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Laboratory Waste – Immutable Fact of Life, or Opportunity for Change?

Dr. Jan Bebermeier, Dr. Joana Tziolis
Eppendorf SE, Germany

Whenever the topic of sustainability comes up in the scientific community, there are many issues to consider which fall into one of two main categories: Energy consumption of laboratory instrumentation and plastic containers of biological, chemical, or radioactive waste. Large bags containing used plastic tips, plates, and tubes are generated in most labs, based on different plastic types. In addition, lab employees are facing packaging materials made from a variety of different materials. Structured space and time dependent separation of the different compounds can help reduce the final amount of hazardous waste and increase the percentage of recyclable waste.

Figure 1: Lab waste – a daily occurrence in the laboratory

Sustainability is becoming increasingly important in everyday life. Wherever we interact in our personal area, we come across a growing number of sustainability topics. The same holds true for our interactions with you, our customers, in laboratories worldwide.

Whereas just a few years ago the topic of sustainability was mainly driven by dedicated employees in academic institutes and research-based companies, there has been a noticeable change for some time now. Purchasing departments as well as procurement systems request information, and we see a growing interest in Eppendorf and our approach to sustainability.
Progress and continuous improvements with respect to sustainability require open communication about product performance, as well as measures taken.

The many facets of sustainability in the laboratory
The disposal of packaging material, as well as products and related waste has thus far not been the focus of discussion. Manufacturers continuously develop and produce new products and consumers consistently add products to their labs; but old devices do not just disappear because something new arrives.

Sustainability also includes the fate of used equipment, such as worn-out centrifuges or broken PCR cyclers, and it must address the question of what to do about used plastic-ware. Even robust and well-designed products will reach the end of their lifetime. Depending on the type of product, as well as the frequency and style of their usage, this time frame will differ. This is also true for Eppendorf products.
Our R&D teams spend a lot of time on theoretical calculations of the lifetimes of the different parts of a new device. These calculated lifetimes typically exceed normal use in the lab by multiple times: Artificial aging-tests using automatic systems test, such as hinges or other mechanical parts, a few thousand or even ten thousand times.

Much of our equipment is still in use after 8-10 years. But there comes a time when the device is worn out, or when it will consume far more energy than a new model.
The lifetime of single-use plastic tubes and tips is mostly extremely short compared to the lifetime of a pipette, a centrifuge, or even a freezer. These consumables may end up as waste within seconds.

This means that all packaging material, consumables, and lab instruments will eventually end up as waste at some time point. But is it really waste? As in other areas, disposals from the lab may also serve as a resource for new products – resources that may be recyclable.

An essential aspect of resource conservation is a reduction of the final waste generated in laboratories. Final waste can be defined as the amount of material which needs to be incinerated based on regulatory and legal requirements.

There are three major different topics related to waste:
> Packaging material
> Single-use consumables
> Instruments and their longevity

Figure 2: Eppendorf Reload System for epT.I.P.S.® Box 2.0

Packaging

The packaging of Eppendorf products enables the safe arrival of the product in your lab. Your investment in new equipment is a financial as well as a resource investment. Both aspects require safe transportation of the product all the way to your bench.
In the case of packaging, we at Eppendorf strive to reduce the volume of waste. Wherever possible, we avoid unnecessary material use in packaging by reducing packaging size or material thickness. We also continuously review those areas in which alternative, more sustainable packaging materials are an option.
If you decide to dispose of the packaging, please follow some guidelines. Distinctions are made between the following types of packaging:
> Primary packaging
> Product packaging
> Transport packaging

Primary packaging
Primary packaging, or auxiliary products, such as the rack system for pipette tips, is often directly associated with the product as the product often depends on the primary packaging for its properties, which include, for example, sterility and ease of use.
Reload systems for pipette tips were introduced at Eppendorf in 2002. These reusable boxes for the tips (and rack systems) can be refilled and sterilized up to 100 times. Compared to, for example, disposable racks for 200 µL (filter) tips with 50 g of plastic per rack, the reusable box (183 g of plastic) with refills proportionally produces only approximately 1.8 g of plastic waste per run.

	Single-use Rack	Reusable Box
Box/ Rack	50 g	183 g/100 = 1.8 g
Tip holder	14 g	14 g
Tips (96x)	33 g	33 g
Filters (96x)	(2 g)	-
Foil box/ rack	(+)*	(+)*
Refill-packaging	/*	67 g/ 5 = 13.4 g
Foil refill	/*	(+)*
Total	**97 g**	**63 g**

*negligible weight

Table 1: Weight-based comparison of the different parts of a single-use tip rack compared to a reload system, based on a 200 µL Eppendorf system

With the introduction of the redesigned disposable filter tip rack systems for the epT.I.P.S.® in 2021, we were able to reduce the use of polypropylene (PP) in the rack systems by up to 35%, depending on tip size.

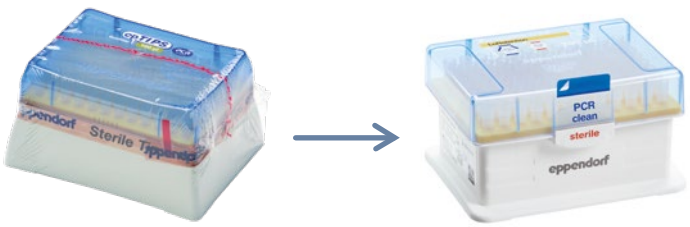

Figure 3: Resource-saving redesigned Eppendorf rack system for ep Dualfilter T.I.P.S.®

The primary packaging of bagged products, i.e., vessels, is currently still made of a composite material. This is necessary to ensure the required functionality, sterility, and transport reliability. The search for substitute materials for these kinds of bags has been initiated.

Figure 4: Primary packaging of bagged Eppendorf consumables

Individual packaging

Some applications in the lab require the highest possible purity levels to avoid contamination and prevent any negative impact on the analysis of the sample. Standard consumables, even if autoclaved, will not suffice. At Eppendorf, one of the highest purity levels is designated "biopur". Every consumable is individually wrapped and fulfills the highest expectations with respect to purity. This packaging is currently made from a non-recycled composite material. Why can Eppendorf not use monomeric or recycled plastic material? We are still facing challenges with leachables in recycled raw materials. These leachables can be transferred to the consumable and in this way, the leachables will also come into contact with the critical sample.

Figure 4: Primary packaging of individually wrapped Eppendorf consumables

Such individual packaging is made from high-quality resources. Is there any chance for recycling?
Again, the answer is challenging: The individually wrapped consumable is removed from the packaging, likely within the Biological Safety Cabinet (BSC). The BSC provides the highest safety for the user as well as the sample. In other words, this is an area which keeps biohazardous samples and reagents contained. Depending on local regulations, waste generated within the BSC may be defined as "contaminated" by standard and must be decontaminated by incineration.

The details of disposal of primary packaging depend on where it is used. Empty polypropylene (PP) tip racks can be fed into the recycling process of unmixed plastics after decontamination. Boxes made of polycarbonate (PC) need to be collected separately. For the final decision as to whether these materials can be collected for recycling, please contact your local safety officer.

Figure 5: Cardboard-based product packaging of Eppendorf consumables

Product packaging

Product packaging is the set of materials surrounding the product in the phase between the final production step and use in the laboratory by the customer. When designing product packaging, legal requirements as well as quality requirements must be taken into account. Depending on the product, aspects such as, for example, functionality, stability, or sterility must be considered. For worldwide shipment, the product should arrive on the customer's premises free of damage. Where possible, we continue to optimize and minimize the packaging material while keeping the product safe.

Whereas the product packaging of single-use consumables can be discarded after some time as consumables within the packaging box are used up, the product packaging material of instruments may be needed again. Why is this?
Some scientists keep the packaging of smaller instruments such as electronic pipettes, cyclers, or mixers for times when, for maintenance, service or calibration purposes, the product needs to be sent to the supplier or to a third party calibration service provider. If you decide to keep this packaging material, please keep in mind the local restrictions with respect to the storage of flammable materials in rooms or hallways. Product packaging is mainly made of cardboard. In many labs, the safety officers (in cooperation with the local fire department) limit the amount of cardboard material in the labs for safety reasons. Quite often, we also see packaging material stored on top of ULT freezers. This is to be avoided as the freezers require air circulation around the instrument. Packaging material blocking air circulation increases the power consumption of the freezer as the compressors need to work harder. Meanwhile, diminished air circulation increases the risk of compressor failure due to constant level of stress on the compressors (overheating).

Depending on the product type and weight, cardboard packaging composed of different material thicknesses is used. Cardboard packaging contains an increasing proportion of recycled paper material. This varies for the different products from, for example, 70 % for the freezers to almost 100 % for the Eppendorf Research® plus pipette. For some types of cardboard packaging, fresh (wood-based) fibers are needed to reinforce the recycling-cardboard material.
Some Eppendorf product packaging is already designed to be plastic-free. By using cardboard-based holders, the product such as the pipette, is sufficiently protected. An expansion of these plastic-free product packaging concepts is planned.

Devices are protected from dust and moisture by a thin polyethylene-based (PE) plastic wrapping. These plastic bags are mainly made of low-density PE (LD-PE). Depending on the weight of the device, padding made of foam (PE) is used. More and more foam packaging parts are based on recycled PE fractions (e.g., up to 30% for some centrifuges). Polystyrene (PS) is no longer used as a packaging material at Eppendorf.
Particularly heavy equipment such as freezers, shakers, and larger centrifuges are transported on special pallets made of wood.

We recommend recycling the cardboard product packaging as well as the PE material at local collection points. Similar to the primary packaging, the user should separate the product packaging from the product outside the laboratory area to ensure contamination-free recycling of these materials. Please check with your local waste and biosafety management.

Transport packaging
Transport packaging is the term we use to describe special packaging of several products of the same type as well as their product packaging. Transport packaging is used for efficient and safe shipment of this bulk packaging from the Eppendorf central warehouse to a regional warehouse or from an Eppendorf warehouse to a distributor or major customer. Transport packaging primarily consists of cardboard packaging with a high proportion of recycled fibers. The transport packaging has thus far not been re-used. We recommend recycling of the cardboard transport packaging at local collection points or recycling depots.

Figure 6: Single-use consumables require assessment of hazard status prior to potential recycling

Single-use consumables
The use of disposable plastic products in biomedical research laboratories is essential.
The former use of glass-based vessels has now almost completely given way to plastic. The manufacturing costs, robustness, and purity of plastic-based products argue against the use of glass. In addition, many experiments are nowadays performed on a microliter or nanoliter scale. For this purpose, vessels and tips with very fine dimensions are required, which cannot technically be manufactured from glass or only at extremely high cost. The life cycle assessment (LCA) of glass production requires several rounds of re-usage until it equals that of plastic production.

These plastic disposables are mostly made of polypropylene (PP) granules.
Based on a study by My Green Lab® in 2021, the global community of laboratories generates 4 times more waste than an equal area of office space. Expressed in absolute numbers, they produce approximately 5 million tons of plastic waste annually.
Since these disposables are used for working with biological, chemical, or radioactive sample material, the resulting plastic waste is contaminated, i.e., potentially harmful to human health and the environment. In many countries, this type of laboratory waste has to be collected separately from other waste in the laboratory. In many laboratories, this waste is double-bagged due to safety conditions. Biohazard waste is then decontaminated via suitable methods such as autoclaving at 121 °C for 20 min prior to final disposal.

Figure 7: Autoclaving of lab consumables in a Systec autoclave (picture kindly provided by Systec)

This process minimizes the transportation risk. Due to safety rules, the plastic-based laboratory waste with direct sample contact is typically sent for thermal utilization. This means that the material is burned in special waste facilities. As many incinerators generate heat for the purpose of heating buildings by district heating or generate electricity via hot air-driven turbines, the carbon energy of the laboratory plastic is still utilized.

Recycling of single-use consumables

Based on our experience in drug stores, where nowadays most of the plastic shampoo or lotion bottles are made of varying amounts of recycled material and can be recycled again, you may expect the same option for the tips and tubes used on the laboratory bench. As long as plastic consumables used in the lab are sorted based on their type of material, this recycling process would technically be possible. Most of the laboratory consumables are made of PP, which can easily be recycled.
However, there are caveats: As already stated, the biggest hurdle is due to the strict safety rules in many countries which specify that contaminated lab waste such as lab consumables must be incinerated.
Such legal frameworks are key; however, the recycling process of lab consumables itself would be challenging. As stated, accurately sorted plastic material can be recycled. Whoever worked in the lab and generated the waste is aware of the waste bag content – besides standard items made from PP, there are polycarbonate-based cell culture bottles, polyethylene terephthalate (PET)-based cell media bottles, high-density (HD)-PE bottle caps, LD-PE foil, and nitrile gloves. This mix of different polymers is accompanied by the remains of buffers, media, solvents, bases, acids, and other chemical substances.
Following the autoclaving process, at the latest, this mixed bag of substances becomes a real challenge for current recycling processes. In other words, even without legal restrictions, a standard recycling process of lab consumables is currently not possible with the existing available technical methods and acceptable costs and effort. Chemical recycling is a promising technology although it still requires a lot of energy and still operates on the scale of pilot systems. A further challenge is what is known as downcycling: many recycling processes for plastic generate recycled plastic of lower quality compared to the original material.
Future technologies may be able to utilize this mix of materials, and the legal situation may change; however, today, thermal destruction is the only way to handle contaminated plastic lab waste.

Interim solutions

When checking the lab waste bin for contaminated material, you may discover items which could be clean: items which were not in contact with samples or contaminated areas. This category of plastic components may not need to be discarded as biohazardous waste. This material can be a key component in reducing the amount of critical lab waste. This group includes the rack systems for pipette tips and outer packaging of disposables. Eppendorf includes these items in the group of auxiliary products that enable the correct use of the actual products. Depending on the way items are used in the laboratory, these auxiliary products may be classified as non-contaminated waste. However, depending on corresponding usage behavior, a definition as contaminated waste with corresponding waste regulations can also be made here.

Eppendorf recommends that our users – as much as possible – separate product packaging or auxiliary products, etc., before bringing them into the laboratory area or before potential contact with any sample material or contaminated work surfaces. This may allow separate collection of this material. Alternatively, prophylactic autoclaving or some other effective decontamination method – as autoclaving requires a lot of energy and water – may facilitate recycling of certain plastic fractions. At all times, local legal regulations will be the primary deciding factor.

Decontamination

Consider the piece of equipment that was used in a laboratory or was used to handle biological samples. Please keep in mind to adequately decontaminate the equipment that needs to be disposed of. Consult local requirements.
For more information, contact your local biosafety officer or waste officer. Check if your local recycling partner has special instructions and documentation requirements. You may also use the Eppendorf decontamination form sheet for guidance.

Disposal of the instrument

Our instruments last for many years, but if they need to be replaced, we kindly ask that you meet local requirements for their disposal. We strongly recommend a certified local recycling partner with experience in laboratory instruments. Keeping it "local" reduces the impact of transportation, and the "certified" aspect is recommended to ensure the safe and sustainable handling of lab equipment. Especially, devices with active cooling contain cooling liquids such as R170/ R290 or, for older equipment, R408/ R508B/ R134a. Safe removal and recycling of these cooling liquids is paramount.

Summary

Laboratories present a special situation when it comes to sustainability and recycling options. Due to contamination risk, regulatory and legal directions limit the options. Nonetheless, there are ways to reduce the volume and weight of critical waste by smart handling of packaging materials.
We at Eppendorf are making and will make further efforts to reduce the resources used for packaging and to optimize the options for separating the materials.

Figure 7 was kindly provided by Systec (www.systec-lab.com)

More information about sustainability at Eppendorf:
www.eppendorf.com/sustainability

About Eppendorf

Since 1945, the Eppendorf brand has been synonymous with customer-oriented processes and innovative products, such as laboratory devices and consumables for liquid handling, cell handling and sample handling. Today, Eppendorf and its approximately 5,000 employees serve as experts and advisors, using their unique knowledge and experience to support laboratories and research institutions around the world. The foundation of the company's expertise is its focus on its customers. Eppendorf's exchange of ideas with its customers results in comprehensive solutions that in turn become industry standards. Eppendorf will continue on this path in the future, true to the standard set by the company's founders: that of sustainably improving people's living conditions.

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Eppendorf SE · Barkhausenweg 1 · 22339 Hamburg · Germany
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