A PRACTICAL GUIDE TO

OPTIMIZING SAMPLE PREPARATION WORKFLOWS FOR HEAVY METALS AND ORGANIC POLLUTANTS IN ENVIRONMENTAL LABS

MILESTONE

HELPING CHEMISTS

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| CONTENTS |

A practical guide to optimizing sample preparation workflows for heavy metals and organic pollutants in environmental labs

1. Introduction

Achieving accurate, efficient, safe and compliant results in environmental laboratories starts long before analysis—at the sample preparation stage. While often overlooked, sample preparation is a cornerstone of laboratory operations, directly impacting productivity, data quality, regulatory compliance, safety and overall operational costs. However, it is also one of the most labor-intensive and challenging aspects of environmental testing, requiring precise workflows to handle a wide range of sample types, regulatory limitations and analytical requirements.

Environmental laboratories process diverse matrices, from aqueous samples like wastewater to solid materials such as soil and sediments. They must also accommodate multiple testing needs, including heavy metals analysis, organic pollutant determination, and emerging contaminants monitoring. The industry operates in a highly competitive environment, where stringent regulations, increasing workloads, and pressure to reduce costs demand streamlined and optimized workflows.

A total workflow approach to sample preparation provides a strategic solution to these challenges, ensuring optimized processes that improve efficiency, enhance quality, reduce costs, and increase safety. By refining each stage of sample preparation—from reagent handling to final analysis—laboratories can streamline operations and reduce manual efforts while ensuring compliance, safety and reliability. In some cases, such as direct mercury analysis, eliminating sample preparation altogether is possible.

Figure 1. Soil testing in an environmental laboratory

However, for most applications, the focus is on optimizing each step to minimize time, effort, and risks.
This eBook presents Milestone's solutions for optimizing sample preparation for both heavy metals and organic pollutant analysis.

- The first section focuses on the **heavy metals workflow,** beginning with the most straightforward approach to mercury analysis before guiding readers through each step of sample preparation for other heavy metals—covering everything from high purity acid supply to vessel cleaning.
- The second section addresses the workflow for **organic pollutant analysis,** from reagent handling to vessel cleaning, detailing how laboratories can improve workflow efficiency, safety, and consistency.

By implementing a total workflow approach, environmental laboratories can enhance productivity, ensure compliance, and achieve high-quality results with greater ease and efficiency, all with measurable Return on Investment.

2.

Optimizing sample preparation for heavy metals analysis

Accurate and reproducible heavy metals analysis rely on a well-structured sample preparation workflow that ensures efficiency, precision, and compliance with environmental regulations. Environmental laboratories handle various sample matrices, including aqueous, soil, sediment, and industrial waste, each requiring a tailored approach to digestion. To achieve low enough reporting limits to meet specific regulatory needs, techniques such as ICP-OES, ICP-MS, and CVAA and CV-AFS, laboratories must carefully manage acid purity, reagent handling, vessel handling, digestion conditions, and contamination control. This chapter outlines the step-by-step sample preparation workflow for heavy metals analysis, highlighting the key challenges and Milestone's solutions to improve efficiency, safety, and data accuracy. However, not all heavy metals require digestion—for mercury analysis, laboratories can eliminate sample preparation entirely with direct mercury analysis (DMA-80 evo).
This chapter covers:

- Eliminating Sample Preparation: Direct Mercury Analysis – How DMA-80 evo provides a reagent-free, high-throughput alternative for total mercury determination.
- Step-by-Step Sample Preparation for Other Heavy Metals – A complete guide covering:
  - Ensuring High-Purity Acids for Reliable Environmental Analysis
  - Optimizing Reagent Handling: Safety, Precision, and Efficiency
  - Vessel Handling in Microwave Digestion: Enhancing Workflow Consistency
  - Microwave Digestion: The Gold Standard in Sample Preparation
  - Improving Filtration Efficiency in Environmental Analysis
  - Ensuring Clean Labware: A Critical Step in Sample Preparation

By implementing Milestone's total workflow approach, laboratories can significantly enhance productivity, improve data reliability, and ensure compliance with regulatory standards while minimizing manual intervention and contamination risks.

Flyer

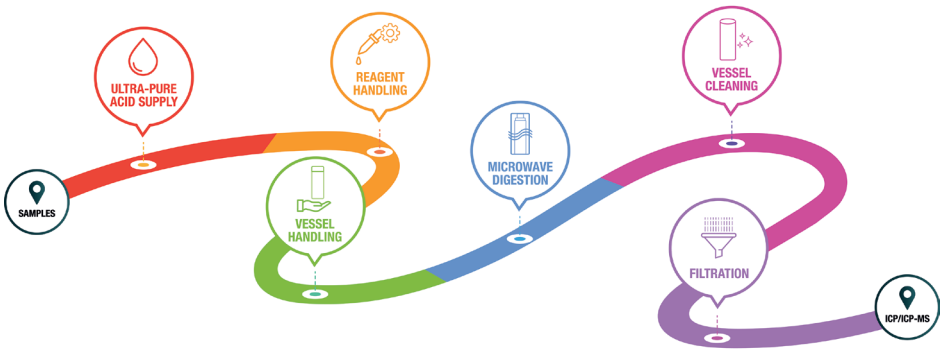
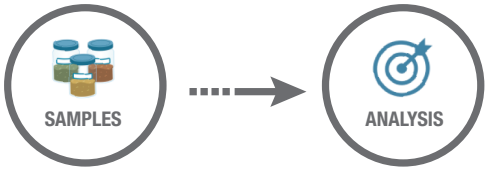


Figure 2. Total Sample preparation Approach for heavy metals analysis of environmental samples

2.1 Key considerations in choosing a microwave digestion system

Mercury analysis offers a unique opportunity to optimize laboratory workflows through direct mercury analysis using EPA Method 7473, which eliminates the need for traditional digestion or extraction steps. This method employs thermal



decomposition, amalgamation, and atomic absorption spectroscopy, delivering unmatched efficiency, simplicity, and cost savings for laboratories focused on total mercury detection.
Traditional mercury analysis techniques, such as cold vapor atomic absorption spectroscopy (CVAA), present significant challenges.
These methods require lengthy sample preparation steps, including digestion, along with daily calibrations and verifications that demand substantial operator time. Furthermore, CVAA workflows generate considerable hazardous waste and expose analysts to dangerous reagents, posing safety risks.
Milestone's DMA-80 evo direct mercury analyzer revolutionizes this process by enabling direct analysis of solids and aqueous samples.
Eliminating the need for reagents and digestion, it offers a streamlined workflow fully compliant with EPA Method 7473.
This method is ideal for detecting total mercury in a wide array of matrices, including soils, sediments, groundwater, surface water and mobility extracts (TCLP and SPLP leachates), following digestion by EPA 3000 series methods where applicable.
The simplicity of the DMA-80 evo begins with its setup. The only preparatory step required is the daily continuing calibration verifications. Operators weigh the sample into a quartz or nickel boat, enter the weight into the software, and place the boat on the 40-position autosampler tray. From there, a single press of the "start" button initiates the process, with the system managing the entire analysis. By utilizing industrial-grade oxygen or air as carrier gas, the closed system minimizes maintenance needs and eliminates the requirement for a fume hood.

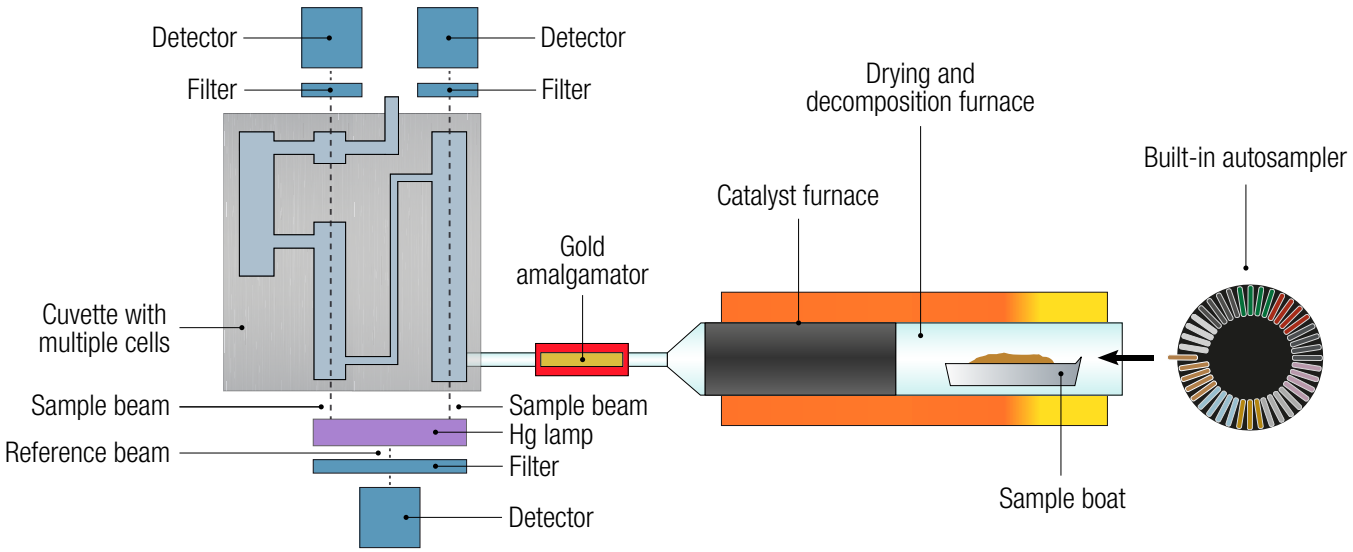


Figure 3. DMA-80 evo principle of operation

Each sample is processed in just six minutes, allowing a batch of 20 samples to be completed in approximately two hours—a remarkable improvement over traditional CVAA workflows. Additionally, the DMA-80 evo achieves 90% cost savings per analysis compared to CVAA, making it an economical choice for high-throughput laboratories.

Equipped with a tricell configuration, the DMA-80 evo excels in analyzing multiple matrices under a single calibration curve without interference. This includes aqueous samples, soils, and solids of any kind, ensuring consistent accuracy and reproducibility. For laboratories handling higher mercury concentrations, configurations such as the Dual Cell or Wide Range models accommodate expanded measurement ranges.

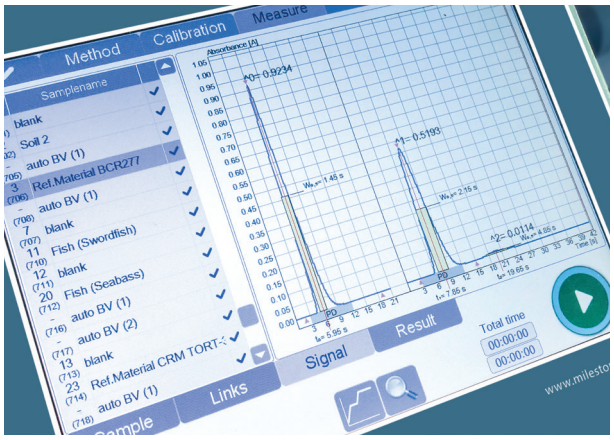


Figure 4. Measurement page of the DMA-80 software, showing the absorbance in each absorption cell (Tricell configuration in this case)

By eliminating the need for sample preparation, direct mercury analysis with the DMA-80 evo sets a new benchmark for environmental workflow simplicity. Laboratories benefit from faster turnaround times, reduced costs, and improved safety while maintaining high data accuracy and reproducibility. This approach aligns perfectly with the goal of a Green Procedure resulting in a streamlined, efficient, and safe environmental laboratory workflow.

Milestone's DMA-80 evo is more than just an instrument; it's a transformative tool that embodies simplicity, productivity, and reliability, an indispensable asset for any environmental laboratory seeking to enhance its mercury analysis capabilities.

Technology Report

Industry Report

BENEFITS OF **DMA-80**

- **Eliminates Sample Preparation**
  Direct analysis of solids and aqueous samples without the need for digestion or reagents
- **Time-Saving Workflow**
  - Processes up to 20 samples in just two hours, with six-minute analysis per sample.
  - Long-lasting initial calibrations that are matrix independent.
- **Cost Efficiency**
  Reduces operational costs by up to 90% compared to traditional CVAA methods.
- **Enhanced Safety**
  Fully enclosed system eliminates exposure to hazardous reagents and mercury vapors, requiring no fume hood.
- **High Versatility**
  Single calibration curve supports diverse matrices, including soils, sediments, and aqueous samples, with no interferences.

2.2 Comprehensive sample preparation workflow for heavy metal analysis

Unlike direct mercury analysis, where sample preparation is eliminated entirely, the analysis of most heavy metals requires precise reagent handling, controlled digestion, and strict contamination prevention. The following sections outline each step of the sample preparation process, addressing common challenges and introducing Milestone's solutions to help laboratories enhance workflow efficiency, minimize manual intervention, and achieve consistent, high-quality results.

2.2.1 In-house acid purification: a reliable and cost-effective solution

The use of trace metal grade acids is critical for achieving the low detection limits required in ICP-OES and ICP-MS analyses, as well as for mercury analysis using CV-AFS. However, these acids are costly, prone to contamination, and often subject to supply chain disruptions, making their consistent availability a challenge for environmental laboratories. Maintaining a reliable supply of high-purity acids is essential for achieving lower limits of quantification (LOQs) and ensuring accurate, reproducible results.

Milestone's duoPUR system provides an efficient and safe solution by enabling laboratories to purify acids in-house using sub-boiling technology. This approach transforms reagent-grade nitric and hydrochloric acids into ultra-pure acids on demand, reducing reliance on external suppliers while ensuring consistently high purity for ultra-trace analyses.

The duoPUR system consists of two quartz stills, each equipped with independent heating elements. Reagent-grade acid is introduced into the stills via a dedicated pump, where the heating elements gently vaporize the surface of the liquid, allowing only the purest acid vapor to be collected. The vapor condenses on a cooled surface and is transferred to a collection bottle, ready for use. Unlike traditional distillation, which can introduce impurities through steam droplets and bubbles, duoPUR's sub-boiling process eliminates these risks, preventing contamination and preserving acid quality.

Commercially available ultra-pure acids come at a high cost, with monthly procurement expenses reaching thousands of dollars. With duoPUR, laboratories can achieve a return on investment in as little as 4 to 12 months, significantly lowering the cost per sample. Additionally, in-house acid purification enhances operational flexibility, allowing labs to mitigate supply chain delays and maintain uninterrupted workflows.

Figure 5. Milestone duoPUR acid purification system with two quartz stills.

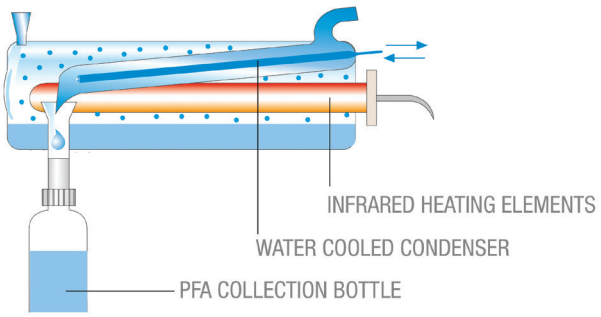


Figure 6. Schematic of sub-boiling distillation system

For laboratories requiring trace metal grade or ultra-trace purity, duoPUR offers the ability to perform a second distillation cycle, further refining acid quality to meet stringent analytical needs. Operators can easily adjust system settings to tailor acid purity levels, ensuring the highest possible performance for demanding applications. Safety remains a top priority in modern laboratories, and duoPUR's sealed design eliminates operator exposure to hazardous acid vapors. The system features automated filling and draining, reducing manual handling, while an intuitive touchscreen interface simplifies operation with preloaded standard methods. By automating the purification process, duoPUR reduces operator workload, ensures regulatory compliance, and provides a consistent, high-quality acid supply for reliable environmental analysis.

BENEFITS OF **duoPUR**

- **Control Over Acid Supply**
  Enables on-demand production of fresh, high-purity acids, reducing reliance on external suppliers.
- **Minimal Reagent Handling**
  Automatic loading and draining, eliminating manual acid handling risks.
- **High Productivity**
  Typically purifies up to 140ml per hour, ensuring a steady acid supply for high-throughput labs.
- **Superior Acid Purity**
  Utilizes high-purity quartz stills, eliminating contamination risks associated with traditional distillation.
- **Cost Savings & ROI**
  Achieves up to 90% savings over commercial high purity acids, with a return on investment within months.

Technology Report

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	duoPUR Double-Distillation Reagent-Grade Nitric Acid	**Baker Ultrex® II** High-Purity Grade Nitric Acid		duoPUR Double-Distillation Reagent-Grade Nitric Acid	**Baker Ultrex® II** High-Purity Grade Nitric Acid
Element	Concentration (ppt)	Concentration (ppt)	**Element**	Concentration (ppt)	Concentration (ppt)
Ag	16	<10	**Mg**	<10	<10
Al	<10	<20	**Mn**	12	<10
As	19	<20	**Mo**	22	<10
Ba	<10	<10	**Ni**	<10	<20
Ca	<10	<10	**Pb**	31	<10
Cd	<50	<10	**Sb**	18	<10
Co	<10	<10	**Sn**	11	<20
Cr	<10	<10	**Ti**	<50	<20
Cu	<10	<10	**V**	<10	<10
Fe	<10	<10	**Zh**	<10	<10

Table 1. Guidelines of digestion conditions and parameters

2.2.2 Optimizing reagent handling: safety, precision, and efficiency

Handling hazardous reagents is a critical step in sample preparation for heavy metals analysis, requiring precise management of concentrated acids such as HNO_3 and HCl. While essential for accurate analytical results, manual reagent handling presents significant challenges, including time consumption, safety risks, and potential analyst errors. Exposure to toxic acid fumes increases the risk of contamination and inconsistent results, making this step a bottleneck in laboratory workflows, especially in high-throughput environments where efficiency and precision are paramount.

Figure 7. Manual reagent dosing

Milestone's easyFILL automated dosing station provides a safer, more efficient, and highly reliable alternative by fully automating reagent handling. Operating within a sealed and ventilated compartment, easyFILL eliminates operator exposure to hazardous acid fumes, ensuring a safer laboratory environment. Its high-precision dispensing system eliminates inconsistencies associated with manual dosing, improving reproducibility while minimizing reagent waste.
The automated peristaltic pump ensures accurate and consistent acid addition, supporting up to six different reagents, including HNO_3,HCl and HF for labs performing EPA method 3052.

Figure 8. Automated acid addition into the digestion vessels

Beyond initial reagent addition, easyFILL seamlessly integrates into the entire sample preparation workflow. It enables post-digestion acidification and pre-dilution for ICP analysis, helping laboratories standardize processes while reducing human error. Additionally, its automatic line flushing system prevents cross-contamination between reagent batches, ensuring consistent and reliable sample preparation.
Designed for durability and long-term reliability, easyFILL is built with corrosion-resistant materials, making it ideal for handling aggressive acids. The system's customizable software includes pre-stored rack configurations and real-time reagent monitoring, allowing laboratories to optimize workflows with minimal manual intervention.
Its broad compatibility with Milestone digestion vessels, ICP autosampler vials, and non-Milestone vessels make it a versatile solution for any laboratory conducting heavy metals analysis.
By automating reagent handling, easyFILL reduces analyst workload, enhances safety, and improves workflow consistency, ultimately contributing to greater laboratory efficiency and cost savings.

BENEFITS OF **easyFILL**

- **Enhanced Safety**
  Automated systems eliminate operator exposure to hazardous acids, aligning with EPA safety regulations.
- **Time Efficiency**
  Reduces analyst workload and manual handling time, enabling faster sample preparation.
- **Improved Accurac**
  Ensures consistent and precise reagent dosing, reducing the risk of contamination and human error.
- **Versatility**
  Compatible with multiple reagents, including concentrated acids, for diverse workflows.
- **Streamlined Workflow**
  Supports pre-dilution and acidification in a single automated step, minimizing interruptions.

Technology Report

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2.2.3 Digestion vessel handling

Sealing microwave vessels is a crucial step in the metals digestion workflow. Ensuring secure and consistent closure is essential to maintain the correct temperature and pressure during processing, which directly impacts the accuracy and reliability of results. However, manual vessel sealing can be labor-intensive, time-consuming, and prone to analyst error.
Milestone's easyCAP addresses these challenges by automating the vessel sealing process. What typically takes 10 to 15 minutes for 24 vessels when done manually is reduced to just 2 to 3 minutes. This not only enhances productivity but also ensures consistency, eliminating variability caused by manual handling.

By integrating the Milestone capping tool, laboratories can optimize their workflows, reduce the time spent on repetitive tasks, and achieve more reliable results. The tool's user-friendly and ergonomic design also minimizes operator fatigue, making it a valuable addition to any lab working with metals.

Figure 9. Automatic capping station in operation

BENEFITS OF **easyCAP**

- **Higher productivity**
  Reduced handling time and faster closing.
- **Greater digestion reliability**
  Standardized vessel closure.
- **Ergonomic**
  Improved work conditions for the operator
- **Compact and affordable**
  With small footprint and limited investment
- **High flexibility**
  Compatible with Milestone MAXI-24 HP and MAXI-44 rotors.

2.2.4 Microwave digestion: the gold standard in sample preparation

Microwave digestion has long been recognized as the gold standard in sample preparation for heavy metals analysis, providing a safer and more reliable alternative to traditional digestion methods such as hot plates and hot blocks. These conventional approaches are often inefficient, requiring long digestion times, posing high contamination risks, and struggling to handle volatile elements like mercury. These limitations result in incomplete digestion, increased blanks, and frequent reprocessing, ultimately impacting productivity and data reliability in environmental laboratories. Milestone's ETHOS UP microwave digestion system is specifically designed to overcome these challenges, integrating advanced technology with a user-friendly design. It significantly improves throughput and turnaround times while delivering exceptional digestion quality, making it an essential solution for laboratories managing high sample volumes.

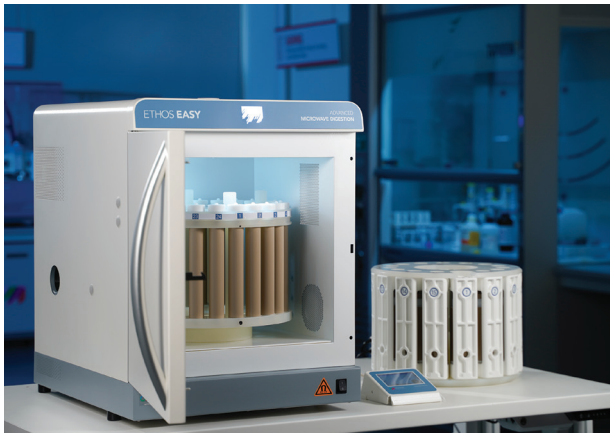

Figure 10. ETHOS UP Microwave digestion system

The ETHOS UP system accommodates a wide range of environmental samples and volumes through its interchangeable rotor configurations. The MAXI-44 high-throughput rotor, for example, allows for the simultaneous digestion of up to 44 samples, significantly increasing productivity for high-demand laboratories for typical soils, sediments and aqueous matrices. Operating at temperatures up to 200°C and pressures of 35 bar, it ensures reliable digestion, even for complex matrices, while its high-capacity design minimizes downtime between runs. For smaller batches or specialized applications, the MAXI-24 high-performance rotor delivers equally consistent and high-quality results. The MAXI-24 is applicable to the above matrices and other more difficult matrices, offering a temperature limit of 220°C and up to 60 bar of pressure. This rotor is an excellent choice for difficult matrices such as those very high in organic character including oils, biosolids, and fish tissue or other non-typical matrices.

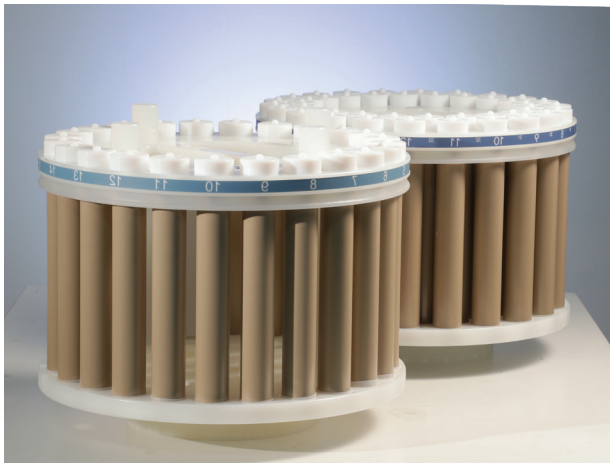

Figure 11. MAXI-24 HP High Performance rotor (front); MAXI-44 High Throughput rotor (back)

Both configurations are fully compatible with key US EPA methods, including 3015, 3051, 3052, 200.7, and 200.8, ensuring reliable and reproducible digestion for aqueous samples, soils, sediments, and other environmental matrices. The closed-vessel design of the ETHOS UP system prevents contamination and volatile element loss by hermetically sealing each sample. This not only enhances data accuracy but also improves operator safety by minimizing exposure to hazardous acid fumes.

For laboratories handling particularly challenging matrices or requiring maximum efficiency and complete digestion, Milestone offers the ultraWAVE 3, an advanced Single Reaction Chamber (SRC) system. Unlike rotor-based microwaves, ultraWAVE 3 allows the simultaneous digestion of multiple sample types in the same run, regardless of composition. The use of disposable glass vials eliminates vessel cleaning, further streamlining workflows and preventing cross-contamination. With its ability to reach higher temperatures and pressures than standard microwave systems, ultraWAVE 3 is ideal for digesting complex, high-organic matrices, ensuring optimal analyte recovery, including mercury.

Figure 12. UltraWAVE 3 with 20 positions rack and glass vials

The transition from traditional hot plate digestion to microwave digestion provides significant advantages for environmental laboratories. Processing 24 to 44 samples in a single run, microwave digestion reduces preparation time while ensuring complete digestion at elevated temperatures. This eliminates residual organic matter, preventing analytical interferences, enhancing data accuracy, and minimizing the need for reprocessing. The hermetically sealed vessels further protect against contamination, ensuring low blanks and high data reliability.
Both the ETHOS UP and ultraWAVE 3 systems seamlessly align with US EPA methods, offering a robust and compliant solution for environmental laboratories. Their intuitive software, complete with preloaded digestion methods, simplifies operations and shortens the learning curve for laboratory staff. By integrating these advanced systems into their workflows, laboratories can achieve superior results while improving productivity, safety, and cost efficiency.

Rotor Guide

Industry Report

BENEFITS OF **ETHOS**

- **Enhanced Productivity**
  Digest up to 44 samples in as little as one hour, significantly reducing preparation time.
- **Improved Digestion Quality**
  Achieves higher temperatures and pressures, ensuring complete digestion and recoveries.
- **Minimized Contamination**
  Closed vessels eliminate external contamination and reduce blanks, improving analytical accuracy.
- **Safety First**
  Sealed vessels prevent loss of volatile elements like mercury, ensuring a safer laboratory environment..
- **EPA Compliant**
  Fully supports EPA methods such as 3015, 3051, 3052, 200.7, and 200.8 for reliable and standardized digestion.

2.2.5 Improving filtration efficiency in environmental analysis

Once a sample has been digested, filtration is often required before proceeding to analysis. Traditionally, this step is performed manually, processing one sample at a time—a method that is time-consuming, increases the risk of contamination, and occupies valuable fume hood space.
Milestone's SFS-24 system addresses these challenges by enabling simultaneous filtration of up to 24 samples under vacuum. Designed to streamline laboratory workflows, the SFS-24 filters samples directly into disposable vessels or autosampler tubes, maximizing efficiency while requiring minimal fume hood space.

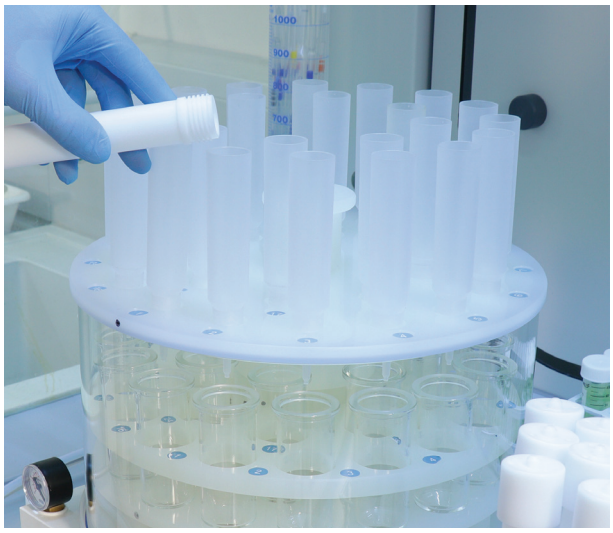

Figure 13. SFS-24 Simultaneous Filtration System with 24 positions

The system utilizes disposable funnels and filters, which are readily available and cost-effective, eliminating the need for cleaning and helps reduce cross-contamination risks. By integrating the SFS-24, laboratories can significantly reduce manual effort, save time, and improve the consistency and reliability of their metals analysis workflow.

Flyer

Video

BENEFITS OF **SFS-24**

- **Rapid**
  Simultaneous filtration of up to 24 samples.
- **Compact**
  It occupies limited space in the fume hood
- **Ergonomic**
  Rotating design makes it easy to pour solutions.

2.2.6 Ensuring clean labware: a critical step in sample preparation

In sample preparation workflows for heavy metals analysis, vessel cleaning is the final step that can be optimized to improve efficiency and safety. Traditional cleaning methods, such as acid baths, are time-consuming, consume large amounts of acid, and pose cross-contamination risks while exposing operators to hazardous vapors. Another approach involves using the microwave digestion system for vessel cleaning; however, this method reduces productivity by occupying the system with cleaning cycles rather than sample digestion. Additionally, repeated exposure to high temperatures and pressure can shorten the lifespan of vessel components.
Milestone's traceCLEAN automated acid steam cleaning system provides an efficient and safe

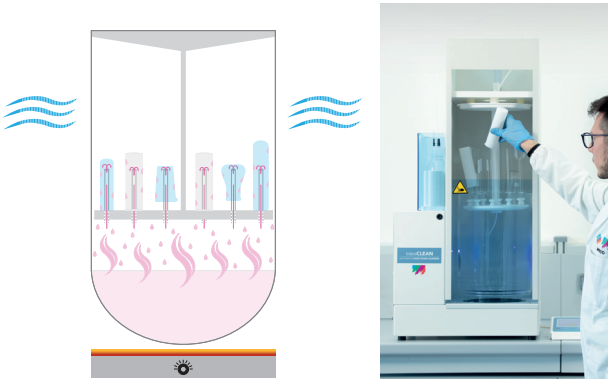

Figure 14. Left: Acid steam cleaning principle of operation; Right: Milestone TraceCLEAN Automated Acid Steam Cleaning System

alternative, effectively removing contaminants from labware and vessels made of Teflon, PFA, glass, and quartz. The system operates within a sealed chamber, where heated nitric acid vapors thoroughly clean the vessels. The vapors then recondense into the main vessel, ensuring efficient acid use while minimizing waste. Any residual vapors are safely vented through a dedicated exhaust system, maintaining a safer laboratory environment. The cleaning efficiency of traceCLEAN matches that of microwave cleaning, with the added advantage of freeing the digestion system for continuous sample processing. Capable of cleaning up to 33 microwave vessels at a time, the system completes an entire cycle in approximately 1.5 hours, dramatically reducing the time, effort, and acid consumption compared to traditional acid baths.

Technology Report

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BENEFITS OF **TraceCLEAN**

- **Time Efficiency**
  Automates cleaning cycles, freeing up operator time and improving laboratory throughput.
- **Safety Assurance**
  Sealed systems minimize operator exposure to hazardous acid vapors during the cleaning process.
- **Reduced Acid Consumption**
  Uses ultrapure acid vapors efficiently, significantly reducing acid usage compared to traditional methods.
- **High Cleaning Quality**
  Ensures thorough cleaning of vessels and labware, reducing the risk of cross-contamination and high blank values.
- **Increased Productivity**
  Keeps digestion systems dedicated to sample preparation rather than cleaning, enhancing overall workflow efficiency.

3.
Optimizing sample preparation for organic pollutants analysis

The analysis of organic pollutants presents unique challenges for environmental laboratories, requiring precise and controlled sample preparation to ensure reliable and compliant results. Unlike heavy metals analysis, where acids play a crucial role in digestion, organic pollutants workflows rely heavily on solvent-based extraction methods, which introduce additional considerations for safety, efficiency, and regulatory compliance.

Sample preparation for organic pollutants involves multiple sequential steps, each contributing to workflow efficiency, cost per sample, safety risks and overall data quality. From handling volatile solvents to ensuring proper extraction, filtration, and evaporation, each phase must be carefully managed to prevent cross-contamination, analyst safety risks, solvent loss, or inconsistencies in analyte recovery.

This chapter outlines the core steps of an optimized sample preparation workflow, including reagent handling, vessel handling, extraction, filtration, evaporation (when required), and vessel cleaning. By implementing modern automation and workflow enhancements, laboratories can streamline their processes, reduce labor-intensive tasks, minimize solvent waste, and improve the reliability of organic pollutants analysis.

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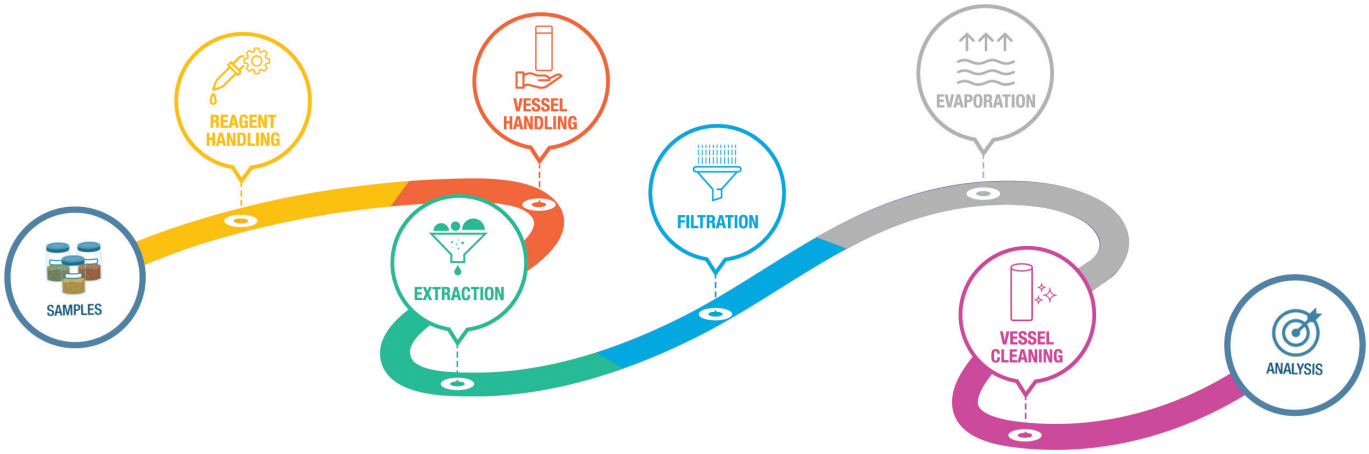

Figure 15. Total Sample preparation Approach for organic pollutants analysis of environmental samples

3.1 Automating solvent handling: enhancing safety and precision in organic pollutants analysis

Solvent handling plays a critical role in the sample preparation process for organic pollutants analysis, requiring the precise management of solvents such as methylene chloride, acetone, and hexane. Organic pollutant workflows rely on solvent extraction, which introduces unique challenges, including analyst exposure to hazardous fumes, managing solvent waste, and variability in manual dosing.

In high-throughput environmental laboratories, where rapid turnaround times and regulatory compliance are essential, manual solvent handling can become a bottleneck. Handling these volatile solvents manually increases safety risks, contributes to workflow inefficiencies, and introduces the potential for inconsistent solvent additions, which can compromise extraction efficiency and analytical accuracy. The latest regulatory restrictions, such as those promulgated by the EPA under the Toxic Substances Control Act (TSCA) on methylene chloride, further emphasize the need for minimizing analyst exposure to toxic solvents.

In addition, the Clean Air Act regulates fume hood emisions for both methylene chloride and hexane since both are classified as Hazardous Air Pollutants (HAPs).

Milestone's easyFILL automated dosing station provides a safer and more efficient solution by fully automating solvent addition within a sealed and ventilated compartment. This eliminates direct operator contact with hazardous solvent fumes while ensuring precise and consistent solvent dispensing. Designed for compliance with EPA regulations, including those governing methylene chloride safety, easyFILL supports laboratories in meeting occupational safety standards while improving workflow efficiency.

Engineered for durability and long-term reliability, easyFILL features a corrosion-resistant polypropylene dosing compartment, while all components in contact with solvents are constructed from high-purity PTFE to ensure chemical resistance and longevity. The system is capable of handling multiple solvent, supporting various extraction methods while reducing solvent waste and operational inconsistencies.

By automating solvent handling, easyFILL significantly reduces analyst workload, enhances safety, and improves extraction repeatability, making it an indispensable tool for laboratories conducting organic pollutants analysis. With precise dosing, minimized solvent loss, and reduced manual intervention, laboratories can streamline workflows while maintaining compliance with the latest safety regulations.

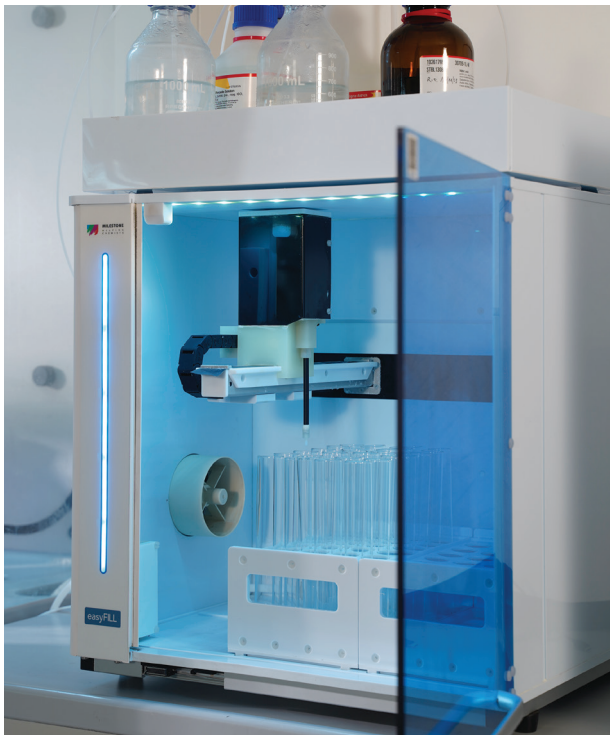

Figure 16. EasyFILL for automated solvent addition into fastEX-24 disposable glass vials

Technology Report

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Webinar

BENEFITS OF **EasyFILL**

- **Broad Compatibility & Precision Dosing**
  Handles up to six reagents, including solvents like methylene chloride, acetone, and hexane or their mixtures, with high-accuracy dispensing via a peristaltic pump (1% precision) for controlled solvent addition.
- **Enhanced Safety & Compliance**
  Fully enclosed sealed and ventilated design eliminates operator exposure to toxic solvent fumes, aligning with EPA and OSHA regulations for handling hazardous chemicals like methylene chloride.
- **Workflow Efficiency & Automation**
  Automates reagent handling, reducing manual labor, operator workload, and potential errors, ensuring consistent and repeatable dosing for high-throughput laboratories.
- **Durability & Lab Integration**
  Constructed with corrosion-resistant polypropylene and high-purity PTFE, ensuring long-term reliability and full compatibility with Milestone and other brands vials and vessels. Offers a small footprint to maximize your laboratory space.

3.2 Optimizing vessel handling for efficient organic pollutants extraction

Vessel handling and sealing are critical steps for the extraction, as they directly impact the accuracy and reliability of results. The effectiveness of the extraction process depends on maintaining precise temperature and pressure conditions, which in turn require a secure and uniform vessel seal before the operation begins. Manual vessel sealing, however, is not only time-consuming but also introduces risks related to operator inconsistency. When vessels are sealed unevenly, it can lead to variations in pressure retention, potentially affecting extraction efficiency and reproducibility. Moreover, the repetitive nature of manual capping increases operator fatigue, making it a less reliable and ergonomic approach. To address this challenge, Milestone has developed an automated capping tool that ensures homogeneous sealing across all vessels, optimizing both efficiency and accuracy. This tool standardizes the sealing process and makes it effortless. By integrating this automation into laboratory workflows, operators can improve consistency, enhance productivity, and minimize errors.

Figure 17. Capping tool for fastEX-24 rotor

Beyond workflow optimization, the Milestone capping tool is designed with ergonomics in mind, reducing manual strain on operators while speeding up sample preparation. Its user-friendly design makes it an essential addition to any lab conducting organic pollutants extraction, ensuring greater efficiency, reliability, and ease of use.

BENEFITS OF **CAPPING TOOL**

- **Higher productivity**
  Reduced handling time and faster closing.
- **Greater digestion reliability**
  Standardized vessel closure.
- **Ergonomic**
  Improved work conditions for the operator
- **Compact and affordable**
  With small footprint and limited investment
- **High flexibility**
  Compatible with Milestone MAXI-24 HP and MAXI-44 rotors.

3.3 Advancing organic pollutants extraction with microwave technology

In environmental laboratories, extraction is a critical step in sample preparation for organic pollutants analysis. However, traditional extraction methods such as Soxhlet, sonication, and pressurized fluid extraction (PFE) often fail to meet the productivity, safety, and cost-efficiency demands of modern laboratories. These conventional approaches are plagued by inefficiencies, including high solvent consumption, lengthy processing times, and operator exposure to hazardous solvents like methylene chloride. Such limitations make them increasingly impractical for laboratories requiring fast, safe, and reproducible workflows.
Milestone's ETHOS X microwave extraction

Figure 18. ETHOS X with fastEX-24 and disposable glass vials

system is designed to overcome these challenges and is fully compliant with EPA Method 3546. It represents a significant advancement in extraction technology, providing faster processing times, reduced solvent use, and enhanced safety, while still delivering high-quality, reproducible results. Conventional extraction techniques present several critical drawbacks. Soxhlet extraction, for example, demands large solvent volumes and extended processing times, often taking up to 24 hours per run. Additionally, its complex setup and lengthy cleaning process make it labor-intensive, consuming valuable operator time and laboratory space. Sonication, although somewhat faster, suffers from low analyte recovery, requiring multiple extraction cycles that further increase solvent consumption and operator intervention. Sonication is being phased out and is already not approved for PCB extractions. Pressurized fluid extraction (PFE), while more modern, is limited to small sample sizes (up to 20 grams), requires lengthy cooling times, is typically a sequential system and suffers from maintenance issues such as clogs and leaks. These challenges reduce productivity and compromise reporting limits, making them less than ideal for fast-paced environmental laboratories.

Milestone's ETHOS X redefines microwave-assisted extraction by integrating advanced technology with user-centric design. Unlike conventional microwave extraction systems, ETHOS X processes up to 30 grams of sample material, enabling lower reporting limits and improved analytical sensitivity compared to systems with smaller sample capacities. This enhanced capability ensures compliance with stringent state and federal regulations, while also reducing overall operational costs.

The system's advanced temperature control guarantees precise and reliable extractions. ETHOS X individually monitors the temperature of each sample, preventing exothermic reactions and ensuring uniformity across all vessels. This best-in-class control is algorithmically managed, ensuring reproducibility and regulatory compliance.

ETHOS X is equipped with 145 mL vessels, offering additional headspace to handle high-temperature extractions safely. The use of disposable glass inserts eliminates the need for cleaning, reducing cross-contamination risks while saving analyst time. With the ability to process 24 samples in just 30 minutes, followed by a 10-minute cooling period, ETHOS X enables laboratories to meet high-throughput demands with ease. Using multiple rotors greatly enhances production capacity.

Beyond workflow optimization, the Milestone capping tool is designed with ergonomics in mind, reducing manual strain on operators while speeding up sample preparation. Its user-friendly design makes it an essential addition to any lab conducting organic pollutants extraction, ensuring greater efficiency, reliability, and ease of use.

The system also addresses key safety concerns associated with solvent extraction. Its vent-and-reseal technology ensures that volatile solvents remain safely contained, protecting operators from harmful fumes. Additionally, its robust design minimizes maintenance requirements, with durable components capable of withstanding demanding laboratory conditions.

Figure 19. Disposable glass vials for fastEX-24 with 30 g of soil.

By significantly reducing solvent usage and eliminating cleaning steps, ETHOS X lowers the overall cost per sample while enhancing laboratory efficiency. Its user-friendly operation facilitates quick onboarding of new staff, ensuring seamless integration into existing workflows. With preloaded EPA Method 3546 programs and customizable settings, ETHOS X adapts to various sample types and moisture content, making it one of the most flexible and advanced extraction systems available today. For regulatory compliance, all data for each extraction batch are saved for documentation purposes.

Application Report

White Paper

Webinar

BENEFITS OF **ETHOS X**

- **Faster Turnaround**
  Extracts 24 samples simultaneously in just 40 minutes, optimizing laboratory efficiency.
- **Improved Sensitivity**
  Processes up to 30 g of sample material, enabling lower reporting limits and meeting strict regulatory requirements.
- **Simplified Workflow**
  Disposable glass inserts eliminate cleaning steps, prevent cross-contamination and save operator time.
- **Cost-Effective**
  Reduces solvent consumption and analyst workload, minimizing the cost per sample and allowing the analyst to attend to other tasks.
- **EPA Compliant**
  Fully supports EPA Method 3546 for reliable and standardized extractions in environmental applications.

3.4 High-efficiency filtration for organic pollutants sample preparation

Filtration is a critical step following sample extraction, ensuring that the sample is properly prepared for evaporation or direct instrumental analysis. Traditionally, manual filtration is performed one sample at a time, making it time-consuming, inefficient, uses significant solvent for rinsing and requires significant fume hood space. Milestone's SFS-24 system provides a more efficient and scalable solution, allowing laboratories to perform simultaneous filtration of up to 24 samples under vacuum. Designed to streamline workflows, the SFS-24 filters samples directly into disposable vessels or evaporation vessels, significantly reducing processing time and operator workload while occupying minimal fume hood space. The system eliminates the need for manual cleaning by incorporating disposable funnels or 40 mL to as large as 100 mL reservoirs/funnels filled with glass wool and sodium sulfate, which are cost-effective and readily available. This prevents cross-contamination and enhances laboratory productivity by eliminating maintenance steps traditionally required in manual filtration methods. By integrating the SFS-24 into their workflow, laboratories can achieve greater efficiency, improved consistency, and enhanced reliability in sample preparation for organic pollutants analysis.

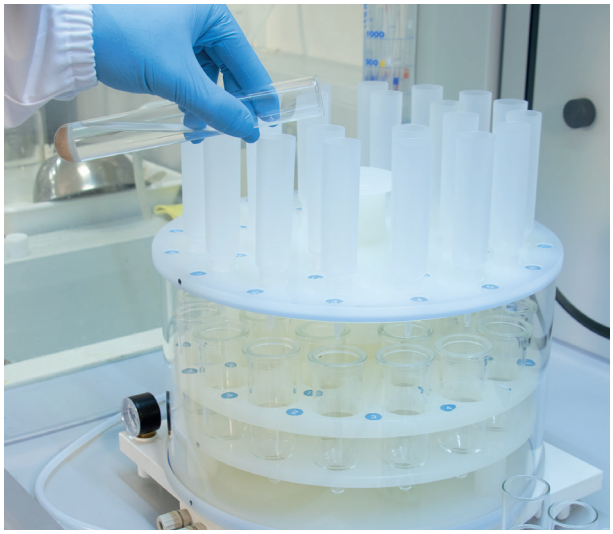

Figure 20. Filtering step with SFS-24 after extraction in fastEX-24 rotor with disposable glass vials

BENEFITS OF **SFS-24**

- **Rapid**
  Simultaneous filtration of up to 24 samples.
- **Compact**
  It occupies limited space in the fume hood.
- **Ergonomic**
  Rotating design makes it easy to pour solutions.
- **Flexible setup**
  Fit several evaporation flasks.

Flyer

Video

3.5 Cleaning-free sample prep for organic pollutants analysis workflows

Once the extraction and filtration steps are complete, proper vessel maintenance is critical for workflow efficiency and data accuracy. However, instead of relying on traditional cleaning methods, Milestone's disposable glass inserts eliminate this step entirely—preventing contamination while simplifying lab operations.

In sample preparation workflows for organic pollutants, cleaning is a critical factor, as residual contamination can lead to carryover and overestimation of target compounds. This issue is particularly concerning when analyzing hard-to-clean pollutants such as dioxins, where even trace amounts from previous samples can compromise analytical accuracy.

Milestone's optimized sample preparation approach eliminates the need for vessel cleaning entirely by utilizing disposable glass inserts. These inserts prevent cross-contamination, ensuring that each sample is processed in a clean, uncontaminated environment. By removing the cleaning step, laboratories can streamline operations, reducing manual labor, solvent consumption, and maintenance time.

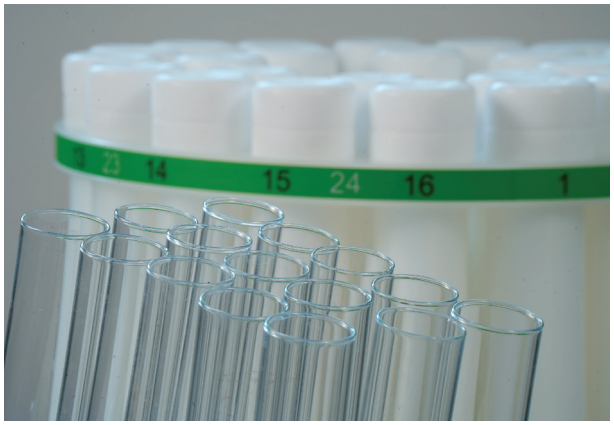

Figure 21. Disposable glass vials for fastEX-24 rotor

Beyond enhancing productivity, this cleaning-free workflow improves efficiency, lowers costs, and ensures reliable data quality, making it an ideal contamination-free solution for organic pollutants analysis.

BENEFITS OF **fastEX-24**

- **Eliminates Cleaning Steps**
  Disposable glass inserts remove the need for cleaning, simplifying laboratory operations.
- **Prevents Cross-Contamination**
  Single-use inserts ensure no carryover between samples, improving data accuracy.
- **Saves Operator Time**
  Removes a labor-intensive step, allowing operators to focus on other critical tasks.
- **Cost Savings**
  Reduces the need for expensive cleaning reagents and additional cleaning time.
- **Streamlined Workflow**
  Supports faster turnaround times by eliminating cleaning-related delays.

4.
Conclusion: optimizing environmental lab workflows for the future

Environmental laboratories are under constant pressure to deliver accurate,method compliant, efficient, and safe results while meeting stringent regulatory requirements, such as those addressing methylene chloride exposure. Milestone's total workflow approach provides a transformative solution to these challenges, offering optimization in every step.
By integrating Milestone's advanced systems, laboratories can achieve:

- **Enhanced Productivity.**
  Streamlined processes reduce analyst time and bottlenecks, allowing laboratories to handle higher sample volumes with ease.
- **Regulatory Compliance and Safety.**
  Milestone's solutions minimize chemical exposure risks for analysts, ensuring compliance with evolving safety standards from EPA and OSHA.
- **High-Quality Results**.
  Reliable and reproducible outcomes for both heavy metals and organic pollutants analysis are consistently achieved through precise control and innovative design.
- **Cost Savings**.
  Reduced reagent consumption, elimination of cleaning steps, and minimized downtime translate into significantly lower operational costs.

These benefits highlight Milestone's commitment to addressing the unique demands of environmental testing labs. By reducing operational expenses and maintaining exceptional analytical standards, Milestone enables labs to remain competitive in an ever-evolving industry. This forward-thinking approach not only solves today's challenges but also equips laboratories to adapt to future demands. Milestone's total sample preparation workflow ensures that environmental labs can confidently operate with safety, efficiency, and reliability at the forefront of their mission.

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