemicals are endocrine disruptors.

A general scientific review[11] has looked at the impact on health of three chemicals used almost exclusively in plastics: polybrominated diphenyl ethers (PBDEs), used as flame retardants in fabrics and electronic products and classified as persistent organic pollutants by the Stockholm Convention; bisphenol A (BPA), a monomer used in the manufacture of polycarbonate as well as in the composition of epoxy resins used to coat food tins and cans; and phthalates, especially DEHP – bis(2-ethylhexyl) phthalate used to make plastics more flexible.

This general review was based on data from nearly 1,000 meta-analyses from 52 systematic reviews, representing the equivalent of 1.5 million data points.

It found solid epidemiological evidence **linking foetal exposure to PBDEs during pregnancy to low birth weight, delayed or impaired cognitive development in children** and loss of intelligence quotient (IQ). Statistically significant evidence of endocrine disruption linked to the functioning of the thyroid hormone system in adults has also been found.

As for BPA, the general review establishes **connections with genital malformations in newborn girls exposed to BPA** in the uterus, **type 2 diabetes** in adults and insulin resistance, as well as **polycystic ovarian syndrome** in women. Exposure to BPA also increases the risk of obesity and hypertension in both children and adults, as well as the risk of cardiovascular disease in adults.

Finally, the general review establishes **links between exposure to DEHP and miscarriages, genital malformations in newborn boys, delayed or impaired cognitive development in children**, loss of IQ, delayed psychomotor development, **early puberty in young girls and endometriosis in young women**. Exposure to DEHP also has **multiple effects on cardiometabolic health**, including insulin resistance, obesity and increased blood pressure.

- *Shortcomings in the assessment of chemicals lead to their danger being underestimated*

Only 161 plastic chemicals have been deemed non-hazardous by national regulations, **but these assessments lack scientific rigour** insofar as they are based either on incomplete information or on only a portion of the hazard criteria.

There is no data on the danger posed by 10,000 chemicals used or present in plastics.

Internationally, only 6% of chemicals are regulated under the Basel Convention, the Stockholm Convention and the Montreal Protocol.

Additionally, while chemicals' toxicity is beginning to be well documented, information on their persistence, bioaccumulation or mobility is more difficult to find, as these criteria are not always included in government assessments.

Finally, **the determination of the thresholds below which the migration of chemicals or their absorption remains tolerable depends on scientific data that is subject to significant change**. For example, until 2023 the threshold value considered tolerable for bisphenol A in the blood was 233 micrograms per litre, defined according to a target corresponding to renal toxicity. Then a new test appeared, based on the quantity of certain immune cells in the spleen. As a result, the European Food Safety Authority (EFSA) revised its tolerable daily intake for bisphenol A to 0.011 micrograms per litre, which is 20,000 times less than before.

- *The population is widely contaminated by plastic chemicals*

Chemicals enter the environment and contaminate it throughout the plastics life cycle. This pollution in turn affects humans, particularly through food, water and air.

A recent study[12] showed that **25% of the 14,000 chemicals contained in plastic materials in contact with food have been found in the human body**. Another publication[13] bringing together the results of studies published between 2020 and 2022 concludes that 61 substances contained in plastic materials in contact with food are potentially carcinogenic to the mammary gland.

For the four most common perfluorinated compounds, which are widely acknowledged to be toxic, the tolerable threshold value for absorption, translated into a threshold value for the blood, has been set at 6.8 micrograms per litre. A major European programme assessed the overall level of contamination in European populations and found that **15% of the European population exceeded this threshold value**. This does not mean that there is an immediate danger, as the threshold value is quite protective, but it does serve as a warning.

As far as the presence of BPA in our bodies is concerned, practically the entire population is above the tolerable threshold since the threshold value was drastically lowered in 2023.

➢ **Plastics are also vectors for chemicals**

Hydrophobic plastics will adsorb hydrophobic chemical pollutants present in the environment, not only allowing them to disperse but to pass through barriers that they would not normally be able to cross.

This 'Trojan horse' effect is exacerbated by plastics' persistence in the environment and their slow decomposition into micro and nanoplastics, which encourages the accumulation of chemicals in the physical environment and in organisms.

Examples include the interactions observed in the laboratory between plastic particles and benzopyrene, a highly toxic polycyclic aromatic hydrocarbon (PAH) and a major air pollutant. Exposure of cells to benzopyrene-contaminated plastic particles allows benzopyrene to penetrate into the cells. In addition, a pro-inflammatory response was observed in cells exposed to particles coated with this pollutant, whereas benzopyrene alone and plastics alone did not induce this effect.

It therefore seems that there is a very specific effect of benzopyrene particles in combination with plastics, the mechanisms of which have yet to be analysed.

The exorbitant costs to society's health of chemicals in plastics

➢ **The results of the first studies into the health costs associated with the use of plastics are particularly worrying**

A 2024 study[14] quantified the health effects of three key chemicals associated with plastics – PBDEs, BPA and DEHP – and translated them into economic costs.

The results pertain only to the United States, which at the time was the only country for which biomonitoring data existed on the population's exposure to plastic chemicals. Only one or two health effects per chemical were selected.

For costs related to exposure to PBDEs, the study considers the economic costs resulting from a decline in cognitive performance, intelligence quotient and human capital following exposure to PBDEs in the uterus. **They are estimated at $202 billion for 2010**.

For the costs associated with exposure to BPA, the study focuses on the cost of increased heart disease, estimated at **$166 billion**, and the cost of strokes, estimated at **$62.4 billion** because of lost productivity.

For the costs associated with exposure to DEHP, the study considers the increased mortality in adulthood between the ages of 55 and 64, based on the value of statistical life. It concluded that more than 40,000 additional deaths a year could be attributed to DEHP exposure in the US population alone, at a **cost of $245 billion**.

In total, the costs would amount to $675 billion a year for these three chemicals and for the United States alone.

Beyond the fact that these 40,000 deaths are unacceptable, quantifying the negative externalities of plastic challenges the widespread idea that plastic is cheap. It is the public who bears the effects and costs of these chemicals, not their producers.

➢ **Indirect costs linked to the production of plastics are also very high**

Chemicals have consequences in terms of pollution and human health throughout the plastics life cycle.

The primary production of plastics is responsible for four times more greenhouse gas emissions than the aviation sector.

Seventy-five percent of these emissions are thought to occur during the extraction of raw materials and the production of monomers and other chemicals.

The workers are particularly exposed to pollution caused by plastics, and high levels of toxic products are found in the air, soil and aquifers around production sites. Benzene, for example, is associated with an increased risk of cancer in local populations, as in Louisiana's 'cancer valley' in the United States.

The Minderoo-Monaco Commission[15] also quantified plastics' impact on pollution and human health, estimating it at several hundred billion dollars a year. These figures still need to be refined and confirmed, but they do raise awareness of the health and public spending costs generated by the plastics industry.

The OPECST nine recommendations

In March 2022, the United Nations Environment Assembly adopted Resolution 5/14 aimed at negotiating a global treaty to put an end to plastic pollution.

In November 2022, a 'coalition of scientists for an effective treaty on plastics' was formed. With 400 members from 64 different countries, it has made several recommendations based on proven scientific knowledge.

In turn, the Office sets out nine recommendations to the treaty negotiators.

1. **Conclude an ambitious and legally binding treaty**

Only an ambitious treaty that improves waste management while imposing measures covering the entire plastics life cycle on countries around the world will bring about a significant reduction in plastic pollution.

2. **Plan for a significant reduction in the production of and demand for new virgin plastics**

There is a direct link between an increase in the production of virgin plastics, an increase in waste and the accumulation of micro and nanoplastics in living organisms, including the human body. Consequently, only binding policies limiting the production of and demand for virgin plastics will help to combat plastic pollution effectively.

3. **Boost the capabilities of governments and scientists**

The lack of institutional expertise and technical capacity, both public and private, to analyse chemicals and polymers, undermines authorities' ability to effectively regulate chemicals of concern. We must therefore promote the exchange of knowledge at a global level, ensure equal access to technical capabilities for all governments and private players, and strengthen institutional resources to ensure a more effective management of chemicals.

It is also essential to **promote independent expertise and science**, particularly through long-term funding. Project-based funding that only covers a few years prevents long-term research funding, for example for setting up and monitoring cohorts. This can lead to a loss of skills and knowledge when the project ends and reduces the effectiveness of public research.

4. **Require greater transparency from manufacturers on plastic chemicals, based on the principle of 'no data, no market'**

For two thirds of chemicals, there is no information on their potential dangers, and for 60% of them, there is no information on their use or presence in plastic materials and products. Many unknown substances are found in plastics, including substances added unintentionally. Essential information may exist, particularly from manufacturers, but it is not available to the general public or the authorities.

Without transparency on the composition of plastics and the presence of chemicals, consumers cannot obtain necessary information on the chemical content of the plastics they use. Most of the population is unaware of the presence of bisphenol A in cans.

The lack of transparency about the chemical composition of plastics makes recycling difficult and potentially dangerous. Harmful products are found in toys made from recycled plastics and in recycled food packaging.

To impose greater transparency on the composition of plastic materials, **governments must adopt a common approach that sets clear standards for the type of information to be collected from stakeholders throughout the value chain**. A **'no data, no market' approach** would help to disseminate essential information to the public.

5. **Reduce the number of chemicals used in polymer formulations**

To be operational, greater transparency on chemicals means imposing a reduction in the number of formulations and simplifying the chemicals used in their composition. Such a measure will also make it easier for administrations to check compliance with regulations on chemicals by limiting the number of analyses required.

6. **Improve the effectiveness of the regulation of chemicals using an hazard-and-group based approach**

Current regulations are based on an assessment of the risks associated with micro and nanoplastics. Analysing the 16,000 plastic chemicals is particularly costly and time-consuming, and requires precise data both on the hazard of each plastic chemical and on exposure to these plastics. In fact, given the large number of chemicals involved, generating and assessing such data is not feasible.

Furthermore, since humans are exposed to many plastic chemicals, assessing exposure for all scenarios to determine the risk involved would introduce insurmountable complexity and risk creating scientific uncertainty.

This is why the Office is proposing an approach based on hazard rather than risk to identify substances of concern that require action more quickly and effectively.

Hazard criteria should be set to identify chemicals of concern, adopting the four criteria used for the PlastChem database: persistence, bioaccumulation, mobility and toxicity.

The 10,000 chemicals for which there is no data must be assessed and regulated as a priority.

To make it easier for experts and political decision-makers, the Office is proposing a group-based **approach**, on the principle that chemicals with similar chemical structures cause identical effects. **Fifteen priority groups of plastic chemicals have been identified**, including bisphenols, phthalates, and PFAS.

7. **Develop more comprehensive life cycle analyses to better assess the negative externalities associated with the production and use of plastics**

Plastics are ubiquitous today, not only because they offer versatility and flexibility that are hard to match, but also because they are a very cheap raw material.

However, the price of plastic does not account for the impact of its production and use on the environment and human health, which is passed on to the general public and public authorities. The Office encourages developing more comprehensive life cycle analyses that account for the negative externalities linked to the production and use of plastics to determine their real price.

8. **Set criteria to help eliminate non-essential plastics**

The treaty must set out, on the one hand, several criteria to help eliminate non-essential plastics, and on the other, a principle of essential use to authorise, for a limited period, plastics that may be deemed dangerous, non-durable or unsustainable, but which are currently essential for society or health.

9. **Limit losses in the environment**

Improving waste management in all countries, particularly developing countries, will not by itself put an end to plastics pollution. On the one hand, poorly managed waste can never be reduced to zero, even in the most advanced economies. On the other hand, plastics are released into the physical and living environment throughout their life cycle, and not just at the end of their life, as illustrated by the losses of industrial granules during production, transport and use.

Improving waste management worldwide is nevertheless essential to limit the losses of plastics to the environment.

In 2019, 22% of plastic waste (79 million tonnes) was poorly managed, i.e. not recycled, landfilled or incinerated. According to an OECD study, if current waste management practices do not improve, poorly managed plastic waste is expected to reach almost 270 million tonnes by 2060, with waste increasing most in countries with less developed waste management systems. This highlights the **need to share best practice and existing technologies to provide technical and financial assistance to developing countries to improve their waste management systems to cope with the increase in waste**.

The OPECST Nine Recommendations

- Conclude an ambitious and legally binding treaty
- Plan for a significant reduction in the production of and demand for new 'virgin' plastics
- Boost the capabilities of governments and scientists
- Require greater transparency from manufacturers on plastic chemicals, based on the principle of 'no data, no market'
- Reduce the number of chemicals used in polymer formulations
- Improve the effectiveness of the regulation of plastic chemicals using an hazard-and-group based approach
- Develop more comprehensive life cycle analyses to better assess the negative externalities associated with the production and use of plastics
- Set criteria to help eliminate non-essential plastics
- Limit losses in the environment

[1] In 2019, the WWF warned of the quantity of plastic ingested by humans, estimated at 5 grams per week – the equivalent of a credit card. In 2021, these results were confirmed in a study by Kala Senathirajah et *al*. « Estimation of the mass of microplastics ingested. A pivotal first step toward human health risk assessment. », *Journal of hazardous Materials*, volume 404, Part B, 15 February 2021.

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