NEOGEN®

Reduction in Primary Energy Demand, Blue Water Consumption and Greenhouse Gas Emissions from Neogen® Petrifilm® Plates Compared to Traditional Microbiological Analysis Method

Abstract

A study examined reductions in primary energy demand, blue water consumption and greenhouse gas emissions from Neogen Petrifilm Plates, which provide an alternative to traditional agar plates for microbiological analysis. Environmental impacts due to raw material inputs, manufacturing, packaging, use, disposal and waste from both Petrifilm Plates and traditional agar plates were compared. GaBi software was used for data analysis. Gross calorific value was used for all calculations. The most conservative analysis was conducted by identifying the lowest environmental impact for the traditional agar plate data sets (best case scenario) while the Petrifilm Plate data sets used the highest environmental impact (worst case scenario). The use of one Petrifilm Plate instead of one agar plate resulted in estimated total reductions of 76% in primary energy demand, 79% in blue water consumption and 75% in greenhouse gas emissions. In addition, the use of Petrifilm Plates produced an estimated 66% reduction in mass of waste disposed. An uncertainty value of ± 50% was applied to all results. These results demonstrate that Petrifilm Plates provide significant reductions in environmental impacts and offer a valuable alternative to traditional agar plates for microbiological analysis.

Introduction

Petrifilm Plates are a rehydratable, dry-film, sample-ready, culture-medium system that contains nutrients, a coldwater-soluble gelling agent and indicator dye(s) that facilitate colony enumeration. One Petrifilm Plate is used to replace one traditional agar plate. They test a wide range of microorganisms including *E. coli*, *Listeria*, yeasts, molds, and *Staphylococcus*. Petrifilm Plates are used for the enumeration of bacteria in environmental monitoring, in-process testing, and finished product testing in the food and beverage industries.

This study, which is representative of all Petrifilm Plates, examined the estimated reductions in primary energy demand, blue water consumption, greenhouse gas (GHG) emissions and waste from the material inputs, manufacturing, packaging, use and disposal of Petrifilm Plates compared to traditional agar plates.

The study was conducted by the 3M Environmental Laboratory, which is an ISO 17025 accredited laboratory with supplemental accreditation to the General Program Instructions for the International EPD® System and ISO 14040/44. This study was conducted outside the scope of that accreditation and utilized ISO 14064-2 and the WRI/WBCSD GHG Protocol Project Standard.

Although the study utilized life cycle analysis data, it only covered aspects of the life cycle common between the two scenarios and does not represent a full life cycle assessment study.

Definitions

- **Blue Water Consumption:** The amount of water moved from one body of water (underground source, river, lake, etc.) to a second body of water and not replaced. This includes water that is evaporated and water incorporated into the product, as defined in the Water Footprint Assessment Manual.[1]
- **CO_2e (Equivalent Carbon Dioxide):** The concentration of CO_2 that would cause the same level of radiative forcing as a given type and concentration of greenhouse gas.
- **GaBi Software:** A life-cycle assessment modeling software from thinkstep AG. GaBi is a modeling, reporting and diagnostic software tool for LCA practitioners
- **Agar Plate:** The combination of a polystyrene petri dish with agar and sample.

Calculations and Results

Boundaries of the Study

The boundaries of this study included raw material inputs, manufacturing, packaging, use, disposal and waste related to traditional agar plates or Petrifilm Plates. Manufacture included all raw materials and primary packaging materials, production processes, manufacturer sterilization processes and emissions from the production of consumable materials used for microbiological analysis. Use included sterilization of the products by the user, preparation of the consumable materials and incubation. Disposal included sterilization of the used product and incineration of the product and primary packaging waste in a medical waste incinerator. Production of secondary packaging materials, production of other ancillary materials used in microbiological analysis, sample preparation and transportation were excluded from this study.

An external ISO 17025 Environmental Laboratory conducted the study[3] based on specifications and available product literature. GaBi software was used for emissions data and data analysis. Gross calorific value was used for all calculations.

The traditional agar plate data set used the lowest amount of environmental impact (best case scenario) while the Petrifilm Plate data set used the highest amount of environmental impact (worst case scenario) in order to conduct the most conservative analysis. A data uncertainty value of ± 50% was assigned to the study results based on engineering estimates and quantitative uncertainty results from life cycle assessments. An uncertainty value of ± 50% approximates data of fair-to-good quality, as defined in the WRI/WBCSD Product Life Cycle and Accounting Standard Quantitative Inventory Uncertainty Guide.[2]

Traditional Microbiological Analysis

The baseline scenario is manufacturing of one petri dish, manufacturing of agar, processing of agar for use in one petri dish and use of one agar plate, including incubation and disposal of the used agar plate.

a. Raw Material Inputs

The raw material inputs of a petri dish were estimated using a simplified GaBi model for plastic injection-molded parts, with polystyrene as the plastic (“DE: Polystyrene granulate (PS) mix”). The only raw material input used in this model was polystyrene.

The impact of manufacturing polystyrene for incorporation into one petri dish (12.4 g) was estimated to be 1.04 ± 50% MJ of primary energy demand, 0.150 ± 50% kg of blue water consumption and 0.0285 ± 50% kg CO_2e of greenhouse gas emissions.

For calculations relating to the components of agar, suitable data sets were not available in the GaBi databases. Therefore, the most conservative comparison scenario was to consider the agar material a zero impact. In this case, conservative was defined as the lowest primary energy demand, lowest blue water consumption or lowest greenhouse gas emissions, to provide the lowest possible values for comparison against the Petrifilm Plate. To account for this, the manufacturing of the raw materials used for agar production were excluded from the study.

b. Manufacturing

The manufacturing of a petri dish was approximated using a simplified GaBi model for plastic injection-molded parts using polystyrene as the plastic (“DE: Plastic injection moulding part (unspecific)”). The impact of manufacturing one polystyrene petri dish (12.4 g) was estimated to be 0.271 ± 50% MJ of primary energy demand, 0.0195 ± 50% kg of blue water consumption and 0.0656 ± 50% kg CO_2e of greenhouse gas emissions.

The impact of manufacturing agar was estimated using the same methodology for energy demand and water use as that of the manufacturing for Petrifilm Plates. For agar preparation, 23.5 g of agar were added to 1 L of water. The resulting mixture was used to fill 67 petri dishes (0.351 g of agar per petri dish). This mass correlated to an impact of 9.27×10^{-3} ± 50% MJ of primary energy demand, 3.63×10^{-3} ± 50% kg of blue water consumption and 6.11×10^{-4} ± 50% kg CO_2e of greenhouse gas emissions for the manufacture of agar used to fill one petri dish.

c. Packaging

For purposes of this study, the baseline assumption was that petri dishes and agar were packaged in two separate containers. Petri dishes are packaged in a low density polyethylene (LDPE) sleeve (25 dishes per package). The largest available container of agar was 25 lb. In the study, this was estimated by use of a 5 gal high density polyethylene (HDPE) pail.

The GaBi data set “US: Polyethylene film (LDPE/PE-LD) PE” was used to model the LDPE sleeve for packaging the petri dishes. The sleeve weighed 18.7 g and contained 25 petri dishes. The impacts of the packaging were 0.0739 ± 50% MJ of primary energy demand, 0.0113 ± 50% kg of blue water consumption and 2.22×10^{-3} kg ± 50% CO_2e of greenhouse gas emissions per petri dish.

A simplified model for blow molding was used to model the HDPE pail for packaging agar. The impacts of packaging agar were 4.07×10^{-3} ± 50% MJ of primary energy demand, 5.61×10^{-3} ± 50% kg of blue water consumption and 1.32×10^{-4} ± 50% kg CO_2e of greenhouse gas emissions per agar plate.

d. Use

Each of the process steps in the preparation of agar and agar plates were evaluated to determine primary energy demand, blue water consumption and greenhouse gas emissions then related to the use case for one agar plate. Impacts for one agar plate were 2.91 ± 50% MJ of primary energy demand, 0.818 ± 50% kg of blue water consumption and 0.209 ± 50% kg CO_2e of greenhouse gas emissions. Process steps and their impacts are shown in Table 1.

Table 1: Results for Use of One Agar Plate

Results for primary energy demand, blue water consumption and greenhouse gas (GHG) emissions for use of one agar plate. All values have an uncertainty of ± 50%.

Process Step	Electricity (MJ)	Water (kg)	GHG (kg CO_2e)
Weigh and pour nutrient agar (23.5 g) into bottle	0	0	0
Measure and pour deionized water (1 L) into bottle	1.26×10^{-3}	0.0152	6.64×10^{-5}
Boil bottle contents (1 minute)	0.0165	3.65×10^{-3}	1.18×10^{-3}
Autoclave bottle (47 minute cycle)	0.0104	0.0455	7.46×10^{-4}
Place bottle in water bath of 45–50°C (variable)	N/A[a]	N/A[a]	N/A[a]
Mix sample and agar then pour sample	0	0	0
Incubate agar plate (48 hours)	2.56	0.568	0.184
Empty remaining contents of bottle	5.55×10^{-5}	2.05×10^{-4}	3.78×10^{-5}
Rinse agar preparation bottle (using 1 L of tap water)	4.33×10^{-5}	0.0150	3.00×10^{-6}
Wash agar preparation bottle (one dishwasher cycle)	0.318	0.0804	0.0228
Rinse bottle three times with tap water (3 × 1 L)	1.30×10^{-4}	0.0449	9.01×10^{-6}
Rinse bottle three times with deionized water (3 × 1 L)	3.79×10^{-3}	0.0456	1.99×10^{-4}
Re-use glass agar bottle	0	0	0
TOTAL	**2.91**	**0.818**	**0.209**

a Assumed no impact as maintaining temperature would vary depending on several variables; for this reason, a value of zero was used as a conservative estimate.

e. Disposal

This study intentionally utilized the most conservative and hygienic method for waste disposal, recognizing that disposal methods vary depending on region and laboratory practices. The agar plates and their components' respective packaging were placed in biohazardous waste bags and autoclaved for 90 minutes. The biohazardous waste bags were then shipped to a medical waste incinerator for ultimate disposal.

The impact of each process step was estimated then related to the use case for one non-inoculated agar plate. The total results were 0.105 ± 50% MJ of primary energy demand, 0.278 ± 50% kg of blue water consumption and 0.0198 ± 50% kg CO_2e of greenhouse gas emissions. Disposal steps and their impacts are shown in Table 2.

In addition to the environmental impacts, the study investigated the amount of physical waste produced as a per volume measurement. Assessing the volume and total weight of agar plates, an average of 3,310 agar plates, 132 petri dish packages, and 0.103 g of packaging can be disposed of in one 55 gal biohazardous waste bag, totaling an average of 112 kg.

Table 2: Results for Disposal of One Agar Plate

Results for primary energy demand, blue water consumption and greenhouse gas (GHG) emissions for disposal of one agar plate. All values have an uncertainty of ± 50%.

Process Step	Electricity (MJ)	Water (kg)	GHG (kg CO_2e)	Weight (g)
Autoclave waste (90 minute cycle)	0.0837	0.200	6.01×10^{-3}	—
Dispose of agar plate (to medical waste incinerator)	2.03×10^{-2}	7.52×10^{-2}	1.38×10^{-2}	33.1
Dispose of agar pail (to medical waste incinerator)	2.96×10^{-5}	1.09×10^{-4}	3.80×10^{-7}	0.0396
Dispose of agar plate packaging (to medical waste incinerator)	5.57×10^{-4}	2.06×10^{-3}	7.16×10^{-6}	0.748
TOTAL	**0.105**	**0.278**	**0.0198**	**33.9**

f. Summary Impact for Traditional Microbiological Analysis

Estimated impacts for raw material inputs, manufacturing, packaging, use, disposal and waste for use of one traditional agar plate were summed. The estimated total impacts for the use of one agar plate were 4.41 ± 50% MJ of primary energy demand, 1.33 ± 50% kg of blue water consumption and 0.280 ± 50% kg CO_2e of greenhouse gas emissions.

Petrifilm Plates

a. Raw Material Inputs

In order to achieve the most conservative comparison, the highest primary energy demand, highest blue water consumption and highest greenhouse gas emissions were used for the Petrifilm Plate model. GaBi data sets were used to estimate the impact of raw materials in Petrifilm Plates. However, two components were excluded from the raw material model, as no data sets were available for those materials. To account for the excluded materials and to increase the estimated environmental impacts, the results of the model were scaled by the percentage of materials with available data sets (by 0.86 or 86%). Corrected (100%) impacts for one Petrifilm Plate were estimated to be 0.169 ± 50% MJ of primary energy demand, 0.0229 ± 50% kg of blue water consumption and 4.10×10^{-3} ± 50% kg CO_2e of greenhouse gas emissions.

b. Manufacturing

The environmental impacts of manufacturing Petrifilm Plates were estimated using a mass-based allocation of the environmental impacts of the manufacturing facility. The estimated impacts for manufacturing one Petrifilm Plate were 0.0622 ± 50% MJ of primary energy demand, 0.0244 ± 50% kg of blue water consumption and 4.10×10^{-3} ± 50% kg CO_2e of greenhouse gas emissions.

c. Packaging

Petrifilm Plates are packaged in a multi-layer foil pouch containing 25 or 50 plates per package. For this study, the more conservative approach was taken and the package with 25 plates, which had a mass of 5.00 g, was used. Estimated impacts from the packaging materials were 2.27×10^{-2} ± 50% MJ of primary energy demand, 5.14×10^{-3} ± 50% kg of blue water consumption and 7.99×10^{-4} ± 50% kg CO_2e of greenhouse gas emissions.

d. Use

Petrifilm Plates do not require preparation. A sample is inoculated onto the Petrifilm Plate then the plate is incubated. For purposes of this study, a 48 hour incubation period was used. The impacts of the incubation related to the use case for one Petrifilm Plate were 0.818 MJ ± 50% of primary energy demand, 0.182 ± 50% kg of blue water consumption and 0.0588 ± 50% kg CO_2e of greenhouse gas emissions.

e. Disposal

The study intentionally utilized the most conservative and hygienic method for waste disposal, recognizing that disposal methods vary depending on region and laboratory practices. The Petrifilm Plates were placed in biohazardous waste bags and autoclaved for 90 minutes. The biohazardous waste bags were then shipped to a medical waste incinerator for ultimate disposal.

The impact of each of process step was estimated then related to the use case for one non-inoculated Petrifilm Plate. The total results were 0.0182 ± 50% MJ of primary energy demand, 0.0459 ± 50% kg of blue water consumption and 2.30×10^{-3} ± 50% kg CO_2e of greenhouse gas emissions. Disposal steps and their impacts are shown in Table 3.

In addition to the environmental impacts, the study investigated the amount of physical waste produced as a per volume measurement. Assessing the volume and total weight of Petrifilm Plates, an average of 16,900 Petrifilm Plates and 676 Petrifilm Plate packages can be disposed of in one 55 gal biohazardous waste bag totaling an average of 37.9 kg.

Table 3: Results for Use of One Petrifilm Plate

Results of modeling primary energy demand, blue water consumption and greenhouse gas (GHG) emissions for the use and disposal of one Petrifilm Plate. All values have an uncertainty of ± 50%.

Process Step	Electricity (MJ)	Water (kg)	GHG (kg CO_2e)	Weight (g)
Autoclave waste (90 minute cycle)	1.64×10^{-2}	3.92×10^{-2}	1.18×10^{-3}	—
Dispose of Petrifilm Plate (to medical waste incinerator)	1.65×10^{-3}	6.11×10^{-3}	1.12×10^{-3}	2.22
Dispose of packaging materials (to medical waste incinerator)	1.49×10^{-4}	5.50×10^{-4}	1.91×10^{-6}	0.20
TOTAL	**0.0182**	**0.0459**	**2.30×10^{-3}**	**2.24**

f. Summary Impact for Petrifilm Plates

Estimated impacts for raw material inputs, manufacturing, packaging, use, disposal and waste for use of one Petrifilm Plate were summed. The estimated total impacts for the use of one Petrifim Plate were 1.07 ± 50% MJ of primary energy demand, 0.277 ± 50% kg of blue water consumption and 0.0695 ± 50% kg CO_2e of greenhouse gas emissions.

Conclusions

This study examined reductions in primary energy demand, blue water consumption and greenhouse gas emissions from Petrifilm Plates, which provide an alternative to traditional agar plates for microbiological analysis. Environmental impacts due to raw material inputs, manufacturing, packaging, use, disposal and waste from Petrifilm Plates and traditional agar plates were compared.

For one microbiological analysis using one traditional agar plate, the total estimated environmental impacts were 4.41 ± 50% MJ of primary energy demand, 1.33 ± 50% kg of blue water consumption, 0.280 ± 50% kg CO_2e of greenhouse gas emissions, and 33.9 ± 50% g of waste was produced.

For one microbiological analysis using one Petrifilm Plate, the total estimated environmental impacts were 1.07 ± 50% MJ of primary energy demand, 0.277 ± 50% kg of blue water consumption, 0.0695 ± 50% kg CO_2e of greenhouse gas emissions, and 2.24 ± 50% g of waste was produced.

Therefore, the total estimated reductions in environmental impacts were 3.35 ± 50% MJ of primary energy demand, 1.05 ± 50% kg blue water consumption, 0.210 ± 50% kg CO_2e in greenhouse gas emissions and 31.7 ± 50% g of waste when using one Petrifilm Plate to conduct a microbiological analysis rather than one agar plate. These estimated environmental impacts are shown in Table 4.

Expressed as percentages, the use of one Petrifilm Plate rather than one agar plate resulted in total estimated reductions of 76% ± 50% in primary energy demand, 79% ± 50% in blue water consumption, 75% ± 50% in greenhouse gas emissions and 94% ± 50% mass reduction in disposal. Furthermore, the use of Petrifilm Plates produced an estimated 66% ± 50% reduction in mass of waste disposed using one 55 gal container. See Figure 1.

These results demonstrate that Petrifilm Plates provide substantial reductions in environmental impacts and offer a valuable alternative to traditional agar plates for microbiological analysis.

Table 4: Summary of Life Cycle Impacts

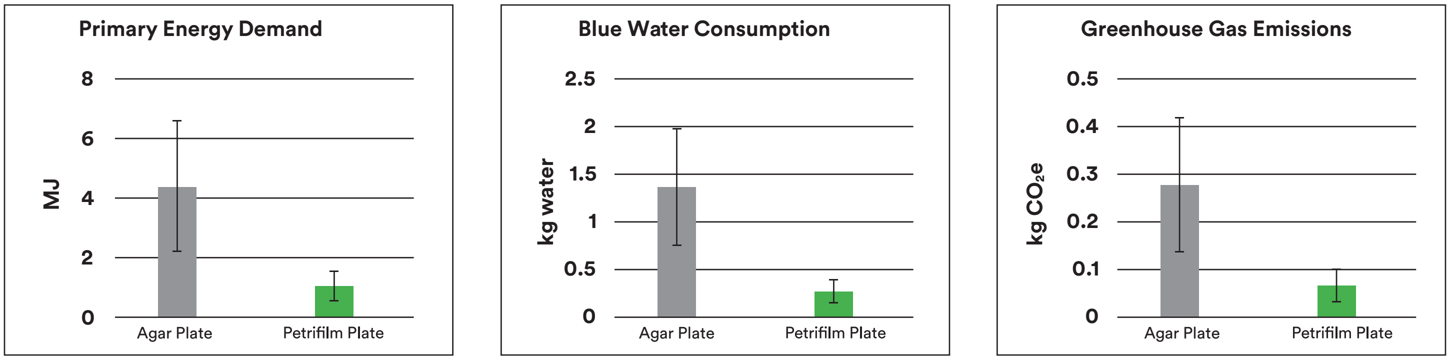
Summary of life cycle impacts for one microbiological analysis. All values have an assigned uncertainty of ± 50%.

Midpoint	Product	Manufacturing and Packaging	Use Phase	Disposal Phase	Total	Reduction due to Replacement of Traditional Agar Plate with Petrifilm Plates
Primary Energy Demand (MJ)	Petrifilm Plate	0.229	0.818	0.0182	**1.07**	—
	Traditional Agar Plate	1.40	2.91	0.105	**4.41**	—
	Difference[a]	**1.17**	**2.09**	**0.0864**	**3.35**	**76%**
Blue Water Consumption (kg water)	Petrifilm Plate	0.0491	0.182	0.0459	**0.277**	—
	Traditional Agar Plate	0.231	0.818	0.278	**1.33**	—
	Difference[a]	**0.182**	**0.637**	**0.232**	**1.05**	**79%**
Greenhouse Gas Emissions (kg CO_2e)	Petrifilm Plate	8.41×10^{-3}	0.0588	2.30×10^{-3}	**0.0695**	—
	Traditional Agar Plate	0.0510	0.209	0.0198	**0.280**	—
	Difference[a]	**0.0426**	**0.150**	**0.0175**	**0.210**	**75%**
Waste produced (g)	Petrifilm Plate	N/A	N/A	2.24	**2.24**	—
	Traditional Agar Plate	N/A	N/A	33.9	**33.9**	—
	Difference[a]	**N/A**	**N/A**	**31.7**	**31.7**	**94%**

[a] The reductions are representative of the product lines and baseline scenarios presented. The calculations in this report cover a small percentage of the Petrifilm Plate portfolio. Product lines not covered by this report may represent an increase in emissions over their baseline scenarios.

Figure 1: Summary of Life Cycle Impacts

Summary of life cycle impacts for one microbiological analysis.



Learn more at **info.neogen.com/Petrifilm**

NEOGEN

---

[1] Arjen Y. Hoekstra, et. al., The Water Footprint Assessment Manual, 2011.

[2] WRI/WBCSD Product Life Cycle and Accounting Standard Quantitative Inventory Uncertainty Guide, 2011.

[3] 3M Environmental Laboratory Report Number CF1148/E14-2195.

Neogen Corporation, 620 Lesher Place, Lansing, MI 48912 USA.