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California Air Resources Board (CARB)
Low Carbon Fuel Standard (LCFS) Proposed Amendments | Stakeholder Feedback

This comment is intended to recommend the use of the carbon-14 testing method to determine the share of biogenic carbon content of Tier 2 fuels and throughout biomethane supply chains. Biogenic content measurements following methods such as ASTM D6866 Method B currently provide critical value to prominent clean fuel standard programs around the world and should be treated as critical information on a fuel's environmental attributes.

Included here you will find:

Recommendations for CARB's Proposed LCFS Amendments

Our recommendation is that CARB's proposed amendments to the Low Carbon Fuel Standard (LCFS) should include direct biogenic content testing requirements following the ASTM D6866 Method B standard for all Tier 2 fuels and throughout biomethane supply chains. Routine biogenic testing requirements currently play a critical role in the United States Renewable Fuels Standard (RFS) and the European Union's Renewable Energy Directive (RED) for their regulation of many biofuels, including biogas upgraded to renewable natural gas (RNG) or biomethane fuels. This comment is specifically meant to address § 95488.7 on Tier 2 Fuel Pathway requirements and § 95488.8 on Fuel Pathway application requirements for all classifications.

Extend Biogenic Testing Requirements to All Tier 2 Fuels

For § 95488.7 on Tier 2 Fuel Pathway requirements our recommendation is that all Tier 2 pathway applications be required to submit routine biogenic testing following ASTM D6866 Method B. Biogenic

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testing is currently required for Tier 2 fuels that are produced by co-processing.[1] This requirement should be extended to all Tier 2 applications because biogenic content is a key environmental attribute to track for any fuels credited under the program. The sustainability documentation required for Tier 2 applications under § 95488.7(a)(4) pursuant to § 95488.9(g) should include routine biogenic test results. This is the only way to guarantee the renewable content of fuels credited under the program.

We recommend reviewing Canada's Clean Fuel Regulation (CFR) requirements for claiming biomass as renewable feedstocks, which include routine direct testing following ASTM D6866. By requiring testing of feedstocks through final products the CFR program is able to accurately quantify renewable content throughout the supply chain.[2] This is especially important for California's LCFS because fuels using a wide range of feedstocks from across the country and world now target the program's incentives.

Beta commented on several Tier 2 applications for biodiesel fuels produced from tallow and used cooking oil (UCO) that ASTM D6866 should have been conducted. For example, Beta commented on Neste's application No. B0458 for renewable diesel (RD) produced from tallow and UCO. Neste's response claimed that these fuels are fully renewable because their tallow and UCO feedstocks are fully renewable, despite deriving energy from their integrated fossil fuel plant. While renewable diesel fuels are drop-in fuels which are not blended during production, they are not necessarily 100% biogenic and should be tested to establish their baseline. Especially given the wide range of feedstocks used to produce RD, including UCO which has been at the center of fraud investigations in the US and EU, these fuels need to be tested to claim biogenic content.

We recommend that CARB review the Netherlands' HVO Regulation, which requires C-14 biogenic content testing for any hydrogenated vegetable oil (HVO) fuels (another term for renewable diesel) claiming renewable content in the country.[3] We also recommend reviewing France's Circulaire TIRIB which requires C-14 biogenic testing for any HVO fuels imported into the country.[4] As member states within the EU bloc, both of these national regulations offer examples of strong approaches to regulating RD from jurisdictions in comparable positions.

Require Biogenic Testing Throughout Biomethane Supply Chains

For § 95488.8 on Fuel Pathway application requirements for all classifications our recommendation is that any biomethane/RNG fuels produced from biogas should be required to submit routine biogenic testing following ASTM D6866. In addition, any book-and-claim accounting system for tracking the environmental attributes of these fuels throughout the supply chain should be required to align any calculations to these biogenic test results. This change would align the program with the best practices

[1] 2020. "Reporting Co-Processing and Renewable Gasoline Emissions Under MRR." *California Air Resources Board*
[2] 2022. "Clean Fuel Regulations: Quantification Method for Co-Processing in Refineries." *Environment and Climate Change Canada*
[3] 2023. "Do I need to perform a C14 analysis for HVO?" *Dutch Emissions Authority*
[4] 2020. "Incentive Tax Relating to the Incorporation of Biofuels (TIRIB)." *French General Directorate of Customs and Indirect Taxes*

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established by the US Renewable Fuel Standard (RFS), the EU Renewable Energy Directive (RED) and Canada's Clean Fuels Regulation (CFR) for biogenic quantification.

This section specifically addresses the proposed modifications to subsection 95488.8(i)(2), specifically that "staff proposes to allow for book-and-claim accounting of biomethane to produce electricity for electric vehicle charging." This section is also meant to address the proposed modifications to subsection 95488.9(b) where, "staff proposes to add a new temporary CI for low-CI electricity produced by fuel cell from biomethane from dairy and swine manure, based on existing program data." It is critical that projects combusting biomethane to produce electricity be required to conduct biogenic testing to book the correct amount of renewable content. Alternative approaches based on calculations, especially based only on existing program data, consistently overestimate the renewable content of fuels, which would lead to credits being claimed for electricity produced from the fossil-based portion of combusted fuels.

The US introduced biogenic testing requirements for fuels produced from biogas in the 2023 Set Rule update to the US Renewable Fuel Standard (RFS), in a section called the Biogas Regulatory Reform Rule (BRRR).[5] This update requires routine biogenic testing for any biogas or RNG fuels seeking to generate RINs under the RFS. Starting on July 1st, 2024 for new facilities and January 1st, 2025 for existing facilities, fuels produced from biogas will need to submit biogenic test results of the biogas at the point of production from the digester/landfill, at the point of upgrading, and after upgrading prior to pipeline injection. By testing the initial feedstock at the anaerobic digester, the biogas derived fuel at the point of upgrading and the final blended fuel, there is a clear demonstration of biogenic content from the raw biogas from these livestock operations to the final energy product.

The EU introduced biogenic testing requirements for fuels produced from biogas in a June 2023 update to the EU Renewable Energy Directive (RED) titled, "Renewable energy- method for calculating the share of renewables in the case of co-processing."[6] This update was specifically issued in response to the discovery of a major case of fraud within the RED program stemming from biodiesel submissions from China which were approved by mass balance calculations.[7] The EU investigation into this issue is still ongoing, and the full extent of the damage is not yet known, but this was a significant setback for the program and quickly plummeted biodiesel prices in the EU. The EU tied biogas and biomethane into the update in order to address these concerns for any fuels containing a mixture of biogenic and fossil content.

[5] 2023. "40 CFR Parts 80 and 1090– Renewable Fuel Standard (RFS) Program: Standards for 2023–2025 and Other Changes." *EPA*
[6] 2023. "Renewable energy- method for calculating the share of renewables in the case of co-processing." *European Commission*
[7] 2023. "ISCC Press Release July 27, 2023." *International Sustainability & Carbon Certification*

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The advantage of this framework is that the EU was able to continue to accept calculation based methodologies like mass and energy balance by requiring routine direct biogenic testing to validate the data. However, calculation based approaches are much more common for co-processing, where all inputs and outputs are concentrated in a single facility, as opposed to biomethane and RNG which are often produced, upgraded and blended at multiple facilities.

One other relevant model specifically for biomethane combusted to produce renewable electricity is Canada's Greenhouse Gas Reporting Program (GHGRP), which requires biogenic testing following ASTM D6866, "If combusted fuels or fuel mixtures contain a biomass fraction that is unknown or cannot be documented." The program specifically requires fuel sampling, "Quarterly for renewable and biomass gaseous fuels derived from biomass including landfill gas and biogas from wastewater treatment or agricultural processes."[8] This is an important model to consider for the proposed modifications to subsection 95488.8(i)(2) and subsection 95488.9(b) because it provides a better approach to measuring the biogenic content of biomethane combustion than making assumptions based on historical program data. Allowing producers to generate credits for electricity produced from biomethane production without routine testing would expose the program to greenwashing and fraud.

The US RFS model of testing at the point of production, at the point of blending with non-renewable components and at the point of injection into a pipeline provides a comprehensive chain of custody for the renewable content in these fuels, making it possible to report and trade only real biogenic content introduced to the grid. Similarly, the EU RED model demonstrates that tying calculation-based accounting approaches to routine direct testing requirements is the most secure way to access the benefits of a book-and-claim system without exposing the program to undue risk. Finally, Canada's GHGRP model provides a successful model of testing at the point of combustion for biomethane intended to produce electricity, without allowing producers to claim credits for more renewable energy than they actually provide. Implementing proper biogenic quantification by requiring routine testing following ASTM D6866 is the most effective way to credit biomethane from production to end use.

Never Rely Exclusively on Mass Balance Calculations

It is critically important that California's LCFS rely on direct testing for biogenic content quantification, rather than allow calculation based approaches such as mass balance, which make claims based on material inputs in production. These calculations allow producers to assume that all of their biomass inputs end up in their facilities' outputs, despite it being well understood in the industry that the input of renewable feedstocks is not the same as the output. Renewable feedstocks will often have different activity than their fossil counterparts and won't necessarily produce the same quantity of outputs.[9] By

[8] 2022. "Canada's Greenhouse Gas Quantification Requirements." *Environment and Climate Change Canada*
[9] 2006. "Determining the modern carbon content of biobased products using radiocarbon analysis." *Bioresource Technology*, 97(16), 2084-2090.

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basing their calculations solely on production inputs rather than outputs these methods systematically over-report the renewable share of fuels.

This is very important to consider for any program certifying biogas which is upgraded to fuels because biogas is often blended with non-renewable content in the process of biomethane production. If California's LCFS relies exclusively on calculations to quantify biogenic content, producers will be able to intentionally claim credits for fossil content used in these energy products. The only reliable way to attribute credits exclusively to the biogenic content derived from biogas is through routine direct testing at the point of production, the point of blending with non-renewable content, and the point of pipeline injection or combustion.

Calculation-based approaches such as book and claim also allow producers to use a system of free allocation, meaning they do not have to guarantee that there is any renewable content in a given output. Producers prefer this because if 10% of their feedstocks are biogenic they can claim that 10% of their outputs are biogenic, even if that's not the case because biogenic content can go in different amounts to different end products. As a result, book and claim systems allow producers to claim that 10% of their outputs are 100% biogenic and the rest are 0%, even if all of the products should be 10% biogenic based on calculations (and would likely C14 test below that).[10] This allows producers to intentionally claim unfounded renewable content in the products which can maximize their incentives, without providing the decarbonization benefits those incentives are meant to promote. In the case of the LCFS, this could mean that producers would be able to claim that 100% of their biomethane fuels are biogenic, even if much of the final fuel contains fossil content, while the remaining biogas is used elsewhere in their operation.

We encourage CARB to review the recent mass balance fraud challenges faced by the EU Renewable Energy Directive (RED) program as an example of this risk.[11] In July 2023 the program discovered rampant fraudulent biodiesel submissions from China, which had been certified by ISCC mass balance. The discovery quickly "caused a dramatic fall in biodiesel prices in European markets."[12] In response to this situation the EU quickly updated the RED's rules to uniformly require routine direct testing, including for producers choosing to use calculation based approaches to verify their calculations.[13] We also re-emphasize to CARB that the EU chose to include biogas derived fuels in this update to protect the integrity of calculations used to track biogenic content through biomethane supply chains as well.

Conclusion

[10] 2024. "The Mass Balance Approach." *International Sustainability & Carbon Certification*
[11] 2023. "ISCC Press Release July 27, 2023." *International Sustainability & Carbon Certification*
[12] 2023. "ISCC Press Release July 27, 2023." *International Sustainability & Carbon Certification*
[13] 2023. "Renewable energy- method for calculating the share of renewables in the case of co-processing." *European Commission*

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Routine testing requirements are a critical part of the verification process and should be used to verify the renewable content of biogas upgraded to fuel in the LCFS. Introducing testing requirements for biogas and biogas derived fuels is in line with the treatment of these fuels under the US Renewable Fuel Standard (RFS) and the EU Renewable Energy Directive.[14] Relying on mass or energy balance calculations alone would allow producers to continue to claim credits for fossil derived content in these fuels by allocating renewable content from elsewhere in their operation which never end up in the final energy product. In addition to the benefit of reliable results under the standard, routine testing requirements would ensure consistency across the board for anyone pursuing the Tier 2 Pathway.

What is Biogenic Testing (Carbon-14)?

Carbon-14 analysis is a reliable method used to distinguish the percentage of biobased carbon content in a given material. The radioactive isotope carbon-14 is present in all living organisms and recently expired material, whereas any fossil-based material that is more than 50,000 years old does not contain any carbon-14 content. Since Carbon-14 is radioactive, the amount of carbon-14 present in a given sample begins to gradually decay after the death of an organism until there is no carbon-14 left. Therefore, a radiocarbon dating laboratory can use carbon-14 analysis to quantify the carbon-14 content present in a sample, determining whether the sample is biomass-based, fossil fuel-derived, or a combination.

The analysis is based on standards such as ASTM D6866 and its international equivalents developed for specific end uses, such as ISO 21644. ASTM D6866 is an international standard developed for measuring the biobased carbon content of solid, liquid, and gaseous samples using radiocarbon dating.[15] There are also many specific international standards based on the use of direct Carbon-14 testing, such as ISO 21644, which is a European standard developed for measuring the biogenic carbon content of waste derived fuels as a fraction of total carbon content.[16]

Carbon-14 analysis yields a result reported as % biobased carbon content. If the result is 100% biobased carbon, this indicates that the sample tested is completely sourced from biomass material such as plant or animal byproducts. A result of 0% biobased carbon means a sample is only fossil fuel-derived. A sample that is a mix of both biomass sources and fossil fuel sources will yield a result that ranges between 0% and 100% biobased carbon content. Carbon-14 testing has been incorporated into several regulations as the recommended or required method to quantify the biobased content of a given material.

ASTM D6866 Method B - The Most Reliable Method

[14] 2010. "40 CFR Part 80 Subpart M– Renewable Fuel Standard." *National Archives Code of Federal Regulations*
[15] 2021. "Standard Test Methods for Determining the Biobased Content of Solid, Liquid, and Gaseous Samples Using Radiocarbon Analysis." *ASTM International (D6866-21)*
[16] 2021. "ISO 21644:2021 Solid recovered fuels: Methods for the determination of biomass content." *International Standardization Organization*

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Carbon-14 is a very well-established method which has been in use by many industries (including the fossil fuel industry) and academic researchers for several decades.

Carbon-14 measurements done by commercial third party testing is robust, consistent, and with quantifiable accuracy/precision of the carbon-14 amount under **ASTM D6866 method B**. The EN 16785 is the only standard that allows a variant of the Mass Balance (MB) method of 'carbon counting' under EN 16785-2. The EN 16785-1 requires that the biocarbon fraction be determined by the carbon-14 method. However, when incorporating this EN 16785 method, certification schemes like the "Single European Bio-based Content Certification" **only** allow the use of EN 16785-1 due to its reliability and the value of a third-party certification. http://www.biobasedcontent.eu/en/about-us/

In ASTM D6866 method B, the carbon-14 result is provided as a single numerical result of carbon-14 activity, with graphical representation that is easily understood by regulators, policy makers, corporate officers, and more importantly, the public. The overwhelming advantage of carbon-14 is that it is an independent and standardized laboratory measurement of any carbon containing substance that produces highly accurate and precise values. In that regard, it can stand alone as a quantitative indicator of the presence of biobased vs. petroleum feedstocks. When carbon-14 test results are challenged, samples can be rapidly remeasured to verify the original reported values (unlike mass balance).

The quantification of the biobased content of a given product can be as low as 0.1% to 0.5% (1 relative standard deviation – RSD) based on Instrumental error for Method B (AMS). This error is exclusive of indeterminate sources of error in the origin of the biobased content, and manufacturing processes. As such a total error of +/-3% (absolute) has been assigned to the reported Biobased Content to account for determinate and indeterminate factors.[17]

It is also important that the program should always require ASTM D6866 Method B, rather than allow Method C for any use. Where ASTM D6866 Method B uses the AMS Instrument to measure ^{14}C, Method C uses Liquid Scintillation Counting (LSC). In Method B, the AMS Instrument directly measures the ^{14}C isotopes. However, in Method C, scintillation molecules indirectly absorb the beta molecules that release with the decay of ^{14}C and convert the energy into photons which are measured proportionally to the amount of ^{14}C in the sample. Since Method B directly measures the ^{14}C isotopes and Method C measures them indirectly, Method B is significantly more precise and should be prioritized in regulations.[18] LSC measurements, like those used in Method C, are commonly used as an internal testing tool when samples are limited and accuracy does not need to be extremely high.

[17]2021. Standard Test Methods for Determining the Biobased Content of Solid, Liquid, and Gaseous Samples Using Radiocarbon Analysis. *ASTM International (D6866-21)*. pp 1-19. doi: 10.1520/D6866-21.
[18]2022. "Testing the methods for determination of radiocarbon content in liquid fuels in the Gliwice Radiocarbon and Mass Spectrometry Laboratory." *Radiocarbon*

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About Beta Analytic

Beta Analytic was among the originators of the use of Accelerator Mass Spectrometry (AMS) for the ASTM D6866 biobased / biogenic testing standard using Carbon-14 to distinguish renewable carbon sources from petroleum sources. Beta began testing renewable content in 2003 at the request of United States Department of Agriculture (USDA) representatives who were interested in Beta's Carbon-14 capabilities for their BioPreferred® Program (www.biopreferred.gov). At their request, Beta joined ASTM under subcommittee D20.96. Beta's previous president, Darden Hood, was positioned as a technical contact for the USDA and within 3 months completed the ASTM D6866-04 standard. The Carbon-14 technique is now standardized in a host of international standards including ASTM D6866, CEN 16137, EN 16640, ISO 16620, ISO 19984, BS EN ISO 21644:2021, ISO 13833 and EN 16785. Carbon-14 analysis can be used on various types of samples (gas, liquids and solids). Beta Analytic continues to be a technical contact for ASTM D6866 with current president Ron Hatfield and is involved with all their latest ASTM D6866 versions.

The Carbon-14 standardized method is also incorporated in a variety of regulatory programs including the California AB32 program, US EPA GHG Protocol, US EPA Renewable Fuels Standard, United Nations Carbon Development Mechanism, Western Climate Initiative, Climate Registry's Greenhouse Gas Reporting Protocol and EU Emissions Trading Scheme.

We are currently technical experts on Carbon-14 in the following committees:

ASTM D6866 (D20.96) Plastics and Biobased Products (Technical Advisor)
ASTM (D02.04) Petroleum Products, Liquid Fuels and Lubricants (Technical Advisor)
ASTM (061) US TAG to ISO/TC 61 Plastics (Technical Expert)
USDA BioPreferred Program TAC (Technical Advisor)
ISO/TC 61/SC14/WG1 Terminology, classifications, and general guidance (Technical Expert)
CEN/TC 411 Biobased Products
CEN/TC 411/WG 3 Biobased content
CEN/TC 61/SC 14/WG 1 Terminology, classifications, and general guidance (Technical Expert)

ISO/IEC 17025:2017 Accredited Laboratory

To ensure the highest level of quality, laboratories performing ASTM D6866 testing should be ISO/IEC 17025:2017 accredited or higher. This accreditation is unbiased, third party awarded and supervised. It is unique to laboratories that not only have a quality management program conformant to the ISO 9001:2008 standard, but more importantly, have demonstrated to an outside third-party laboratory accreditation body that Beta Analytic has the technical competency necessary to consistently deliver

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technically valid test results. The ISO 17025 accreditation is specifically for natural level radiocarbon activity measurements including biobased analysis of consumer products and fuels, and for radiocarbon dating.

Required tracer-free facility for Carbon-14

For carbon-14 measurement to work, be accurate, and repeatable, the facility needs to be a tracer-free facility, which means artificial/labeled carbon-14 is not and has never been handled in that lab. Facilities that handle artificial carbon-14 use enormous levels relative to natural levels and it becomes ubiquitous in the facility and cross contamination within the facility, equipment and chemistry lines is unavoidable. Results from a facility that handles artificial carbon-14 would show elevated renewable contents (higher pMC, % Biobased / Biogenic values), making those results invalid. Because of this, Federal contracts and agency programs (such as the USDA BioPreferred Program) require that AMS laboratories must be 14C tracer-free facilities in order to be considered for participation in solicitations.

Areas where cross-contamination might occur include but are not limited to; biomedical or nuclear reactors, isotope enrichment / depletion columns, water, soil, plant, or air samples collected near or at biomedical / nuclear reactor sites, medical, industrial, or hazardous waste sites, samples specifically manipulated to study the uptake / fractionation of stable isotopes due to biological or metabolic processes. To learn more about the risks associated with testing natural levels Carbon-14 samples in a facility handling artificially enhanced isotopes please see the additional information provided after this comment.

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2024. "The Mass Balance Approach." *International Sustainability & Carbon Certification*
https://www.iscc-system.org/certification/chain-of-custody/mass-balance/

Demand a Tracer-Free Laboratory for Radiocarbon Dating

As part of its commitment to provide high-quality results to its clients, ISO/IEC 17025-accredited Beta Analytic does not accept pharmaceutical samples with "tracer Carbon-14" or any other material containing artificial Carbon-14 (14C) to eliminate the risk of cross-contamination. Moreover, the lab does not engage in "satellite dating" – the practice of preparing individual sample graphite in a remote chemistry lab and then subcontracting an AMS facility for the result.

High Risk of Cross-Contamination

Pharmaceutical companies evaluate drug metabolism by using a radiolabeled version of the drug under investigation. AMS biomedical laboratories use 14C as a tracer because it can easily substitute 12C atoms in the drug molecule, and it is relatively safe to handle. Tracer 14C is a well-known transmittable contaminant to radiocarbon samples, both within the AMS equipment and within the chemistry lab.

Since the artificial 14C used in these studies is phenomenally high (enormous) relative to natural levels, once used in an AMS laboratory it becomes ubiquitous. Cross-contamination within the AMS and the chemistry lines cannot be avoided. Although the levels of contamination are acceptable in a biomedical AMS facility, it is not acceptable in a radiocarbon dating facility.

Biomedical AMS facilities routinely measure tracer-level, labeled (Hot) 14C samples that are hundreds to tens of thousands of times above the natural 14C levels found in archaeological, geological, and hydrological samples. Because the 14C content from the biomedical samples is so high, even sharing personnel will pose a contamination risk; "Persons from hot labs should not enter the natural labs and vice versa" (Zermeño et al. 2004, pg. 294). These two operations should be absolutely separate. Sharing personnel, machines, or chemistry lines run the risk of contaminating natural level 14C archaeological, geological, and hydrological samples.

Avoid the Risks

Find out from the lab that you are planning to use that they have never in the past and will never in the future:

- accept, handle, graphitize or AMS count samples containing Tracer or Labeled (Hot) 14C.

- share any laboratory space, equipment, or personnel with anyone preparing (pretreating, combusting, acidifying, or graphitizing) samples that contain Tracer or Labeled (Hot) 14C.

- use AMS Counting Systems (including any and all beam-line components) for the measurement of samples that contain Tracer or Labeled (Hot) 14C.

Tracer-Free Lab Required

Recently, federal contracts are beginning to specify that AMS laboratories must be 14C tracer-free facilities in order to be considered for participation in solicitations.

A solicitation for the National Oceanic and Atmospheric Administration (NOAA) has indicated that "the AMS Facility utilized by the Contractor for the analysis of the micro-samples specified must be a 14C tracer-level-free facility." (Solicitation Number: WE-133F-14-RQ-0827 - Agency: Department of Commerce)

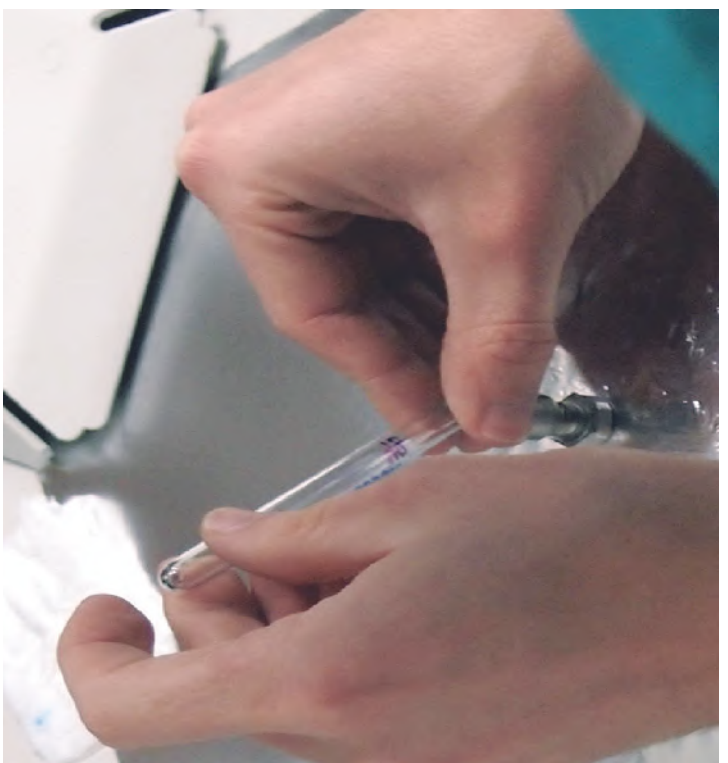
As a natural level radiocarbon laboratory, we highly recommend that researchers require the AMS lab processing their samples to be Tracer-free.

No Exposure to Artificial Carbon-14

According to ASTM International, the ASTM D6866 standard is applicable to laboratories working without exposure to artificial carbon-14 routinely used in biomedical studies. Artificial carbon-14 can exist within the laboratory at levels 1,000 times or more than 100 % biobased materials and 100,000 times more than 1% biobased materials. Once in the laboratory, artificial 14C can become undetectably ubiquitous on materials and other surfaces but which may randomly contaminate an unknown sample producing inaccurately high biobased results. Despite vigorous attempts to clean up contaminating artificial 14C from a laboratory, isolation has proven to be the only successful method of avoidance. Completely separate chemical laboratories and extreme measures for detection validation are required from laboratories exposed to artificial 14C. Accepted requirements are:

(1) disclosure to clients that the laboratory working with their products and materials also works with artificial 14C
(2) chemical laboratories in separate buildings for the handling of artificial 14C and biobased samples
(3) separate personnel who do not enter the buildings of the other
(4) no sharing of common areas such as lunch rooms and offices
(5) no sharing of supplies or chemicals between the two
(6) quasi-simultaneous quality assurance measurements within the detector validating the absence of contamination within the detector itself.

ASTM D6866-22 – Standard Test Methods for Determining the Biobased Content of Solid, Liquid, and Gaseous Samples Using Radiocarbon Analysis.



Useful Reference

1. Memory effects in an AMS system: Catastrophe and Recovery. J. S. Vogel, J.R. Southon, D.E. Nelson. Radiocarbon, Vol 32, No. 1, 1990, p. 81-83 doi:10.2458/azu_js_rc.32.1252 (Open Access)

"... we certainly do not advocate processing both labeled and natural samples in the same chemical laboratory." "The long term consequences are likely to be disastrous."

2. Recovery from tracer contamination in AMS sample preparation. A. J. T. Jull, D. J. Donahue, L. J. Toolin. Radiocarbon, Vol. 32, No.1, 1990, p. 84-85 doi:10.2458/azu_js_rc.32.1253 (Open Access)

"... tracer 14C should not be allowed in a radiocarbon laboratory." "Despite vigorous recent efforts to clean up the room, the "blanks" we measured had 14C contents equivalent to modern or even post -bomb levels."

3. Prevention and removal of elevated radiocarbon contamination in the LLNL/CAMS natural radiocarbon sample preparation laboratory. Zermeño, et. al. Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms
Vol. 223-224, 2004, p. 293-297
doi: 10.1016/j.nimb.2004.04.058

"The presence of elevated 14C contamination in a laboratory preparing samples for natural radiocarbon analysis is detrimental to the laboratory workspace as well as the research being conducted."

4. High level 14C contamination and recovery at XI'AN AMS center. Zhou, et. al. Radiocarbon, Vol 54, No. 2, 2012, p. 187-193
doi:10.2458/azu_js_rc.54.16045

"Samples that contain high concentrations of radiocarbon ("hot" samples) are a catastrophe for low background AMS laboratories." "In our case the ion source system was seriously contaminated, as were the preparation lines."

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