PSCI PHARMACEUTICAL SUPPLY CHAIN INITIATIVE

Building responsible supply chains

The PSCI Wastewater Analysis Project

Assessment of in-Region Laboratory Capability for Wastewater API Analysis in India

2022-2025



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1.0 Foreword



This report summarizes important work undertaken by members of the Pharmaceutical Supply Chain Initiative to determine the capabilities of commercial analytical laboratories, in India, to accurately measure concentrations of active pharmaceutical ingredients in industrial wastewater samples in country.

This is the first published study of its kind in India to be conducted by an industry consortia in this space. The findings will be valuable to both industry and wider stakeholders, particularly given India's role as a major global hub for pharmaceutical manufacturing and the importance of ensuring emissions of pharmaceuticals to the environment are effectively controlled to minimize the risk of adverse ecotoxicological and potential and/or potential human health effects.

I am pleased to write the foreword to this report, because for the AMR Industry Alliance and other AMR focused stakeholders, confidence in the ability to determine concentrations of antibiotics in the environment is essential. The AMR Industry Alliance Standard and WHO guidelines for antibiotic manufacturing both require concentrations of antibiotics in receiving waters to be controlled to below predicted no-effect concentrations (PNECs), which, for many antibiotics, are parts per billion.

While concentrations can be calculated by mass balance (a chemical engineering approach frequently used in industry to determine emission concentrations), there are occasions where measurement of concentrations may be needed (e.g. to validate mass balance results), or are required. Some stakeholders call for regulations requiring antibiotic concentrations less than PNECs as determined by sampling and analysis. The ability to perform such analysis in country becomes essential should such analysis need to be performed at scale, when cost and challenges of sending samples overseas to analytical laboratories with proven capability to perform such exacting analyses are well established.

The report paints a picture, the conclusions and recommendations are important, and attention should be paid by pharmaceutical companies (and their suppliers) who wish to use in-country analysis, and by stakeholders, who may need to rely on it.



Stephen Brooks

Manufacturing Work Group lead, AMR Industry Alliance

2.0 Disclaimer

This publication has been developed by the Pharmaceutical Supply Chain Initiative (PSCI) as a voluntary guidance resource for PSCI members and suppliers. It is intended to support understanding of wastewater analytical capability in India and to share learnings from the PSCI Wastewater Laboratory Assessment project.

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→ **This report is intended to support understanding of wastewater analytical capability in India and to share learnings from the PSCI Wastewater Laboratory Assessment project**

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→ Organizations should independently assess the suitability of any analytical laboratory, method, and QA/QC approach for their own operational, regulatory, and risk assessment needs

PSCI members may request access to the underlying project data held in the PSCI project archives at any time. To do so, please email info@pscinitative.org with your request, and the PSCI team will support retrieval and sharing in line with the project's data-handling approach.

3.0 Executive Summary

PSCI is proactively enabling the pharmaceutical sector to respond to a global PIE AMR challenge, as stakeholder demand for analytical wastewater results continues to grow. The project recognizes that while analytical capability exists globally, it tends to exist in pockets of the world, creating barriers for companies that require reliable, residual API content analysis capable of detecting low-level concentrations of antibiotics in complex wastewater streams.

PSCI therefore initiated this work to assess existing regional analytical services, beginning in India - a region with a significant concentration of API manufacturers and a strong PSCI regional presence. The findings will support longer term sector planning and decision making.

Developing regional analytical capacity is driven in part by PSCI members' interest in the availability of credible analytical capability, alongside the practical challenges of shipping wastewater samples internationally. Cross-border transport can introduce delays, temperature excursions, and handling risks that may affect sample integrity - particularly for low-level concentration analysis. It can also be time- and resource-intensive, requiring additional cold-chain packaging, courier and customs coordination, and extended chain-of-custody management, often resulting in slower turnaround. These considerations support PSCI's rationale for strengthening in-region capability to enable more timely, controlled, and reliable sample handling and analysis.

→ **The objective was to evaluate whether local providers can deliver robust wastewater API analysis at low-level concentrations in complex matrices, consistent with member expectations for sensitivity, accuracy, comparability to validated reference laboratories, and overall data quality**

Following a collective request from PSCI member companies, reflecting a shared priority, PSCI conducted an assessment of in-country laboratories in India. The objective was to evaluate whether local providers can deliver robust wastewater API analysis at low-level concentrations in complex matrices, consistent with member expectations for sensitivity, accuracy, comparability to validated reference laboratories, and overall data quality. Two laboratories (SGS and SMS) were selected from an initial pool of 14 for detailed evaluation based on their established infrastructure and analytical maturity. Together the laboratories analyzed 57 wastewater samples provided by four PSCI member companies, while split samples were assessed by member-validated reference laboratories to enable comparison.

The assessments showed that both laboratories possess significant capability, including modern instrumentation and competent scientific teams. The supporting infrastructure for wastewater API analysis capable of detecting very low concentrations of antibiotics in complex wastewater streams is well developed. However, the study also identified that current workflows and standard service approaches are not yet consistently optimized for decision-grade analysis, where high reproducibility, matrix-specific performance evidence, and strong comparability across laboratories are required. This was reflected in observed variability between the candidate laboratories and reference laboratories, and in instances where general analytical approaches were applied instead of the project-specific method development commissioned by PSCI. Taken together, these findings highlight opportunities to strengthen analytical rigour, enhance method verification and validation practices, and support more proactive engagement with member companies to align expectations and improve consistency of outputs.

A further learning relates to roles and accountability. In this project, PSCI aimed to assess existing capability, not to provide capability building. Members therefore retain responsibility for reviewing laboratory methods, ensuring alignment with technical expectations, and supporting labs with clarifications as needed. Clear communication channels between members and laboratories are essential to achieving reproducible, decision grade API analysis. PSCI's role is to provide the baseline assessment (not to confer approval) while individual members must undertake the final steps required for their own operational needs.

The assessment confirms that the two India based laboratories have a strong foundational capability to support sector needs. At the same time, the review identified variability in outputs, insufficient analytical rigour and gaps in method development and validation. Addressing these areas through strengthened method development, improved analytical consistency and greater process transparency is expected to enable both laboratories to reliably meet PSCI member expectations for credible analytical results.

Overview of the key project learnings:

Key point

1. Established PSCI's first structured approach to evaluating regional wastewater API analytical capability, creating a practical precedent for future capability-building work.
2. High member participation and technical input were critical to delivery, helping sustain progress and resolve challenges throughout the project.
3. Participating laboratories demonstrated solid foundational capability, alongside clear, targeted opportunities to strengthen robustness/comparability at low-level concentrations.
4. The assessment model proved transferable and can be adapted for use in other regions with similar objectives and constraints.
5. Cross-border shipment issues (e.g., delays, temperature excursions, breakage) reinforced the value of in-region testing to reduce transport-related risks to sample integrity.
6. The work underscored the importance of clear expectations, appropriate oversight, and fitness-for-purpose QA/QC when members engage laboratories.
7. Outputs from this phase provide a platform for broader, scalable impact to improve data confidence and supporting consistent environmental stewardship across the supply chain.



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4.0 Acronyms and Abbreviations

Acronym	Full Form
AMR	Antimicrobial Resistance
API	Active Pharmaceutical Ingredient
CAPA	Corrective and Preventive Action
CPCB	Central Pollution Control Board
CSE	Centre for Science and Environment
FAPAS	Food Analysis Performance Assessment Scheme
GLP	Good Laboratory Practice
IDL	Instrument Detection Limit
LC-MS/MS	Liquid Chromatography–Tandem Mass Spectrometry
LIMS	Laboratory Information Management System
LLE	Liquid-Liquid Extraction
LoD	Limit of Detection
LoQ	Limit of Quantification
MDL	Method Detection Limit
NGT	National Green Tribunal
PEC	Predicted Environmental Concentration
PNEC	Predicted No-Effect Concentration
PO	Purchase Order
ppb	Parts per Billion
PSCI	Pharmaceutical Supply Chain Initiative
QA/QC	Quality Assurance / Quality Control
RQs	Risk Quotients
SOP	Standard Operating Procedure
SPE	Solid Phase Extraction
SME	Subject Matter Expert
UNEP	United Nations Environment Programme
WHO	World Health Organization
WWTP	Wastewater Treatment Plant

4.1 List of Tables

S. No.	Title	Description
Table 1	Laboratory Deliverables Against Purchase Order Requirements	Comparison of expected deliverables vs actual practices for SGS Labs and SMS Lab

5.0 Introduction

The PSCI is proactively enabling the pharmaceutical sector to strengthen its response to emerging expectations around wastewater monitoring and the presence of pharmaceuticals in the environment (PiE). Across the industry, there is an increasing need for reliable, standardized analytical testing capable of detecting active pharmaceutical ingredients (APIs) at very low limits of detection. This need is becoming more prominent as stakeholders place growing emphasis on responsible environmental practices, and as companies seek to demonstrate robust, science-based management of their wastewater discharges.



Against this backdrop, concerns relating to antibiotics in the environment and the wider challenge of antimicrobial resistance (AMR) have gained particular prominence. With a recent UN declaration stating that AMR is *"one of the most urgent global health threats and development challenges"* of our time and warns that, AMR could add up to $1 trillion annually in healthcare costs by 2050[1]. There are several causes of AMR, including over and misuse of antibiotics in human and animal health in the agriculture and aquaculture sectors. Human health is inextricably linked to environmental health and as such there are concerns that the presence of antibiotics in the environment may also contribute to antibiotic resistance in humans through the development and subsequent spread of resistance in environ mental bacteria.

Organizations across the pharmaceutical and healthcare value chain are responding by setting voluntary standards and engaging closely with suppliers on this issue. The PSCI has developed a range of tools and guidance for its members and their suppliers to support responsible manufacturing and environmental stewardship.

While high-quality analytical capability exists globally, it is often concentrated only in specific regions, meaning that many companies must ship wastewater samples long distances for testing. Such shipments can encounter challenges including customs delays, extended transit times, sample degradation, and risks to integrity when analyzing at very low detection limits. These well-recognized logistical constraints underline PSCI's focus on expanding regional analytical capability so that members and suppliers can access timely, reliable testing without relying on long-distance international movement of samples.

It is within this wider global context that India becomes a particularly important region of focus. As a major hub for pharmaceutical manufacturing, India plays a central role in the global supply chain, with Medicines and Med Tech devices becoming the fourth largest merchandise export item for the Indian economy[2].

Regulatory interest in India is increasing. The National Green Tribunal (NGT) has directed the Central Pollution Control Board (CPCB) to establish a monitoring mechanism for API residues discharged into river systems, and CPCB has subsequently issued draft guidelines on API monitoring for State Pollution Control Boards. The Centre for Science and Environment (CSE), in its 2023 report *"Containing Antibiotic Pollution from Manufacturing"*, also highlighted the need to strengthen India's analytical capacity[3].

1 United Nations General Assembly. (2024). Political Declaration of the High-Level Meeting on Antimicrobial Resistance. Retrieved from https://www.un.org/pga/wp-content/uploads/sites/108/2024/09/FINAL-Text-AMR-to-PGA.pdf

2 Kashyap, K. R. N. (2024, November 16). The rise of India's pharmaceutical industry to a forecasted $450 billion. Forbes. https://www.forbes.com/sites/krnkashyap/2024/11/16/the-rise-of-indias-pharmaceutical-industry-to-a-forecasted-450-billion/

3 Centre for Science and Environment (CSE). (2023, November 23). Containing antibiotic pollution from manufacturing. https://www.cseindia.org/containing-antibiotic-pollution-from-manufacturing-11962#:~:text=November%2023%2C%202023&text=Among%20others%2C%20discharge%20from%20manufacturing,%27hotspot%27%20for%20effective%20action



International frameworks echo a balanced perspective. The WHO 2024 global guidance document on *"wastewater and solid waste management for manufacturing of antibiotics"* underscores the need for rigorous monitoring and capacity building related to manufacturing effluent, while situating this within a broader systems approach to AMR. Similarly, the UNEP 2023 AMR Report identifies pharmaceutical pollution as one driver of environmental AMR and emphasizes the need for standardized analytical infrastructure[4].

Pharmaceutical companies have a responsibility to manage the environmental impact of their operations. Risk assessment frameworks typically require calculating Predicted Environmental Concentrations (PECs), Predicted No-Effect Concentrations (PNECs), and Risk Quotients (RQs) - often at thresholds below 10 ng/L, particularly for antibiotics[5].

Sampling wastewater to this degree of sensitivity is technically demanding and few commercial laboratories are equipped with the necessary instrumentation and expertise. India has reportedly had minimal domestic capacity for the type of analysis needed to monitor API discharges in wastewater. The combination of low PNECs, complex wastewater matrices, and the lack of standardized analytical methods necessitates sophisticated equipment and trained analysts, capabilities that are not yet widely available in India. At present, most PSCI members and their suppliers ship wastewater samples to laboratories primarily in Europe or the United States for analysis.

5.1 Problem Statement

PSCI members and suppliers operating in India face constraints in accessing domestic laboratory services with validated methods and standardized capability to detect APIs at ng/L (ppb-range) limits of detection, as typically required for robust PiE monitoring. Although analytical capability exists globally, it is available only in pockets of the world, leaving many regions without reliable in country options.

As a result, companies commonly ship wastewater samples abroad for analysis - a process that introduces significant logistical, cost, and time burdens, including risks related to customs delays, extended transit, sample degradation, breakage, and challenges maintaining integrity at very low detection limits. These issues can hinder timely; science based environmental management and limit the ability of suppliers to respond efficiently to the increasing stakeholder demand for analytical wastewater results.

Within this context, PSCI identified the need to strengthen regional analytical capability so that members and suppliers can access high quality, decision grade wastewater testing without relying on long distance international shipment of samples. India, a major global manufacturing hub with a large API supply base represents a region where expanded analytical capability would meaningfully support the sector and improve the practicality and reliability of wastewater monitoring.

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in annual healthcare costs could be added by AMR by 2050 according to a recent UN declaration

4 United Nations Environment Programme (UNEP). (n.d.). Bracing for Superbugs: Strengthening environmental action in the One Health response to antimicrobial resistance. https://www.unep.org/resources/superbugs/environmental-action

5 Tell, J., Caldwell, D. J., Häner, A., Hellstern, J., Hoeger, B., Journel, R., & Larsson, D. G. J. (2019). Science-based targets for antibiotics in receiving waters from pharmaceutical manufacturing operations. Integrated Environmental Assessment and Management, 17(6), 1105–1115. https://doi.org/10.1002/ieam.4141

5.2 The PSCI Wastewater Lab Project

In response, PSCI initiated a project to develop local capability in India for API testing in wastewater. This project aimed to:

1 **Assessing Current Analytical Capability in India**

This project aimed to assess and document the current capability of commercial analytical laboratories in India to conduct wastewater API analysis for PSCI members and their supply chains. The emphasis was on determining alignment with member needs and intended use cases, including sensitivity, robustness, comparability, and practical operational considerations. This phase did not include capacity-building activities; it focused on evaluating existing capability under defined project conditions.

2 **India: A Strategic Starting Point**

India was chosen as the initial regional hub for this initiative due to a combination of factors: its central role in global active pharmaceutical ingredient (API) manufacturing, increasing regulatory attention, and a growing national interest in monitoring pharmaceutical wastewater.

3 **Regional Engagement and Learning**

The project offered a valuable opportunity to refine strategies for engaging laboratories. The insights gained from this regional effort will help shape future initiatives in other strategically important regions.

4 **Bridge the Gap Between Research and Practice**

Although analytical research on pharmaceutical pollutants is well established, a key challenge remains: ensuring PSCI members are aware of, confident in, and actively making use of the available analytical capabilities.

The purpose of this report and the objective of the associated project phase was to provide a clear, evidence-based understanding of the current capability of India-based commercial analytical laboratories to support PiE-related wastewater API analysis. The work assessed the performance of existing laboratories, with particular focus on their ability to detect pharmaceutical pollutants at concentrations below 10 ng/L/PNEC, consistent with the sensitivity typically required for antibiotic analysis. By identifying current strengths, limitations, and opportunities to better meet PSCI member expectations, the findings were intended to inform future member decision-making and engagement with India-based laboratories. In the longer term, this is expected to support more timely, cost-effective, and locally accessible testing options, while aligning with national regulatory ambitions to strengthen domestic monitoring capability. monitoring capability.

5.2.1 Introduction of the Selected Laboratories

Following a structured landscape review and capability assessment, two Indian laboratories were identified as suitable candidates for participation in the PSCI wastewater analytical phase: SGS Labs and SMS Labs Services Pvt. Ltd. Both laboratories were selected based on their established LC-MS/MS infrastructure, prior experience analyzing complex environmental matrices, and demonstrated willingness to engage with PSCI members on method development and data quality expectations.

While neither laboratory had previously undertaken routine low-level concentration wastewater antibiotic analysis at the outset of this project, both possessed the foundational instrumentation, trained analysts, and operational systems required to participate in a structured capability assessment. Since then, it is understood that both laboratories are now routinely conducting low-level wastewater antibiotic analyses for some pharmaceutical companies. Their involvement in this project provided an opportunity to evaluate readiness, identify areas for methodological strengthening, and inform the continued development of regional analytical capacity.



6.0 Project Planning

The PSCI Wastewater Laboratory project was designed as a multi-phased initiative to assess and enhance the capability of Indian laboratories to detect Active Pharmaceutical Ingredients (APIs) in wastewater - particularly antibiotics, which are of global concern due to their link to antimicrobial resistance (AMR)[6]. This section outlines the structured planning and technical design that supported the delivery of the project.

Phase 1: Feasibility Assessment (2022)

The initial phase of the project focused on scoping the technical and operational landscape for wastewater API analysis in India. A landscape review of Indian testing laboratories was conducted to assess their analytical capabilities, followed by a consultation with PSCI members to define core testing and reporting requirements. Labs were invited to complete a detailed questionnaire and participate in interviews to further evaluate their experience and infrastructure. This phase concluded with a summary report (available upon request from the PSCI Secretariat) identifying a shortlist of candidate labs with the potential to participate in subsequent activities.

Phase 2: Laboratory Shortlisting (2023)

Building on the feasibility work, Phase 2 moved into direct engagement and evaluation of the shortlisted labs. A project team was formed comprising subject matter experts and technical representatives from multiple PSCI member companies. Together, they carried out site visits to better understand each lab's technical capabilities, quality systems, and readiness to participate in a project. Two laboratories were selected to move forward into the next stage based on their infrastructure, existing analytical experience with APIs, and willingness to develop or adapt methods for wastewater testing.

→ **A project team was formed comprising subject matter experts and technical representatives from multiple PSCI member companies**

Phase 3: The PSCI Wastewater Analysis Project (2024 - 2025)

The third phase of this project consisted of a phase designed to evaluate the capability of selected Indian laboratories to analyze active pharmaceutical ingredients (APIs) in real wastewater matrices through side-by-side testing. Wastewater samples were collected from participating PSCI member manufacturing sites and distributed to the two Indian laboratories selected in Phase 2. Each laboratory was tasked with analyzing a defined subset of APIs (four per lab), with a particular emphasis on antibiotics.

Where feasible, laboratories applied existing validated analytical methods. In cases where suitable methods were not available, new methods were developed and validated in alignment with each laboratory's instrumentation and technical capabilities. To provide an external benchmark, participating PSCI members submitted split samples to their preferred validated laboratories. This approach enabled comparison across multiple analytical platforms and methodologies, offering a broader perspective on analytical performance and variability.

Detection and quantitation limits were a critical requirement of this phase. For each API, Method Detection Limits (MDLs) were assessed relative to the corresponding Predicted No-Effect Concentration (PNEC), a key benchmark used in environmental risk assessment. While PNECs are traditionally applied to receiving waters where dilution is assumed, increasing regulatory and stakeholder interest prompted consideration of these thresholds at the point of discharge. This was particularly relevant for antibiotics, which often have PNECs in the low nanogram-per-litre range and therefore pose significant analytical challenges.

A standardized sampling and analysis plan was developed by PSCI member Subject Matter Experts (SMEs), with careful coordination of logistics to maintain sample integrity throughout collection, storage, transport, and handling. Participating laboratories were instructed to apply their own validated methods rather than use a harmonized protocol. While this introduced inherent methodological variability, it also provided valuable insight into real-world laboratory practices and highlighted opportunities for future method refinement and cross-laboratory validation.

To support data quality and comparability, minimum quality assurance and quality control (QA/QC) requirements were defined and shared with all participating laboratories. These criteria played a critical role in enabling meaningful side-by-side assessment of results and form an important foundation for future expansion or replication of this work.

6 Lessa, F. C., & Sievert, D. M. (2023). Antibiotic Resistance: A Global Problem and the Need to Do More. Clinical Infectious Diseases, 77(Supplement_1), S1–S3. https://doi.org/10.1093/cid/ciad226

7.0 Methodology



7.1 Lab Report Requirements

To ensure a standardized output, each participating laboratory was asked to structure their reports to include the following:

- **Introduction:** Laboratories were asked to specify the analyte, analytical method, and instruments used.
- **Reagents and Materials:** Laboratories detailed all reagents and materials used, including their purity.
- **Apparatus/Glassware:** Key apparatus and labware used in the process were described.
- **Sample Preparation:** Laboratories explained how samples were received and processed (e.g., filtration, extraction, storage).
- **Sample Analysis:**
  - The analytical procedures used to detect APIs were requested.
  - The identification methods for each API.
  - QA/QC procedures and how analytical interferences were handled.
  - Information on how Instrument Detection Limits (IDL), MDLs, and Limits of Quantification (LoQs) were determined.
  - The instrument calibration and verification process.
  - Quantification and validation methods for each API.
  - Approaches for identifying and mitigating sample matrix or method interferences.
  - Representative chromatograms for key analytes were requested.

Through this carefully planned approach and collaborative execution, the project aimed to establish a replicable framework for evaluating local lab capability - making wastewater API analysis more accessible, efficient, and reliable for the pharmaceutical sector in India.

7.2 Sampling Strategy and Logistics

A core component of this project involved the collection and handling of wastewater samples under realistic field conditions. The aim was to evaluate laboratory performance in detecting Active Pharmaceutical Ingredients (APIs) across a wide concentration range from sub-parts per billion (ppb) to parts per million (ppm). Samples were collected during periods of active pharmaceutical production, such as during equipment cleaning, when the likelihood of API discharge is highest.

To ensure consistency across sites, PSCI Subject Matter Experts (SMEs) developed a centralized sampling protocol, which was shared with participating member companies and laboratory partners. The protocol encouraged the collection of representative samples while allowing for flexibility across different manufacturing contexts.

Daily composite samples collected over several consecutive days were preferred, as they provide a more comprehensive picture of wastewater characteristics. However, grab samples were considered appropriate for in-process waste streams or equipment rinses, where concentrations may be higher and more variable. For wastewater treatment plant (WWTP) samples, facilities were asked to account for hydraulic retention time when determining the start and end points of sampling.

Where automatic samplers were available, 24-hour composite samples were collected, with flow-weighted composites preferred. In cases where such equipment was not available, daily composites were manually assembled from a series of grab samples taken throughout the day. Each sample was split and sent to both the selected candidate laboratory (e.g., SGS or SMS) and the sponsoring member's validated laboratory, enabling direct comparison of analytical results.

Sampling events typically included between six and eight samples. A standard six-sample package consisted of one high-concentration sample, three consecutive daily composite WWTP effluent samples representing lower concentrations, and two quality control samples (a duplicate and a blank). Each of these was duplicated for analysis by both laboratories.

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mg/L additional ascorbic acid was required by SGS, while SMS did not prescribe any preservative under its current method

Sample containers varied depending on laboratory requirements. Amber glass bottles were preferred for SGS and SMS, unless samples were shipped frozen-in which case HDPE or Greiner tubes were acceptable. If amber glass was unavailable, bottles were wrapped in aluminium foil to prevent light exposure. SGS required 1-litre samples, while SMS required 0.5 litres. All containers were rinsed with sample water prior to filling, sealed tightly, and left with approximately 10% headspace.

The same packaging and handling guidance was also provided for split samples submitted to member-validated reference laboratories, to ensure consistency across shipments and support comparability of results. Preservative requirements differed by laboratory: SGS required the addition of 50 mg/L ascorbic acid, while SMS did not prescribe any preservative under its current method. After preparation, all samples were refrigerated until shipment.

Each sample was clearly labelled with its number, date and time of collection, origin, and the API to be analysed. A simple spreadsheet was maintained on-site to track sample details, including the collector's initials and location.



7.3 Sample shipment

7.3.1 Containers

Samples were packaged with care to prevent breakage and leakage. Glass containers were wrapped in protective material and placed inside sealed plastic bags. Ice packs were included to maintain a cool temperature during transit. Packages were marked as fragile, with clear instructions to keep upright and handle with care. Shipping companies were consulted to ensure all regulatory and handling requirements were met.

7.3.2 Preservation

To avoid delays, members were provided with guidance to ship samples via next-day or two-day air, with a strong recommendation to avoid dispatch on Thursdays or Fridays to prevent weekend hold-ups. Shipment instructions specified that documentation detailing the samples should be included and protected in a waterproof sleeve, together with any lab-specific paperwork as required. Members were also asked to ensure packages were clearly labelled as Water Samples for Testing, in accordance with applicable shipping regulations.

7.4 Sample Matrix

Samples covered a range of matrices including in-process rinses, combined manufacturing effluents, and WWTP influent/effluent. Matrix characteristics (pH, conductivity, TSS, COD/BOD where available) were recorded by sites when feasible to support interpretation of extraction efficiency and ion suppression/enhancement. Note: Where anonymisation was required, site-specific identifiers and operational details were withheld.

→ Samples covered a range of matrices including in-process rinses, combined manufacturing effluents, and WWTP influent/effluent



7.5 Analytical Approach and Quality Controls

Participating laboratories applied their own validated methods to reflect current client service conditions. This enabled assessment of real world performance and identification of method specific variability. In parallel, member validation laboratories provided benchmark data for the same split samples.

Defining a single universal acceptance criterion was not feasible given the limited dataset, differing extraction workflows (e.g., direct inject with filtration vs liquid liquid extraction), instrument platforms, calibration models, and internal standard strategies. Accordingly, evaluation focused on concordance trends, identification of systematic bias, and alignment of reported detection capability with PNEC relevant targets.

Minimum QA/QC expectations communicated to laboratories included: matrix matched spike recoveries at multiple fortification levels; matrix spike duplicates; method blanks; laboratory control samples; continuing calibration verification; assessment of carryover; and documentation of MDL/LoQ determination.

→ **Following the analytical data review, PSCI SMEs conducted on-site assessments at SGS Labs and SMS Labs to corroborate laboratory practices and investigate potential factors contributing to variability observed in the comparative analysis**



7.6 Lab Visits

Following the analytical data review, PSCI SMEs conducted on-site assessments at SGS Labs and SMS Labs to corroborate laboratory practices and investigate potential factors contributing to variability observed in the comparative analysis. These visits were essential to validate the interpretation of data and to understand the operational context behind the reported results.

The primary purpose of these visits was to bridge the gap between numerical findings and practical workflows. By observing processes firsthand, SMEs could assess whether differences in reported concentrations were influenced by method execution, sample handling, or equipment configuration rather than inherent analytical limitations. This step ensured that conclusions drawn from the data were grounded in a clear understanding of laboratory practices.

8.0 Observations and Findings

8.1 SGS Labs - Data Analysis Findings

A comparative review of analytical results between the candidate laboratory and the validation laboratories focused on the APIs Meloxicam, Amoxicillin, Ampicillin and Azithromycin. Although sampling events typically included multiple split samples, only 13 paired data points were available for comparative evaluation, as member-validated reference results were not available for two of the substances and could not be included in the assessment. 23% of the concordant data points were consistently reported as non-detects by both the candidate laboratory and the validation laboratory(ies). Among the subset of samples where APIs were quantified (detects), approximately 20% fell within ±30% of the reference values. Most quantified results were within the same order of magnitude; however, around 20% of detects differed by two orders of magnitude, reaching up to approximately 100-fold. This pattern indicates inconsistent quantification at low concentrations and can limit confidence in decision-grade wastewater API data for ultra-trace applications. This matters because the quantified detects are the results most relevant to environmental risk assessment, where reliable measurement at ng/L levels is needed to support robust interpretation.



Instances where the laboratory reported substantially higher concentrations sometimes inconsistent with the wider dataset and even implausible, suggesting potential issues relating to extraction efficiency, instrument sensitivity, matrix-effect correction, sample contamination, and/or sample instability during transport and handling. These discrepancies have practical implications: over-estimation can lead to unnecessary escalation of site investigations, while under-estimation or non-detects can obscure genuine environmental risks and undermine confidence in data used to support science-based wastewater stewardship expectations.

Although spike recovery is referenced elsewhere as having been conducted in water samples, spike recovery data in the relevant sample matrix are not presented here due to sensitivities associated with the underlying data. While such data would aid interpretation, as recovery results outside acceptable ranges can indicate that a method does not sufficiently account for matrix complexity, they are available upon request from the PSCI Secretariat.

In complex matrices, insufficient method optimization can lead to unpredictable analyte losses or signal suppression. This, in turn, affects both precision and accuracy, meaning that the same sample may yield materially different results depending on subtle variations in preparation or extraction.

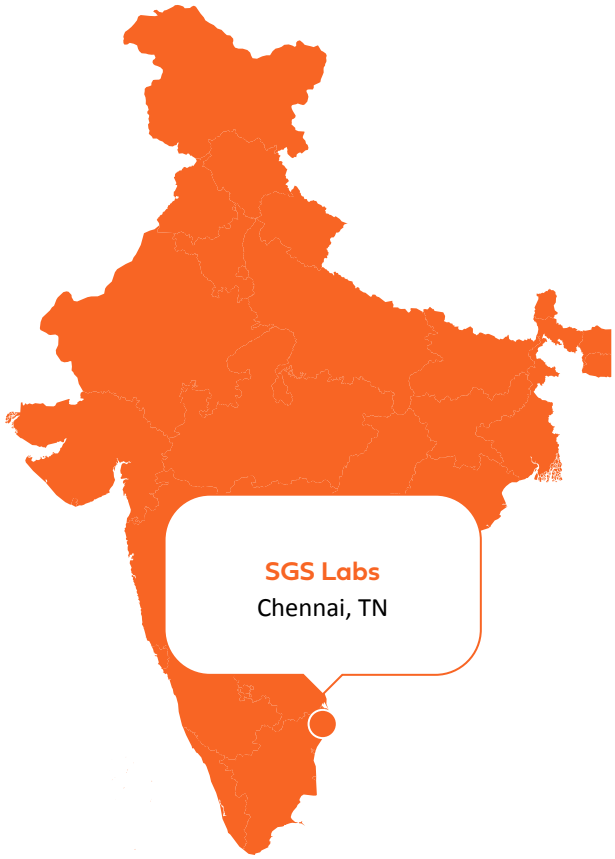
Challenges during sample transport may have partly contributed to the differences observed between laboratories. It is therefore critical to understand and preserve analyte stability at the concentration range of interest throughout transport.

Overall, the findings suggest that while the laboratory has a strong technical foundation, its current workflows require further refinement to achieve the reproducibility, sensitivity, and analytical rigour expected for lower-level concentration wastewater API analysis. Addressing these issues particularly through matrix-matched recovery studies and strengthened method verification will be critical to improving confidence in future analytical outputs.

8.2 SGS Labs - Lab Visit Observations

SGS operates a multi-floor facility in Chennai, primarily serving food, environmental, and wastewater analysis. The laboratory is equipped with six LC-MS/MS triple quadrupole instruments, dedicated sample preparation areas, and precision balances capable of five-digit accuracy. Senior management demonstrated openness and transparency during the visit, providing access to records and documentation.

The team examined the method used for PSCI samples, which had been shared with PSCI by the laboratory. This method represented an adaptation of an existing multi-analyte LC-MS/MS protocol rather than a newly developed method for Meloxicam as initially requested. The adapted method met basic detection and quantitation requirements, and the laboratory provided additional method details to PSCI to support transparency and evaluation. The LC-MS/MS platform used was an Agilent 6460 coupled with a 1290 Infinity HPLC, configured for triple quadrupole operation.



0.22

µm syringe filters were used to filter samples, without validation of potential analyte adsorption or loss

8.2.1 Key observations included:

- **Recovery Studies:** Conducted using laboratory water rather than matrix-matched wastewater samples, limiting the ability to evaluate matrix effects and optimize recovery.
- **Sample Preparation:** pH adjustment (5–7) was applied prior to injection, but its impact on analyte stability and recovery was not assessed.
- **Filtration:** Samples were filtered through 0.22 µm syringe filters without validation of potential analyte adsorption or loss.
- **Enrichment Techniques:** Direct injection was used following pH adjustment and filtration; alternative enrichment methods such as SPE or liquid-liquid extraction were not explored.
- **Data Documentation:** Most records were maintained digitally, with limited handwritten entries and absence of individual laboratory notebooks, which could affect traceability.

The visit confirmed that SGS Chennai, India has strong infrastructure and technical capability. Opportunities for improvement include implementing matrix-specific recovery studies, validating filtration and pH adjustment steps, exploring enrichment techniques for complex matrices, and strengthening documentation practices to support data integrity and reproducibility. These enhancements will help align laboratory practices with PSCI expectations for precision and consistency in wastewater API analysis.

8.3 SMS Labs Services Pvt. Ltd. - Data Analysis Findings

A comparative review of analytical results between the candidate laboratory and the validation laboratories was conducted for the APIs Gentamycin, Clarithromycin, Valsartan, and Prednisolone, with 30 data points available for comparison. Overall, 63.3% of data points were consistently reported as non-detects by both the candidate laboratory and the validation laboratory(ies), meaning these paired results cannot be assessed against a percentage-difference criterion. Across the subset of quantified detects, the observed inter-laboratory differences spanned approximately >200-fold to >136,000-fold, including cases where one laboratory reported a non-detect and the other reported a quantified concentration (with fold differences estimated using the reported LOD/LOQ as a conservative comparator). This degree of divergence indicates that comparability and quantification at low concentrations can be substantially improved through strengthened method verification, matrix-appropriate recovery evidence, enhanced contamination/carryover controls, and more consistent QA/QC and data review practices when generating data intended for environmental risk assessment.

Further review identified instances where one laboratory reported non-detects while another laboratory quantified measurable concentrations, as well as cases where higher concentrations were reported for certain compounds. Such differences can arise from a range of methodological and matrix-related factors (e.g., extraction efficiency, matrix effects, and instrument sensitivity) and highlight the value of strengthening matrix-specific recovery evidence, validating key extraction and reconstitution steps, and applying harmonized QA/QC practices to support consistent interpretation across laboratories.

63.3%

of data points were consistently reported as non-detects by both the candidate laboratory and the validation laboratory(ies)



8.4 SMS Labs Services Pvt. Ltd. – Lab Visit Observations

SMS Labs is a leading analytical service provider with capabilities spanning food, water, environmental, and agricultural matrices. The facility employs a Laboratory Information Management System (LIMS) for sample tracking and offers controlled storage conditions at −20 °C, 2–8 °C, and ambient temperatures. Instrumentation includes four LC-MS/MS triple quadrupoles, three GC-MS/MS systems, HS-GC-MS/MS, ICP-MS, LC-ICP-MS, and AAS, supporting a broad analytical scope.

During the visit, the team reviewed the laboratory's general method (SMSLA/LS/SOP/32), which is based on USEPA 1694 and validated for detection of up to 100 compounds at ppb levels. This method was applied for PSCI samples, with an additional dedicated method developed for Prednisolone. The LC-MS/MS platform used for the project was an Agilent 6475 coupled with 1290 Infinity II HPLC, capable of achieving detection limits as low as 0.001 ppb.

→ **The facility employs a Laboratory Information Management System (LIMS) for sample tracking and offers controlled storage conditions at −20 °C, 2–8 °C, and ambient temperatures**



8.4.1 Key observations included:

- **Recovery Studies:** Conducted using Milli-Q water blanks rather than matrix-matched wastewater samples. This approach limits the ability to assess matrix effects and may influence recovery accuracy.
- **Sample Preparation Workflow:** Liquid-liquid extraction was employed, involving pH adjustment (5–9), methylene chloride partitioning, and nitrogen evaporation. While effective for certain APIs, the impact of pH adjustment on analyte stability was not evaluated.
- **Reconstitution Solvent:** Final extracts were reconstituted in water, which may affect recovery for APIs with low water solubility (e.g., Clarithromycin), leading to observed recovery ranges of 84–86%.
- **Filtration and Validation:** Filtration steps were not validated for potential analyte adsorption, and while raw data was largely available, some gaps were noted in calibration curve preparation and recovery solution documentation.

The visit confirmed that SMS Labs has strong baseline infrastructure and technical capability. Opportunities for improvement include reinforcing matrix-specific recovery studies, validating extraction and filtration steps, and ensuring comprehensive documentation of method development and QA/QC processes.

9.0 Discussion on the Variations Observed

Observed variability between candidate labs and validation labs stems from multiple factors: divergent extraction workflows, calibration models, instrument tuning parameters, and potential differences in analyte stability during transport and storage (e.g., temperature control and holding times). Matrix complexity exacerbates these differences, particularly when high-concentration samples are processed alongside trace-level samples, increasing risks of carryover and contamination.

Both labs referenced international guidance tolerating differences in reported values within ±20% and expanded uncertainty up to 50% for complex residue analysis. The data generated in this work indicate that, particularly at low-level concentration levels and in complex matrices, inter-laboratory variability can be substantially greater, in some instances spanning orders of magnitude. PSCI therefore aims for tighter reproducibility to enable confident environmental risk assessments. Achieving this requires harmonized QA/QC protocols, matrix-matched recovery studies, and proficiency testing to benchmark inter-lab performance.

Although laboratories reported satisfactory sample integrity upon receipt, feedback from project participants indicates that transport and handling conditions were not uniformly controlled across shipments. Anecdotal examples included samples being held at customs under ambient rather than refrigerated conditions, variable temperature control during transit, and delays in receipting at the receiving laboratory. Such factors introduce risks related to analyte degradation, adsorption, or other stability related losses, particularly at the low-level concentration range of interest.

While the precise contribution of these logistical factors to the observed variability cannot be quantified from the available data, they represent a plausible source of additional uncertainty. These experiences also highlight the value of strengthening in country or in region analytical capability for wastewater API testing, which can reduce reliance on cross border shipping and minimize transport related risks (e.g., customs delays, temperature excursions, and extended holding times).

Building regional capacity would support faster turnaround, improved control of pre analytical conditions, and greater confidence that measured differences reflect true sample characteristics rather than transport artefacts.

To better manage these risks in future phases, improved control and documentation of transport conditions will be critical, including clearly defined requirements for temperature management, maximum holding times, and chain of custody procedures. The routine use of internal standards should also be strongly considered to help account for recovery losses, matrix effects, and potential degradation. Ideally, isotopically labelled (e.g. deuterated) analogues of the target APIs would be added prior to extraction; where feasible, addition at the point of sampling would further enable correction for losses occurring during transport and storage. This approach is consistent with isotope dilution mass spectrometry principles, where labelled standards are introduced at the earliest possible stage so that they experience the same recovery losses, matrix effects, and processing variability as the target analytes, thereby improving quantification accuracy and precision.

Taken together, future phases should prioritize stronger control of transport conditions, the definition of minimum QA/QC requirements, and structured inter laboratory comparison exercises. These should be supported by harmonized validation parameters and consistent QA/QC measures during sample analysis, rather than prescriptive alignment of analytical methods, to improve data reliability while allowing laboratories to apply techniques best suited to their capabilities.

PSCI members may request access to the underlying project data held in the PSCI project archives at any time. To do so, please email info@pscinitative.org with your request, and the PSCI team will support retrieval and sharing in line with the project's data-handling approach.

9.1 Verification against the PSCI Lab Project Phase III Plan

A detailed review of deliverables relative to the outputs generated suggests that some requirements were met, while others would benefit from strengthening. Both laboratories achieved baseline calibration and reporting limit expectations; however, key QA/QC elements such as matrix-spike recoveries and field blank analyses were not available. This underlines the importance of clearly documenting minimum QA/QC expectations in advance and incorporating interim check-ins and data reviews during analytical campaigns to support consistent, fit-for-purpose outputs.



Table 1. Laboratory Deliverables Against Purchase Order Requirements

S. No.	Deliverables in PO	SGS Labs	SMS Lab
a	Analysis of spikes, prepared in the lab or for selecting API prepared in the field, as a measure of accuracy (expressed as a percentage of the spike concentration). The lab should establish a range of recoveries that is acceptable.	Analysis of spikes was done with lab. water instead of sample blank.	Analysis of spikes was done with lab. water instead of sample blank.
b	Analysis of duplicates, collected in the field, as a measure of precision (variance in measured concentrations). The lab should establish a level of precision that is acceptable.	Yes	Yes
c	Analysis of blanks, collected in the field, to detect possible contamination issues.	No	No
d	Analysis of standards to assess instrument calibration and method performance. The lab should prepare the standards and establish acceptance criteria.	Yes	Yes
e	Detection and quantitation limits are essential components of the analytical method. Target Method Detection Limits (MDLs) and Limits of Quantitation (LoQ) are relative to the respective Predicted No-effect Concentration (PNEC).	Yes, as specified in PO.	Yes, as specified in PO.
f	Development of analytical methods for project-specific APIs, as required under the PO.	Required to develop analytical methods for *Meloxicam*.	Required to develop analytical methods for *Prednisolone*.

10.0 Project Learnings

This initiative was the first project of its kind undertaken by PSCI to evaluate regional analytical capability for wastewater API analysis, and it holds particular significance for the organization. As a pioneering effort, it demonstrated how PSCI can proactively enable the pharmaceutical sector by building a clearer understanding of analytical capacity in key manufacturing regions and by supporting members with insights that directly respond to emerging global expectations. PSCI therefore initiated this work to assess the current availability, consistency, and suitability of regional analytical services, beginning in India - a region with a significant concentration of API manufacturers and a strong PSCI regional presence. The findings are intended to provide an evidence base to help PSCI and members understand current conditions and identify areas for consideration, where relevant.

One of the strongest learnings from this phase was the high level of engagement from PSCI member companies. Their responsiveness, commitment, and collaborative approach were consistently highlighted as a critical success factor. Members contributed technical expertise, practical insights, and continuous support throughout the process, helping navigate challenges and maintain momentum even when delays occurred. This collective effort underscores the value of PSCI's collaborative model and is formally acknowledged in the Acknowledgements section.



The project also generated important insights into the current state of analytical capability in the region. The assessments confirmed that both laboratories possess mature infrastructure and skilled teams capable of low-level concentration API analysis, while also identifying opportunities for improvement in method development, analytical rigour, and proactive communication. These findings provide a concrete foundation for targeted capability enhancement - both within the participating laboratories and as guidance for PSCI members engaging with analytical partners in the future.

A key project learning is that this type of assessment is replicable and scalable. This project demonstrated that it is both feasible and valuable to evaluate and enable analytical capability in different parts of the globe. The approach applied in India can be adapted by PSCI or by individual members to assess labs in other regions, ultimately supporting a more globally distributed network of analytical facilities and reducing reliance on long distance sample shipments.

The project also reaffirmed that many of the delays and logistical hurdles experienced were expected - and, importantly, were one of the reasons the project was undertaken in the first place. As anticipated, customs challenges, long transit durations, broken bottles, cost escalations, and occasional loss or degradation of samples all occurred during execution.[7] These disruptions did not undermine the project; rather, they validated the rationale for developing regional analytical capability, since such challenges are substantially reduced when sample movement takes place within a smaller geography. Domestic shipments proved smoother, quicker, and easier to remediate when issues arose, reinforcing the value and necessity of regionally accessible laboratory services.

Overall, the learnings from this project will directly inform PSCI member practices going forward. They emphasize the importance of method alignment, clear communication of expectations, and appropriate member oversight when engaging laboratories, alongside a strong focus on analytical quality, robustness, and fitness for purpose. PSCI member companies will continue to apply their own judgement, supported by their internal research when assessing laboratory suitability. Collectively, these insights provide a strong basis for improving sampling logistics, strengthening confidence in analytical data, and promoting consistent, high-quality environmental management across the supply chain. The project has also created momentum for broader industry impact, offering a model that PSCI and its members can replicate globally to advance environmental stewardship and build analytical capability in a scalable, sustainable way.

→ A key project learning is that this type of assessment is replicable and scalable

7 Shipment records and member reports documented these issues.

11.0 Recommendations

This project phase confirmed that both SGS Labs and SMS Labs possess a strong foundational capability and the core infrastructure required for wastewater API analysis. However, the assessment also highlighted variability in results, gaps in method development, and the need for greater analytical rigour. The following recommendations are therefore intended to support PSCI members in responsibly engaging these laboratories, while also guiding the targeted improvements needed for both labs to consistently deliver decision-grade data aligned with PSCI expectations. Implementing these actions will enable PSCI members to make use of the laboratories' existing strengths, while ensuring that analytical outputs meet the accuracy, reproducibility and traceability required for environmental risk assessment.

Strengthening Analytical Practices at Candidate Laboratories

1 Adopt validated methods with local verification

To minimize result variability and confirm testing capability, candidate laboratories should use a validated (member validated) reference method and conduct method verification locally before applying it to routine testing.

2 Clarify compound stability requirements

Clear instructions must be provided regarding compound thermal sensitivity. Explicitly specifying whether heating steps are permitted will help avoid degradation during sample preparation.

3 Provide appropriate blank matrices for recovery studies

Provide explicitly labelled wastewater blank matrices with no or very low target API concentrations and a composition that is as similar as possible to the samples being tested. Where possible, blanks should be matrix-matched to each sampling point, as post-final treatment matrices may not be representative of influent or intermediate streams. Blank matrices may also be used for standard addition calibration where appropriate.

4 Introduce internal standards to improve accuracy and comparability

Where pre-analytical stability is a concern, laboratories should consider adding isotopically labelled internal standards at the point of sampling (where operationally feasible) so that losses during transport and storage are tracked and can be corrected through isotope dilution. This approach is most feasible for grab sampling under controlled sampling conditions (e.g, pre-dosed bottles or sealed ampoules) and may be less practical for composite sampling, remote field collection, or where site safety/governance constraints limit handling of spiking solutions. Stability is analyte-dependent; preservation and short holding times remain essential.

5 Flag high-concentration samples for LC–MS/MS

Samples expected to exceed the upper limit of the calibration curve should be clearly labelled so laboratories can apply appropriate dilution steps and bring results within the validated instrument range.

6 Ensure pre testing alignment

Effective coordination is essential. Prior to testing, laboratories and member companies must align on sample types, analytical methods, expectations, and any method specific nuances. This reduces misinterpretation and prevents unnecessary rework.

7 Monitor data continuously during testing

During the analytical period, interim data review should be conducted to identify issues early and allow timely corrective measures, rather than waiting until results are final.

8 Specify raw data and digital record requirements

Purchase orders should clearly define expectations for raw data, digital data capture, audit trails, and data retention to ensure transparency and traceability.

→ Explicitly specifying whether heating steps are permitted will help avoid degradation during sample preparation

Project delivery learnings for future PSCI capability assessments

This first PSCI capability assessment generated practical learnings not only on analytical considerations, but also on how to design and run regional capability projects in a consistent, collaborative, and scalable way. Several delivery elements materially improved outcomes and should be carried forward into future phases.

To strengthen future PSCI projects, the following operational practices are recommended:

- Set a clear project governance model early (roles, decision rights, escalation routes, and timelines) to maintain momentum when delays occur.
- Build structured engagement points into the plan (e.g., kick-off alignment, mid-project check-ins, and close-out feedback sessions) to surface issues early and avoid late-stage rework.
- Apply a consistent approach to reporting and interpretation safeguards, including clear scope boundaries, non-endorsement language, and appropriate limitations, to support responsible use of findings.
- Standardize project artefacts for re-use (screening criteria, site-visit templates, data-request checklists, and reporting formats) to improve efficiency and comparability across future regional assessments.
- Design outputs for accessibility and longevity, including concise summaries, clear definitions, and consistent terminology, so that learnings remain useful for members beyond the immediate project.



11.1 SGS Labs: Key Takeaways and Planned Actions

At a Glance

Key Point	What this means and planned action from SGS
Method selection should match expected concentration ranges	Early indication of likely API concentration ranges from sample submitters supports choosing the most appropriate analytical approach from the outset.
More regular, direct communication would streamline delivery	Establish clearer touchpoints during analysis to resolve questions in real time, reduce delays, and support faster issue resolution.
Reinforce packaging requirements to reduce transport breakages	Ensure bottles are shipped with ~10% headspace to prevent expansion-related breakage under frozen conditions; communicate this requirement consistently to participating companies.
Matrix blanks should be clearly labelled and provided in sufficient volume	Clearly identify blanks to avoid misclassification; provide adequate volumes (e.g., ~500 mL) to support matrix-matched calibration/linearity work and reduce uncertainty linked to matrix effects.
Matrix effects and possible contamination may contribute to differences	Strengthen matrix-aware QA/QC (e.g., recovery checks, contamination controls, carryover prevention) to improve confidence in wastewater-specific analysis.
Method development completed and shared	SGS developed an analytical method covering all four APIs and shared it with PSCI; technical feedback received will be used to refine the method further where required.
Practical improvements identified for future phases	Focus areas include clearer analytical expectations, consistent sample handling practices, and communication protocols to support continued improvement in wastewater API analysis across participating laboratories.

As the project concluded, SGS Laboratories shared their reflections on the analytical work and outlined several areas that could help strengthen future wastewater API testing. Their feedback focused on methodological considerations, communication practices and logistical issues.

SGS noted the importance of selecting analytical methods that match the expected concentration ranges of incoming samples. They explained that *"if it is an input water, there should be a high concentration of APIs… [and] these are to be tested with techniques like HPLC-UV,"* while *"discharging water… should be tested with high accurate systems like LCMS."* Early clarity from sample-submitting companies about likely concentration ranges would help ensure the most suitable method is applied from the outset.

The team also highlighted the benefit of more regular communication with companies during the analysis. They noted that certain issues *"could have been discussed at that point in time,"* suggesting that more direct dialogue would have helped address questions earlier and avoid delays.

Sample handling was another practical area raised. SGS observed that some shipments arrived without the required headspace, explaining that *"there should be a 10% headspace… otherwise in frozen condition it will expand and break the bottles."* Reinforcing this requirement with participating companies would help avoid damage during transport.

They also emphasized the importance of clearly labelled matrix blanks. Although blanks were included with the samples, they were not identified as such, which led to confusion. As SGS explained, *"we received some blank samples, but it was not mentioned as blank… that is why we had taken [them] as a sample."* They noted that clearly marked blanks - ideally in sufficient volumes such as *"500 mL… for linearity preparation"* would support calibration work and reduce uncertainty linked to matrix effects.

When discussing the differences between candidate-lab and validation-lab results, SGS suggested that *"matrix effects… and maybe some contamination"* were likely contributors. This has informed their thinking on how to approach wastewater-specific analysis as they continue to develop experience in this area.

SGS also confirmed that they developed an analytical method for all four APIs within scope and have shared this with the PSCI team. They welcomed the technical feedback provided and plan to refine the method further where needed.

Overall, the points raised by SGS reflect practical steps that could help improve future work, including clearer communication channels, more consistent sample-handling practices and closer alignment on analytical expectations. These insights will support continued improvements in wastewater API testing across participating laboratories.

11.2 SMS Labs Services Pvt. Ltd: Key Takeaways and Planned Actions

At a Glance

Key Point	What this means and planned action from SMS Labs Services Pvt. Ltd
Close-out feedback captured clear improvement priorities	Feedback sessions enabled SMS to respond to the report's recommendations and identify practical steps to strengthen future wastewater API analysis.
Matrix-matched validation and matrix effects	SMS committed to using PSCI-supplied matrix blanks (rather than Milli-Q water) for validation/recovery work and to undertake matrix suppression/enhancement studies to better characterize matrix effects.
Stronger extraction controls and contamination checks	SMS plans to refine extraction by incorporating SPE cartridges to improve robustness and reduce risks of false positives/false negatives and cross-contamination, supported by more systematic use of field blanks.
External benchmarking and ongoing performance assurance	SMS reaffirmed participation in FAPAS (Food Analysis Performance Assessment Scheme) proficiency testing—an ISO/IEC 17043-accredited programme operated by Fera Science Ltd.—when the next cycle becomes available, to support independent performance benchmarking.
Operational readiness and embedding learnings	SMS acknowledged customs-related shipment delays and will strengthen internal handling processes, while embedding project learnings into routine practice to better support industry needs.

As part of the project's close-out, the PSCI held dedicated feedback sessions with SMS Laboratories, providing the team with the opportunity to comment on their experience and to respond directly to the recommendations set out in this report. Through these discussions, SMS reflected on the project findings and identified several areas where methodological alignment and analytical rigour can be strengthened.

A key area acknowledged by the laboratory was the need to improve the use of appropriate blank matrices during validation and recovery studies. SMS recognized that their use of Milli-Q water instead of PSCI-supplied matrix blanks introduced unnecessary variability and committed to correcting this in future work, noting that *"using [Milli-Q] water instead of the matrix blank was a limitation… [and] the matrix blank provided by PSCI should be used."* They also agreed to refine their extraction approach, including incorporating solid-phase extraction (SPE) cartridges to enhance method robustness, as they explained that *"using SPE cartridges… helps avoid false positives or false negatives and reduce cross-contamination during extraction."*

In addition, SMS highlighted their intention to undertake matrix suppression and enhancement studies, as well as to systematically include field blanks, to improve precision and strengthen the analytical outputs generated from wastewater API testing. SMS reaffirmed their commitment to external benchmarking through participation in the FAPAS proficiency testing programme once the next cycle becomes available.

Operationally, the laboratory acknowledged that customs clearance challenges created delays for international sample shipments and indicated that they would work to strengthen their internal processes to ensure smoother handling in future. Finally, SMS emphasized their intention to embed the learnings from this project into routine practice, stating their commitment to *"implement the points raised in this meeting and strengthen our methods so that we are in an even better position to serve the industry."*

→ A key area acknowledged by the laboratory was the need to improve the use of appropriate blank matrices during validation and recovery studies

12.0 Conclusions

At a glance:

1. Both laboratories have modern LC MS/MS instrumentation and supporting infrastructure suitable for low level wastewater API analysis.
2. Site visits confirmed capable teams with relevant experience in LC MS/MS operation, calibration, and routine QA/QC.
3. Comparative results showed variability for a subset of quantified measurements at low concentrations, indicating a need to strengthen comparability for decision use.
4. Clearly defined transport and storage controls (e.g., temperature management and holding times) are essential to protect sample integrity and reduce avoidable uncertainty.
5. A structured, targeted CAPA programme can improve robustness, traceability, and confidence in decision grade outputs over time.
6. The assessment approach used in India provides a practical template that can be applied in other regions.
7. Shipping disruptions encountered during delivery reinforced the value of building in region capability to reduce transport-related risks.
8. The same capability assessment model can be adapted to other analytical domains where services are concentrated (e.g., Industrial Hygiene).
9. The improvement pathway is achievable within a defined timeframe, supported by verification evidence such as updated validation packages and reproducible performance.
10. The work provides a strong foundation for a next phase focused on targeted capability building and broader regional expansion.



The assessment confirmed that both SGS Labs and SMS Labs have the contemporary LC-MS/MS instrumentation and supporting infrastructure required for low-level concentration API detection in wastewater. Their Agilent triple-quadrupole platforms, dedicated preparation areas, controlled storage conditions, precision balances, and LIMS collectively enable GLP-like workflows and complex extraction procedures such as SPE and LLE.

Site visits further showed that both laboratories employ skilled analysts experienced in LC-MS/MS operation, calibration, QA/QC, and environmental residue analysis. This provides a strong foundation for adapting methods to variable wastewater matrices and achieving ppb-level detection aligned with PNEC targets.

However, the comparative dataset indicated inter-laboratory variability and limited concordance across a subset of quantified results. As analytical methods may legitimately differ while still producing accurate outcomes, the focus should be on comparability and fitness for purpose rather than alignment of methodologies. To strengthen confidence in future datasets, reliable sample transport and storage conditions that preserve sample integrity should be clearly defined (e.g., temperature control and holding times), and both laboratories should implement a structured CAPA plan. This should include method verification against reference procedures, matrix-appropriate recovery and precision criteria, strengthened carryover controls, and complete raw-data traceability to support long-term consistency and defensibility.

A key conclusion from this project is that this type of capability assessment is both replicable and scalable. The approach used in India: laboratory screening, capability evaluation, member collaboration, and structured follow-up offers a practical model that PSCI and its members can apply in other regions to build local analytical capability.

The project also reaffirmed that the logistical challenges encountered: customs delays, shipping interruptions, broken bottles, and potential sample degradation were expected. Shorter-distance domestic shipments proved smoother and far easier to remediate, reinforcing the value of reducing geographic dependency for high-sensitivity analyses.

These learnings extend beyond wastewater testing. Similar capability constraints exist in Industrial Hygiene (IH), where analytical services are concentrated in a few global hubs. The model applied in this project can therefore be adapted to assess and strengthen regional IH analytical capability.



Overall, the project demonstrates that India-based laboratories possess the technical foundation, infrastructure, and personnel necessary to support PSCI members' wastewater API monitoring needs. With targeted methodological refinement and improved analytical rigour, both labs are expected to be able to deliver high-quality, decision-grade data. Based on the scope of improvements identified, such refinement is achievable within an estimated 3–12-month period, provided that laboratories implement a structured Corrective and Preventive Action (CAPA) plan. This would typically include method verification against member-validated procedures, matrix-matched recovery studies and use of internal standards, strengthened QA/QC controls, updated SOPs, analyst training, and interim data reviews to confirm progressive improvement. Verification of CAPA completion would rely on the submission of revised validation packages, demonstration of reproducible ppb -level detection capability, and, where appropriate, a focused inter-laboratory comparison using shared wastewater samples. The project provides a strong basis for the next phase of capability building and a replicable model for expanding regional analytical services globally reducing logistical burden, improving data reliability, and advancing PSCI's mission to proactively support responsible, science-based environmental management across the pharmaceutical supply chain.

3–12

months, estimated timeframe to achieve identified improvements, contingent on laboratories implementing a structured Corrective and Preventive Action (CAPA) plan.

12.1 Next Steps for PSCI Member Companies - Practical guidance for member-led follow up

PSCI member companies are encouraged to use the learnings from this phase as a practical reference when conducting their own laboratory assessments and when planning subsequent wastewater API monitoring work in India or other regions. The following steps provide a structured, non prescriptive approach to support member decision making, recognizing that each member will apply its own judgement, supported by internal evaluation when selecting and managing analytical partners.

Practical tips for member-led assessments:

1. Planning (what 'good' looks like)

- ☐ Define the use case and decision context (screening, trend monitoring, decision grade) and list target APIs.
- ☐ Set performance needs: expected concentration ranges, reporting limits (LOD/LOQ), and required deliverables (QA/QC summary and any raw data expectations).
- ☐ Agree reporting conventions early (units, qualifiers, treatment of non detects).

2. Sampling & Transport (protecting sample integrity)

- ☐ Specify minimum transport/storage controls: temperature management, holding times, packaging/ bottle requirements (including headspace), and chain of custody.
- ☐ Plan for cross border contingencies where relevant (temperature logging, escalation contacts, delays at customs).
- ☐ Flag potential high concentration samples so the laboratory can apply appropriate dilution within the validated working range.

3. Analysis & QA/QC (evidence performance in matrix)

- ☐ Request matrix matched performance evidence (recovery, precision, selectivity) near decision relevant concentrations; prioritize comparability and fitness for purpose over identical methods.
- ☐ Use internal standards (ideally isotopically labelled/ deuterated), added prior to extraction; where feasible, consider addition at sampling (or equivalent field approach) to account for transport/storage losses.
- ☐ Provide clearly labelled matrix blanks (no/very low target APIs, compositionally similar to sampling point, sufficient volume) to support recovery work and, where appropriate, standard addition calibration.
- ☐ Align minimum QA/QC expectations (calibration range, blanks/duplicates, recovery checks, carryover controls, acceptance criteria).

4. Review (to build and maintain confidence)

- ☐ Set communication checkpoints (sample receipt, early QA/QC review, exception reporting) to resolve issues quickly.
- ☐ Use targeted comparisons to build confidence (focused inter lab comparisons using shared wastewater samples and/or proficiency testing where available).
- ☐ Require traceability for decision grade datasets (calibration/QC results, deviations/CAPA, and supporting documentation to interpret results near detection limits).

How these learnings support future projects

Applied consistently, these steps provide a repeatable and adaptable framework for future regional capability evaluations and routine monitoring programmes. The guidance is intended to strengthen data reliability, reduce avoidable transport-related risks, and improve comparability across laboratories, while preserving member discretion in laboratory selection and in defining what is fit for purpose for specific sites and decision contexts.
The observations and learnings reflect the specific scope, samples, and conditions assessed in this project and should be interpreted accordingly. Taken together, the report provides a constructive foundation for future capability building and continued progress toward science-based wastewater stewardship across the pharmaceutical supply chain.

13.0 Appendices

13.1 Acknowledgements

The PSCI Wastewater Laboratory Assessment project would not have been possible without the dedication, expertise, and generous contributions of many individuals across member companies, project partners, and collaborating laboratories. We extend our sincere appreciation to the following contributors.

Figure A1.
Overview of the project team structure, showing the participating testing and validation laboratories, PSCI project leads, subject-matter experts, local technical contributors, and the PSCI Secretariat who collectively supported the wastewater laboratory project.

Testing Labs

- SGS Lab (India)
- SMS Labs Services Pvt. Ltd (India)

Validation Labs

- TZW Lab (Germany)
- Smithers Lab (USA)
- Amriton Lab (India)
- Validation Lab 4 (Netherlands)

PSCI Secretariat



Simon Hodgson
SLR Consulting



Beth Quinn
SLR Consulting

PSCI Lead Project Team Members

Pfizer



Ranjana Ganguly



Tim Swenson
Retired

Boehringer Ingelheim



Dr. Reinhold Maerck



Karin Tradt
Ramboll, on behalf of Boehringer Ingelheim

Centrient



Subhash Bhardwaj



Yoginder Bhatia

Novartis



Malcolm Doak



Gemma Janer Gual

PSCI SME's



Manjit Singh
Independent Consultant



Dr. Rominder Suri
WET Center



Debbie Heuckeroth
Kenvue

Local SME's



Peter Paul Raj
Pfizer Chennai Lab



Maheshwaran Shanmugham
Pfizer Chennai Lab

Project Leads

Ranjana Ganguly
Pfizer



Ranjana is gratefully acknowledged for the expertise and perspective she brought to this project. With over 30 years' experience as a Chemical Engineer in Environment, Health & Safety (EHS) across regulatory, consulting, and industry roles, Ranjana contributed a uniquely holistic and practical, risk-based lens. As a member of the PSCI India regional team (2019–2025) and the PSCI Board (2023–2025), she brought a strong understanding of PSCI member expectations and the Indian pharmaceutical operating context. Her global site-operations experience also helped ground discussions in the practical challenges the industry faces in accessing credible analytical capability across regions. Ranjana's insights and steady guidance throughout the project were invaluable.

Tim Swenson
Pfizer – Co-lead with Ranjana till February 2025



We gratefully acknowledge Tim's pivotal role in shaping this project phase. Tim led the development of the Sampling and Analytical Plan and brought more than 30 years of experience at Pfizer into the project. His commitment was evident, including consistently joining early morning calls at 6:00 a.m. local time. His leadership, diligence, and generosity of time were instrumental to the success of this project.



PSCI Lead Project Team Members

Dr. Reinhold Maerck
Boehringer Ingelheim



Reinhold, Head of Corporate EHS&S Regulatory Intelligence at Boehringer Ingelheim, served as both a key subject matter expert and the lead of the PSCI PiE/AMR Topic Team. His leadership was central in ensuring strong alignment between this project and the broader PiE/AMR programme. His active engagement and technical expertise significantly strengthened the project's direction.

Karin Tradt
Ramboll, on behalf of Boehringer Ingelheim



Karin contributed valuable regulatory and water stewardship expertise, drawing on her experience as a Senior Chemical Consultant (REACH, Biocides, Water Stewardship). Her detailed feedback and practical insights directly informed and improved the development of this report.

Subhash Bhardwaj
Centrient Pharmaceuticals



Subhash, Senior Manager (Analytics) in Manufacturing Sciences & Technology, has served as the subject matter expert for analytical development. His strong analytical expertise enabled a thorough review of the observed results and provided valuable insights into potential method improvements. His critical understanding of method development, validation, and data interpretation will continue to be a significant asset to PSCI going forward.

Yoginder Bhatia
Centrient Pharmaceuticals



As Senior Manager for Water Management, Yoginder brought significant on the ground expertise regarding facility level systems and wastewater operations. His input helped shape practical recommendations and a realistic understanding of sampling and treatment dynamics.

Malcolm Doak
Novartis Pharmaceuticals



Malcolm played a valuable role in the project's technical development and the review of key analytical components. His engagement supported refinement of methodology and interpretation.

Gemma Janer Gual
Novartis Pharmaceuticals



As environmental risk assessor involved in the PiE program, Gemma contributed thoughtful technical insight and participated actively in project discussions, particularly during project planning phases, helping to ensure balanced representation across member companies and sectors.

Project Subject Matter Experts (SMEs)



Manjit Singh
Sustainability Edge Consulting

A long standing supporter of the PSCI since its formation, Dr. Singh brought deep expertise in sustainability, AMR, and pharmaceutical supply chains. Recently retired from Centrient, former PSCI Chair and now Founder of Sustainability Edge Consulting, he played a key role in the final stage of this project, visiting both laboratories in Chennai and preparing a detailed independent report. His long institutional memory and technical breadth were invaluable contributions.



Peter Paul Raj
Pfizer

LOCAL SME

Peter Paul (Raju), Manager of CMC Statistics at Pfizer, was instrumental as an on the ground SME in Chennai. His visits to the testing laboratories and detailed observations provided critical context for data interpretation and shaped several of the findings presented in this report.



Dr. Rominder Suri
Temple University

Dr. Suri, Director of the Water & Environmental Technology (WET) Center at Temple University, served as the primary SME for data analysis. His expertise in water technology and environmental analytics strengthened the methodological rigor of the project. We especially appreciate his willingness to join calls from the U.S. timezone and his thoughtful interpretation of complex analytical outputs.



Maheshwaran Shanmugham
Pfizer

LOCAL SME

Mahesh, a Senior Manager at Pfizer, also served as an on the ground SME in Chennai. His close engagement with both laboratories, and the practical feedback he provided from site visits, enabled a deeper and more accurate understanding of analytical performance.



Debbie Heuckeroth
Kenvue

Debbie, Global Senior Principal Environmental Management at Kenvue, supported the project through her involvement in the PSCI PiE/AMR Team. Her detailed, constructive review of this report significantly enhanced its clarity, accuracy, and completeness. We are grateful for the time and care she invested.

Simon Hodgson
SLR Consulting



SECRETARIAT

We also acknowledge Simon Hodgson for his thoughtful guidance as lead secretariat and for providing a steady senior voice throughout the project. His support and leadership were instrumental in helping to steer the work and maintain alignment across partners.

Beth Quinn
SLR Consulting



SECRETARIAT

We also acknowledge Beth Quinn for her leadership as project manager. Beth served as the main point of initial contact for all participating laboratories and brought together the two subject matter expert reports on data analysis and lab visits to produce this report. Her coordination and guidance have been central to the progress and completion of this work.

Recognition for previous project team members

Acknowledgement is extended to Aditya Shirodkar (Abbott) and Nikhil Khotre (Novartis) for facilitating screening site visits that helped identify suitable laboratories for this project.

Recognition for sites who contributed the samples for analysis

- Pfizer Goa site team led by site EHS Leader Anush Naik.
- Centrient Toansa site team led by Yoginder Bhatia, with additional recognition to Parveen Kumar *(recognized for contributions during the earlier stages of this project phase; now no longer with Centrient)* and Sudhir Singh Sanwal *(provided key technical insights and reviewed the data generated from the lab experiments)*.
- Boehringer Ingelheim site team with thanks to the local EHS/operations colleagues who supported sampling coordination.
- Novartis Slovenia and Ljubljana site. Site work led by David Holobar, with Viknesh V as PM.

Additional Recognition

In addition to those listed above, we extend our thanks to the broader PSCI membership, the PiE/AMR Topic Team, and the participating laboratories for their collaboration, responsiveness, and commitment to advancing improved wastewater analytical capabilities across the supply chain. We also acknowledge Alejandro Fiocco for his valuable support in connecting PSCI experts with members of the PEG working group, helping to strengthen collaboration and technical input across the project.



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