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Small Tubes – Big Impact: The Carbon Footprint of Safe-Lock Tubes BioBased

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As scientists, we're committed to tackling the climate crisis and finding solutions that make a real difference. Yet, we know that our own work – especially the use of disposable plastics in the lab – has an impact on the environment. These materials are vital for scientific progress, but they present a challenge we can't ignore. That's why we're exploring new paths. By moving from fossil-sourced materials to biobased alternatives, we can help reduce our carbon footprint without compromising on quality. In this White Paper, we compare the carbon footprint of microtubes made from both fossil-sourced and biobased materials. We show how much greenhouse gas emissions can be saved with the switch.



Sustainability in the laboratory is more important than ever. More and more scientists are taking the first steps to make their laboratory work more sustainable. Obviously, one major concern of almost everyone working in the laboratory is the large amount of plastics waste generated by the use of single-use plastic consumables. Besides the pure waste load, the carbon footprint of the production and the disposal of the plastics have a significant impact on their sustainability evaluation. The simple answer could be: Avoid plastic and use glass. The reality is, we can't avoid plastics entirely. Single-use items help to avoid contamination (which may occur if they are re-used), they ensure the quality of scientific results by providing reliable product quality, and they often simply save valuable time of every one of us. Additionally, polypropylene can circumvent downsides of glass-lab ware like sample loss due to sample adsorption to surfaces [1].

How can we tackle the challenge of reducing the carbon footprint in our labs otherwise? Finding ways to use less plasticware isn't easy – especially when reliability and safety are at stake. One promising step is to rethink the materials we use for single-use plastics. By choosing alternatives with a lower carbon impact, we can make meaningful progress together.

Switching from primary fossil oil-sourced plastics (here inafter shortly referred to as "fossil-sourced") to biobased materials (second generation material) offers a real opportunity to reduce greenhouse gas emissions by the laboratories.

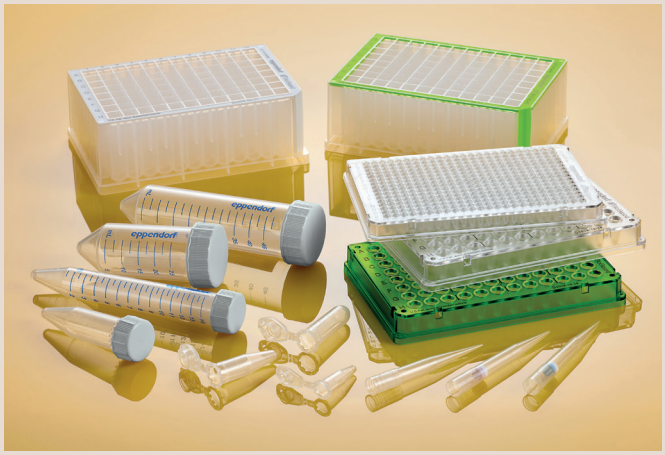


Figure 1: Eppendorf portfolio of biobased consumables

The first biobased products for laboratories are available. Since 2022, we have introduced a range of biobased products: biobased tubes, biobased PCR plates, biobased deep well plates (DWP), biobased pipette tips, and biobased Safe-Lock tubes – with more to come. But the key question for the scientists remains: How much greenhouse gas emissions can I actually save by making the switch?
And what can we learn to shape the next generation of sustainable products?
In this White Paper, we take a closer look at our Eppendorf Safe-Lock® tubes BioBased. By comparing their carbon footprint to that of traditional fossil-sourced options, we hope to uncover new ways to help you – and us – make an even greater impact.

Life cycle analysis and carbon footprint

Every product leaves an environmental footprint at every stage of its life cycle – from sourcing raw materials, to manufacturing and use, all the way to disposal whether through incineration, landfill or ideally, recycling (goal: re-use/ refurbishing). A Life Cycle Assessment (LCA) helps us see the full picture of environmental impacts of a product (or a service or a process). By examining each step, we can spot opportunities to improve and may even be able to compare the environmental performance of different products. The analysis requires a similar calculation approach and similar data quality.
To ensure meaningful results, an LCA relies on consistent methods and high-quality data. We recently conducted an LCA for our biobased 5 mL tubes, uncovering valuable insights (see our White Paper 93). While LCAs are complex and require significant resources, they give us – and you – the knowledge to make more informed, sustainable choices.

As many scientists focus on the carbon footprint of a product (and related savings), a shorter version of the LCA is valid as well: the Product Carbon Footprint (PCF). Respective data about the epT.I.P.S.® BioBased are published in White Paper 114.

What is a Product Carbon Footprint?

We calculated the Product Carbon Footprint (PCF) using mathematical rules and data methodologies similar to those in a Life Cycle Assessment (LCA). The standards, scope, and boundaries we choose shape the final results. While an LCA looks at a range of environmental impacts, a PCF focuses solely on climate change – specifically, greenhouse gas emissions.

Range of assessment

When assessing a product's carbon footprint, one of the two most common scenarios are:

> In a cradle-to-grave approach, greenhouse gas emissions across the entire life cycle – from raw material sourcing to end-of-life are calculated.

> In a cradle-to-gate scenario, the focus is on the early stages: sourcing, pre-processing, and manufacturing.

We might select the cradle-to-gate approach if we want to concentrate on the beginning of the product's journey, or if data for later stages – like use or disposal – are not reliable or not available. Choosing the right scenario helps us, and you, gain the most relevant insights for making sustainable decisions.
Once we have defined the functional unit, scenario, geographical boundaries, and further key assumptions in detail, you need to gather all the data. This means looking closely at every part of the process, i.e., the energy flows, services, and material inputs and outputs of the process: All these data must be obtained either from the manufacturer, suppliers or, if this is not possible, from databases. It is essential to note whether original data were used in the analysis or whether data had to be modeled using proxy data from databases (e.g. distances). Data quality must also be checked and assured.
With all the data in hand, we calculate the greenhouse gas impact using emission factors – numbers that tell us how much CO_2-equivalents is released for each material, service, or energy source. These factors can come from suppliers (primary data) or trusted databases (secondary data). By converting everything into CO_2-equivalents, we can clearly see where improvements are possible and identify the best opportunities to reduce emissions.



Figure 2: Functional unit of PCF - Safe-Lock tube, 1.5 mL, BioBased, PCR clean with 2 bags of 500 tubes each

The carbon footprint of fossil-sourced and biobased Safe-Lock tubes

The range of data hinges on the chosen life cycle scenario. Microtubes are used in laboratories around the world. Due to their enormous quantities used in the global scientific world, switching to a biobased product can have a real impact on reducing the carbon footprint in the laboratory work.
To make informed decisions on which tube to chose, we need reliable data. We partnered with an independent external party to calculate and compare the carbon footprints of our Safe-Lock tube products: one group made from fossil-sourced plastic, the other from biobased material.
The sourcing of the biobased material is based on second generation material, such as vegetable oil waste from the food industries (= recycling of previously used material).
Our biobased tubes are made with a 100% biobased share, based on the mass-balance-approach*. To ensure transparency and trust, both our supply chain of the biobased material as well as the Eppendorf factory is checked and verified by ISCC PLUS. The biobased tubes as products are checked and validated by the ACT® label of My Green Lab®.

The carbon footprint was calculated compliant to the ISO 14067 guidelines. The functional unit on which the PCF calculation is based is defined as follows:

a) Functional Unit: Safe-Lock tube, 1.5 mL, BioBased, PCR clean (#0030 123 140)
> 1,000 tubes, biobased, PCR clean
> 2x bags with 500 tubes each
> Packaging material including the primary plastics and secondary cardboard packaging for the individual containers and tertiary packaging cardboard box

b) Functional Unit: Safe-Lock tube, 1.5 mL, PCR clean (#0030 123 328)
> 1,000 tubes, fossil-sourced, PCR clean
> 2x bags with 500 tubes each
> Packaging material including the primary plastics and secondary cardboard packaging for the individual containers and tertiary packaging cardboard box

The carbon footprint was calculated based on a cradle-to-grave concept. In this White Paper, we focus on the cradle-to-gate scenario which is a part of the complete calculation but ending at the gate of Eppendorf.
The cradle-to-gate scenario included raw material sourcing, manufacturing, and a sterilization step as well as transportation between different sites. See also Figure 3.

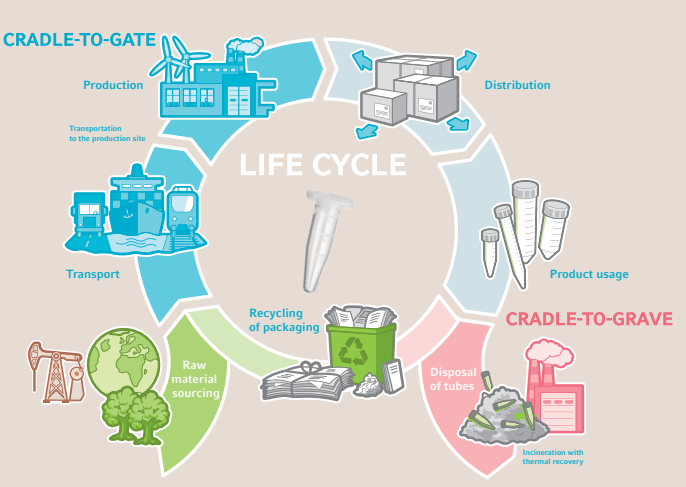


Figure 3: Eppendorf Safe-Lock tubes BioBased

*More information about biobased material and mass-balance-approach: www.eppendorf.com/biobased

To calculate the Product Carbon Footprint (PCF), we began with a detailed Bill of Materials (BoM) that listed every part, material, and weight of each component needed for production. Transport routes for each material and efforts in manufacturing were measured.
Once all the data was collected, emission factors were assigned or estimated. Some suppliers were already able to provide a PCF for their specific raw material or component, but most of the raw material data still had to be researched in databases (primarily Ecoinvent 3.11). The overall quality of data is considered high. Emission factors for the energy mix or truck transportation were also obtained from specific databases. Based on these emission factors, the product carbon footprints were calculated. The scale-up calculation from single tubes to complete functional units and vice versa can lead to rounding errors, as many values are very small.
To clearly mark the fundamental differences between both products, we split the carbon data into two groups:

> Analyzing the raw material impact only to show the real impact of the biobased material.

> Analyzing the complete product: This value is important for your own calculation in the laboratory as the total product value represents the real CO_2e savings compared to the fossil-sourced material.

Biogenic Carbon

Biogenic carbon emissions were addressed in this calculation. Biogenic carbon emissions take into account the fact that plant material absorbs CO_2 as it grows and releases exactly the same amount when it burns or decomposes. This results in net zero emissions – no additional CO_2 is released into the atmosphere. In contrast, non-biogenic fossil materials release CO_2 during combustion, increasing the total amount of CO_2 in the atmosphere. If you compare fossil-based materials to plant-based materials, you save exactly this amount of CO_2 emissions by using the plant-based material.
Biogenic carbon significantly increases the CO_2 savings until the "Gate" and decrease appropriately until the "Grave", resulting in +/- zero. The inclusion of biogenic carbon in the calculation of the carbon footprint is still under discussion in the community.
Following the standards, we decided to provide both values wherever possible: The carbon footprint including and excluding biogenic carbon.

Raw material only

Based on supplier data, it is possible to calculate and compare carbon values of a Safe-Lock tube based on the raw material, as the tubes in both products are exactly the same and only differ in the feedstock (incl. biogenic carbon):

> A single 1.5 mL Safe-Lock tube made from fossil-sourced material has a carbon footprint of 2.1 g CO_2e (#0030 123 328).

> A single 1.5 mL Safe-Lock tube made from biobased material has a carbon footprint of 1.7 g CO_2e (#0030 123 140).

Switching from fossil-sourced to biobased material saves 0.4 g CO_2e emission per tube. Extrapolated, these are 440 g CO_2e savings per package of 1,000x. Keep in mind that this is the limited view on raw material, only.

Total product (cradle-to-gate)

The functional unit (one sales unit with 1,000x tubes) requires for:

> Fossil-sourced tubes 3.01 kg CO_2e for (incl. biogenic carbon) and 3.01 kg CO_2e (excl. biogenic carbon).

> Biobased tubes 0.32 kg CO_2e (incl. biogenic carbon) and 3.51 kg CO_2e (excl. biogenic carbon), see also Table 1.

Order number	Material	Volume	Quality	Quantity per sales unit	Incl. biogenic carbon (kg CO_2e)	Excl. biogenic carbon (kg CO_2e)
#0030 123 140	Biobased	1.5 mL	PCR-clean	1,000x	0.32	3.51
#0030 123 328	Fossil	1.5 mL	PCR-clean	1,000x	3.01	3.01

Table 1: Comparison of cradle-to-gate evaluation for Eppendorf Safe-Lock tubes 1.5 mL PCR-clean as biobased or fossil-sourced; calculation based on ISO 14067 (functional unit = sales unit)

Total product (cradle-to-grave)

The functional unit (one sales unit with 1,000x tubes) requires for:

> Fossil-sourced tubes 7.03 kg CO_2e (incl. biogenic carbon) and 6.72 kg CO_2e (excl. biogenic carbon)

> Biobased tubes 4.34 kg CO_2e (incl. biogenic carbon) and 4.04 kg CO_2e (excl. biogenic carbon), see also Table 2.

Order number	Material	Volume	Quality	Quantity per sales unit	Incl. biogenic carbon (kg CO_2e)	Excl. biogenic carbon (kg CO_2e)
#0030 123 140	Biobased	1.5 mL	PCR-clean	1,000x	4.34	4.04
#0030 123 328	Fossil	1.5 mL	PCR-clean	1,000x	7.03	6.72

Table 2: Comparison of cradle-to-grave evaluation for Eppendorf Safe-Lock tubes 1.5 mL PCR-clean as biobased or fossil-sourced; calculation based on ISO 14067 (functional unit = sales unit)

Learnings

1) The major positive impact within biobased feedstock is caused by biogenic carbon. The biobased total product has a 38% lower carbon footprint (cradle-to-grave).

2) The cradle-to-gate approach is critical for the calculation of biobased material excl. biogenic carbon. The same process "to-grave" provides a positive impact of biobased feedstock.

The largest part of the PCF can be attributed to five main contributions. These are the production of the polymer and its precursors, the waste treatment of tubes, the production of the packaging and finally the air and road transport for sales units sold to markets outside Germany. The production of the tubes and the transport of raw materials for their production have minor impacts.
The highest reduction potential within the fraction of own operations is expected from further increasing the proportion of products made from 2nd generation biobased polymers in the Eppendorf portfolio. A further reduction of the material thickness (polymer per unit) is no option due to the needed stability of the tubes. Additional savings can be achieved by further reducing packaging material and the already low proportion of air transport.

Both absolute values (raw material as well as total product) seem to be marginal when checking the single tube. The emission savings are increasing when being upscaled to real laboratory scale. How many tubes do you use per week, per month, or per year? In addition, you probably use Safe-Lock tubes with different volumes like 0.5 or 2.0 mL.
Based on the CO_2e emissions of the raw material for the 1.5 mL tubes, Eppendorf and the related external partner agency have calculated the carbon emissions and carbon savings for other microtube sizes. This means that every laboratory can now get an idea of the carbon emissions associated with the use of these tubes.

ID	Article ID	Material source	Volume (mL)	Quality	Regional Version	Quantity per sales unit	Incl. biogenic carbon [kg CO_2e]	Excl. biogenic carbon [kg CO_2e]
1	0030 121 023	fossil	0.5	epQuality	EU	500x	1.9	1.8
2	0030 121 058	fossil	0.5	epQuality	USA	500x	2.2	2.2
3	0030 123 301	fossil	0.5	PCR-clean	EU	500x	1.9	1.8
4	0030 123 310	fossil	0.5	PCR-clean	USA	500x	2.2	2.2
5	0030 120 086	fossil	1.5	epQuality	EU	1,000x	6.9	6.6
6	0030 123 905	fossil	1.5	epQuality	USA	500x	4.2	4.1
7	0030 123 328	fossil	1.5	PCR-clean	EU	1,000x	7.0	6.7
8	0030 123 395	fossil	1.5	PCR-clean	USA	500x	4.3	4.1
9	0030 120 094	fossil	2	epQuality	EU	1,000x	7.3	7.0
10	0030 123 840	fossil	2	epQuality	USA	500x	4.6	4.4
11	0030 123 344	fossil	2	PCR-clean	EU	1,000x	7.5	7.1
12	0030 123 417	fossil	2	PCR-clean	USA	500x	4.6	4.5
13	0030 123 042	biobased	0.5	epQuality	EU	500x	1.2	1.1
14	0030 123 050	biobased	0.5	epQuality	USA	500x	1.6	1.5
15	0030 123 069	biobased	0.5	PCR-clean	EU	500x	1.2	1.1
16	0030 123 077	biobased	0.5	PCR-clean	USA	500x	1.6	1.5
17	0030 123 085	biobased	1.5	epQuality	EU	1,000x	4.3	4.0
18	0030 123 093	biobased	1.5	epQuality	USA	500x	2.9	2.8
19	0030 123 140	biobased	1.5	PCR-clean	EU	1,000x	4.3	4.0
20	0030 123 158	biobased	1.5	PCR-clean	USA	500x	2.9	2.8
21	0030 123 166	biobased	2	epQuality	EU	1,000x	4.5	4.2
22	0030 123 174	biobased	2	epQuality	USA	500x	3.1	3.0
23	0030 123 182	biobased	2	PCR-clean	EU	1,000x	4.6	4.3
24	0030 123 190	biobased	2	PCR-clean	USA	500x	3.2	3.1

Table 3: Carbon footprint of different fossil-sourced and biobased microtube formats and purity grades, cradle-to-grave based on ISO14067, incl. and excl. biogenic carbon (functional unit = sales unit with 500x resp. 1,000x tubes)

Lessons learned and outlook

We need to reduce carbon emissions, and we need to know our impact reduction potential. The first step is to have reliable data on the carbon footprint of a product. Based on this data, laboratories can calculate their carbon impact and carbon reduction potential related to a specific product. This use case clearly shows the major levers in product design and logistics that lead to a 38% reduction in carbon emissions for the Safe-Lock tubes 1.5 mL BioBased compared to the fossil-sourced tubes. This was achieved by changing to a biobased material.
However, the aim of a PCF for a company is not to stop at the result, but to draw conclusions for the future. In this case, additional optimization levers were identified. These include further regionalization for materials and services as well as further reduction of fossil-sourced materials.

Such a reduction does not only include the switch to bio-based materials but also the switch to other materials with a lower carbon footprint, such as recycled polymers for packaging materials. What are the prospects for the future? These two PCFs as some further ones for other plasticware are just the beginning and many more product carbon footprints must and will follow.
The ecodesign regulation (EU) 2024/1781, also known as ESPR, will request many product data to be published, not limited to carbon emissions. With the product carbon information, laboratories will be able to choose the most ecological product in terms of carbon emissions – and companies can identify the biggest levers to improve their manufacturing and product design.

References

[1] Chem. Eur. J. 2024, e202403000
[2] Whitepaper 093
[3] Whitepaper 114

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 4,500 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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