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Reduction in Primary Energy Demand, Blue Water Consumption and Greenhouse Gas Emissions from 3M™ Molecular Detection Assay 2 – *Salmonella* Method Compared to ISO 6579 Cultural *Salmonella* Method

Abstract

A study examined reductions in primary energy demand, blue water consumption and greenhouse gas emissions from the 3M™ Molecular Detection Assay 2 – *Salmonella* method, which provides an alternative to ISO 6579 for the detection of *Salmonella* in foods. Potential environmental impacts due to raw material inputs, manufacturing, packaging, use, disposal and waste from both the 3M Molecular Detection Assay 2 – *Salmonella* and ISO 6579 methods were compared. GaBi software was used for data analysis. Gross calorific value was used for all calculations. Although the models have several assumptions and data gaps, the results demonstrate reasonable estimates for the relative potential environmental impact for each scenario in the scope of the study. When the methods differ, the most conservative analysis was conducted by identifying the lowest potential environmental impact for the ISO 6579 data sets (best case scenario) while the 3M Molecular Detection Assay 2 – *Salmonella* data sets used the highest potential environmental impact (worst case scenario). Assuming a 1% *Salmonella*-positive rate detected by both methods, the 3M Molecular Detection Assay 2 – *Salmonella* method resulted in reductions of 77% in primary energy demand, 77% in blue water consumption and 76% in greenhouse gas emissions compared to the ISO 6579 method. In addition, the use of the 3M Molecular Detection Assay 2 – *Salmonella* method reduced waste mass by 83% compared to the ISO 6579 method. The results are estimates based on modeling and have an uncertainty values identified in Table 3. These results demonstrate that the 3M Molecular Detection Assay 2 – *Salmonella* method provides significant reductions in potential environmental impacts and offer a valuable alternative to the cultural ISO 6579 method for the detection of *Salmonella* in foods.

Introduction

3M has a corporate initiative to develop products that reduce potential environmental impacts. These products include the 3M™ Molecular Detection System, which is used for the rapid and specific detection of pathogenic organisms in food, feed, and food process environmental samples. The 3M Molecular Detection Assay 2 – *Salmonella* kit consists of lysis solution and amplification/detection reagent. It can be used in direct replacement to following the ISO 6579:2002, Microbiology of food and animal feeding stuffs — Horizontal method for the detection of *Salmonella* spp., ed. 2002[1] which consists of agar plates and slants, and biochemical and serological confirmation reagents and materials.

This study for 3M Molecular Detection Assay 2 – *Salmonella*, 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 all components in using the 3M Molecular Detection Assay 2 – *Salmonella* method compared to the ISO 6579 method.

The study was conducted by the 3M Environmental Laboratory,[2] 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 14064-2:2006[3] and the WRI/WBCSD GHG Protocol Project Standard[4] to collect data.

The study covered aspects of the life cycle common between the identified scenarios and does not represent a full life cycle assessment (LCA) considering all potential environmental impacts.

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.[5]
- **CO_2e (Equivalent Carbon Dioxide):** The concentration of carbon dioxide that would cause the same level of radiative forcing as a given type and concentration of greenhouse gas.
- **GaBi Software:** Product sustainability software from thinkstep AG. GaBi[6] is a modeling, reporting and diagnostic software tool for LCA practitioners.
- **Agar Plate:** The combination of a polystyrene petri dish with agar.
- **Agar Slant:** The combination of a glass or plastic tube with agar.
- **Media:** Nutritive compositions for the cultivation of microorganisms.

Calculations and Results

Boundaries of the Study

The boundaries of this study included raw material inputs, manufacturing, packaging, use, disposal and waste related to the ISO 6579 method or 3M Molecular Detection Assay 2 – *Salmonella* method. 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 materials 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, due to potential biohazard status. Production of secondary packaging materials, production of other ancillary materials used in microbiological analysis, sample preparation and transportation were excluded from this study, as they are expected to have negligible impact on the final comparison. Energy use of the 3M™ Molecular Detection Instrument was included in the evaluation. Manufacturing of the 3M Molecular Detection Instrument was excluded from the study, as were all other capital goods required for testing (e.g., incubator, dishwasher, autoclave, etc.) The study used activity data from 3M Food Safety, 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 ISO 6579 method data set used the lowest amount of potential environmental impact (best case scenario) while the 3M Molecular Detection Assay 2 – *Salmonella* data set used the highest amount of potential environmental impact (worst case scenario) to conduct the most conservative analysis where the steps differ. 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.[7]

The ISO 6579 method is a current international standard for determining the presence of *Salmonella* in food, feed and environmental samples. This method includes the following steps: sample preparation, primary enrichment, primary analysis, secondary enrichment and secondary analysis. The 3M Molecular Detection Assay 2 – *Salmonella* method was developed by 3M to be an alternative method to ISO 6579 for the detection of *Salmonella* in food, feed and related environmental samples. Compared to the ISO 6579 method, the 3M Molecular Detection Assay 2 – *Salmonella* method replaces the primary analysis of the food sample and, given a negative result, would eliminate any secondary enrichment and analysis. However, if the 3M Molecular Detection Assay 2 – *Salmonella* method indicates a presumptive positive test result, the secondary enrichment and analysis would be the same as the ISO 6579 method.

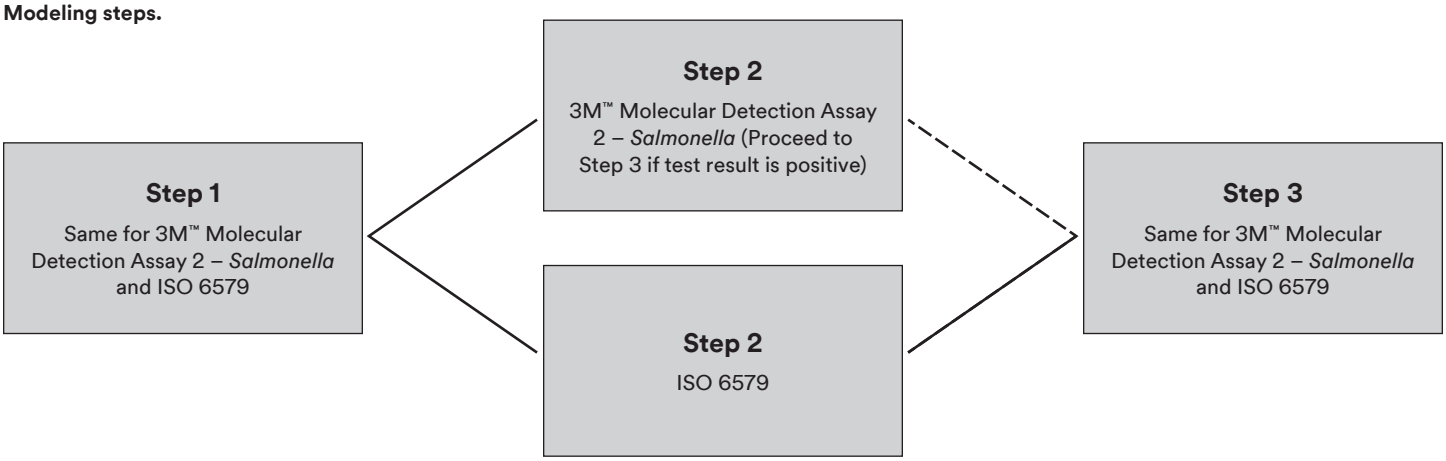
The ISO 6579 method was divided into three steps for ease of modeling and comparison:

- Step 1 includes sample preparation and primary sample enrichment/pre-enrichment;
- Step 2 includes the primary analysis using agar media; and
- Step 3 includes secondary enrichment and secondary analysis, including confirmation.

In the ISO 6579 method, all three steps are completed for all tests, regardless of a positive or negative test result in Step 2.

The 3M Molecular Detection Assay 2 – *Salmonella* method was also divided into three steps. Step 1 and Step 3 are identical to the ISO 6579 method and Step 2 is a unique step that includes the use of the 3M Molecular Detection Assay 2 – *Salmonella* and the 3M Molecular Detection Instrument for sample analysis. Figure 1 shows the steps included in each method. The dotted line from Step 2 — 3M Molecular Detection Assay 2 – *Salmonella* to Step 3 indicates that the method only proceeds to Step 3 if there is a positive test result in Step 2.

Figure 1.
Modeling steps.



Three different scenarios were evaluated (based on one 3M Molecular Detection Assay 2 – *Salmonella* kit containing 96 tests):

1. 0 positive tests; 96 negative tests (0% positive samples).
2. 1 positive test; 95 negative tests (1% positive samples).
3. 19 positive tests; 77 negative tests (20% positive samples).
4. 96 positive tests; 0 negative tests (100% positive samples).

In all scenarios, a positive result is a food sample that contains *Salmonella* and a negative test is a food sample that does not contain *Salmonella*.

Results of Potential Environmental Impacts — ISO 6579 Method

The baseline scenario is the ISO 6579 method. This method is used to detect *Salmonella* in food, feed and related environmental samples. The method uses enrichment media and agar plates and slants to selectively grow, differentiate and detect *Salmonella* species. Generally, the method includes sample preparation, primary sample enrichment, primary sample analysis, secondary sample enrichment and secondary sample analysis. For this study, the process was divided into three steps for ease of modeling and comparison. Step 1 includes the sample preparation and primary sample enrichment. Step 2 includes the primary sample analysis. Step 3 includes the secondary sample enrichment and the secondary sample analysis required for the confirmation of *Salmonella* being present in the sample.

The raw materials included in the GaBi model for the ISO 6579 method include general laboratory items such as pipette tips, petri dishes, weighing spoons, weighing boats, Pyrex® bottles, plastic bags, test tubes and caps; various media and reagents; and the primary packaging components for the laboratory consumables (secondary and larger packaging items were not included). The generic laboratory materials were modeled based on the material type.

The potential environmental impact of all components in the ISO 6579 method from contributions of the raw materials, use, and waste disposal stages are found in Table 1. All results except for mass of waste have an uncertainty value of ± 50%.

Table 1.
ISO 6579 method results.

	Greenhouse Gas Emissions (kg of CO_{2e})	Primary Energy Demand (MJ)	Blue Water Consumption (kg)	Waste Mass (kg)
ISO 6579 Scenario	**454**	**7,050**	**2,630**	**79.6**
Raw Material Impact	35.0%	58.8%	50.1%	NA
Use Impact	30.8%	32.3%	33.8%	NA
Waste Disposal Impact	34.2%	8.92%	16.1%	NA

For calculations relating to the components of agar media and testing reagents used in the ISO 6579 method, suitable data sets were not available in the GaBi databases. 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 3M product.

Results of Potential Environmental Impacts — 3M Molecular Detection Assay 2 – *Salmonella*

The 3M Molecular Detection Assay 2 – *Salmonella* method was developed by 3M to be an alternative method to ISO 6579 for the rapid detection of *Salmonella* in enriched food, feed and food process environmental samples. Compared to the ISO 6579 method, the 3M Molecular Detection Assay 2 – *Salmonella* method replaces the primary analysis of the food sample and, given a negative result, would eliminate any secondary enrichment and analysis (confirmation steps). However, if the 3M Molecular Detection Assay 2 – *Salmonella* method indicates a positive result in the food sample, the method utilizes the same confirmation steps as the ISO 6579 method. Except for the primary analysis (Step 2) all other steps are assumed to be identical. To achieve the most conservative comparison, the highest primary energy demand, highest blue water consumption and highest greenhouse gas emissions were used for the 3M Molecular Detection Assay 2 – *Salmonella* model.

The raw materials GaBi data sets were used to estimate the impact of raw materials in the 3M Molecular Detection Assay 2 – *Salmonella* method and standard laboratory materials, including laboratory items such as pipette tips, petri dishes, weighing spoons, weighing boats, Pyrex bottles, plastic bags, test tubes and caps; various media and reagents; and the primary packaging components for the laboratory consumables (secondary and larger packaging items were not included). The generic laboratory materials were modeled based on the material type.

The 3M Molecular Detection Assay 2 – *Salmonella* method, used for primary analysis (Step 2), contains the 3M Lysis Solution, 3M Reagent Control, 3M Molecular Detection Assay 2 – *Salmonella* reagent, racks, caps and various packaging components. Many of the components used in the 3M Molecular Detection Assay 2 – *Salmonella* method did not have suitable analogue in the GaBi databases, therefore a generic data gap process was used to model these materials. In all scenarios, the generic unknowns utilized the most conservative comparison scenario against the ISO 6579 method. In this case, conservative was defined as the highest primary energy demand, highest blue water consumption or highest greenhouse gas emissions, to provide the highest possible values for comparison against the ISO 6579 method.

Four scenarios were used to allow for the most accurate comparison with the ISO 6579 method:

1. 0 positive tests; 96 negative tests (0% positive samples).

2. 1 positive test; 95 negative tests (1% positive samples).

3. 19 positive tests; 77 negative tests (20% positive samples).

4. 96 positive tests; 0 negative tests (100% positive samples).

In the 3M Molecular Detection Assay 2 – *Salmonella* method, all samples are analyzed through Step 1 and the primary analysis (Step 2). Only positive tests require secondary analysis to confirm the presence of *Salmonella* in the sample (Step 3). The total impact of raw materials, use and disposal were evaluated and are found in Table 2. All results except for mass of waste have an uncertainty value of ± 50%.

Table 2.
3M Molecular Detection Assay 2 – *Salmonella* method results.

	Greenhouse Gas Emissions (kg of CO_{2e})	Primary Energy Demand (MJ)	Blue Water Consumption (kg)	Waste Mass (kg)
Scenario 1: 0% positives	**106**	**1590**	**586**	**12.7**
Raw Material Impact	28.3%	52.1%	42.9%	NA
Use Impact	40.4%	44.0%	49.3%	NA
Waste Disposal Impact	31.3%	3.9%	7.8%	NA
Scenario 2: 1% positives	**108**	**1620**	**597**	**13.0**
Raw Material Impact	28.5%	52.4%	43.1%	NA
Use Impact	40.2%	43.6%	48.9%	NA
Waste Disposal Impact	31.3%	4.0%	8.0%	NA
Scenario 3: 20% positives*	**144**	**2200**	**801**	**19.8**
Raw Material Impact	31.4%	55.5%	45.7%	NA
Use Impact	36.7%	39.0%	43.7%	NA
Waste Disposal Impact	31.9%	5.4%	10.6%	NA
Scenario 4: 100% positives*	**297**	**4700**	**1670**	**21.2**
Raw Material Impact	36.0%	60.2%	49.7%	NA
Use Impact	31.3%	32.3%	35.8%	NA
Waste Disposal Impact	32.7%	7.5%	14.5%	NA

*Scenarios 3 and 4 are unlikely in the field, however, those scenarios were still evaluated to demonstrate the potential environmental impact across a range of positive results.

Results of Potential Environmental Impacts — 3M Molecular Detection Assay 2 – *Salmonella* vs. ISO 6579

The results for the comparison of 3M Molecular Detection Assay 2 – *Salmonella* to ISO 6579 are shown in Table 3. Scenarios 1–3 demonstrate that the 3M Molecular Detection Assay 2 – *Salmonella* method provides substantial reductions in potential environmental impacts and offer a valuable alternative to ISO 6579 for microbiological analysis. In scenario 4 the results were nonconclusive. However, Scenario 4 results are expected since the confirmation step (Figure 1, Step 3) for both methods are the same.

Table 3.
Comparison of ISO 6579 and 3M Molecular Detection Assay 2 – *Salmonella* methods.

	Greenhouse Gas Emissions (kg of CO_{2e})	Primary Energy Demand (MJ)	Blue Water Consumption (kg)	Waste Mass (kg)
Scenario 1: 0% positives[a]	77% (30% – 92%)	77% (32% – 92%)	78% (33% – 93%)	84% (NA[b])
Scenario 2: 1% positives[a]	76% (29% – 92%)	77% (31% – 92%)	77% (32% – 92%)	84% (NA[b])
Scenario 3: 20% positives[a]	68% (5% – 89%)	69% (6% – 90%)	70% (9% – 90%)	75% (NA[b])
Scenario 4: 100% positives[a]	NC (-97% – 78%)	NC (-100% – 78%)	NC (-91% – 79%)	73% (NA[b])

[a] (uncertainty range); [b] actual calculations

A strong correlation exists between the number of positive test results and each evaluated environmental impact. As fewer samples test positive for *Salmonella*, there is a larger reduction in potential environmental impact when comparing 3M Molecular Detection Assay 2 – *Salmonella* to ISO 6579.

Conclusions

This study examined reductions in primary energy demand, blue water consumption and greenhouse gas emissions across four different scenarios comparing 3M Molecular Detection Assay 2 – *Salmonella* to ISO 6579. Potential environmental impacts due to raw material inputs, manufacturing, use, disposal and waste from 3M Molecular Detection Assay 2 – *Salmonella* and ISO 6579 methods were compared. Overall 3M Molecular Detection Assay 2 – *Salmonella* demonstrated substantial reductions in environmental impacts compared to ISO 6579 method.

The study did not include a full life cycle assessment considering all potential environmental impacts. A detailed LCA study could be conducted for each scenario of the 3M Molecular Detection Assay – *Salmonella* and ISO 6579 methods; however, the LCA study would provide little additional value and would likely confirm the results presented in this study.

References

1. ISO 6579:2002, Microbiology of food and animal feeding stuffs — Horizontal method for the detection of *Salmonella* spp., ed. 2002.

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4. WRI/WBCSD, GHG Protocol for Project Accounting, ed. 2004.

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6. thinkstep, GaBi Software-System and Database for Life Cycle Engineering, copyright 1992–2016 thinkstep AG. (Compilation 7.3.3.153, DB version 6.115).

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

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