CEMS & CEQMS AUDIT METHODOLOGY

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AGENDA

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02 Why CEMS Audit ??

03 Types of Assessments under Audit

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Background of CEMS

What is CEMS

The continuous emission monitoring system (CEMS) comprises of all the equipment necessary to determine the concentration of gaseous emission and/or particulate matter concentration or emission rate using pollutant analyser measurements and a conversion equation, graph or computer program to produce results in units of the applicable emission limits or standards.

Installation of Continuous Emission Monitoring System (CEMS) for real time pollution monitoring of stack emissions and Continuous Effluent Quality Monitoring System (CEQMS) for effluent quality monitoring were mandated by Central Pollution Control Board (CPCB).

To be installed in 17 categories of highly polluting industries, Sewage Treatment Plants (STPs), Common Bio Medical Waste and Common Hazardous Waste Incinerators and Common Effluent Treatment Plants (CETP) in India.

Background of CEMS

In August 2018, CPCB also mandated installation of CEMS for industries which are using boilers.

CEMS are tools for monitoring the characteristics of flue gas such as:

- *Concentration of particulate matters (PM)*
- *Gaseous pollutants (nitrogen oxides (NO_X), sulphur dioxides (SO_X), oxygen (O_2), carbon monoxide (CO), hydrogen chloride (HCl), hydrogen fluoride (HF), ammonia (NH_3), mercury (Hg) etc.)*
- *temperature (T), moisture (H_2O), pressure and gas flow etc.*

CEQMS is used to monitor the quality of water or wastewater parameters such as:

- *pH, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Dissolved Solid (TDS), Total Suspended Solids (TSS), Dissolved Oxygen (DO) etc. and flow etc.*

The purpose of mandating the real time monitoring is to strengthen the monitoring and compliance mechanism and shift towards self-regulation.

Purpose of CEMS

- *Not just a regulatory requirement, it is actually a proven tool to ensure optimised process, adequate pollution monitoring & control and compliance.*
- *Pioneering countries- the US, Europe have experienced the benefit and many countries are following.*
- *Future, demands for accurate, less manpower intensive and quicker solutions, going to be era of real time monitoring.*
- *A win-win situation for all- Government, industry and public at large. Good for India.*

Purpose of CEMS

Industry gets-

- ✓ *opportunity to adopt self- monitoring,*
- ✓ *better compliance,*
- ✓ *better operational optimization,*
- ✓ *better/optimized pollution control with less human intervention,*
- ✓ *less unwanted regulatory interference.*

Government gets-

- ✓ *better compliance check,*
- ✓ *better regulatory vigil with available limited resources,*
- ✓ *better quality and abundant data for policy level assessment,*
- ✓ *action plans and improvements.*

India gets-

- ✓ *better implementation of international commitments towards environment,*
- ✓ *better international recognition and support for sustainable development,*
- ✓ *effective environmental conservation and public health plans.*

Benefits of CEMS

- ✓ ***Compliance with legislation***
- ✓ ***Enables industries and regulators to obtain real-time emission data to take preventive and corrective measures on time.***
- ✓ ***Important tool to strengthen environment compliance enforcement systems.***
- ✓ ***Provide continuous measurement of data for long periods of time, at the monitoring site of interest, without skilled staff being required to perform the analysis.***

Why CEMS Audit ???

The main objective of auditing CEMS :

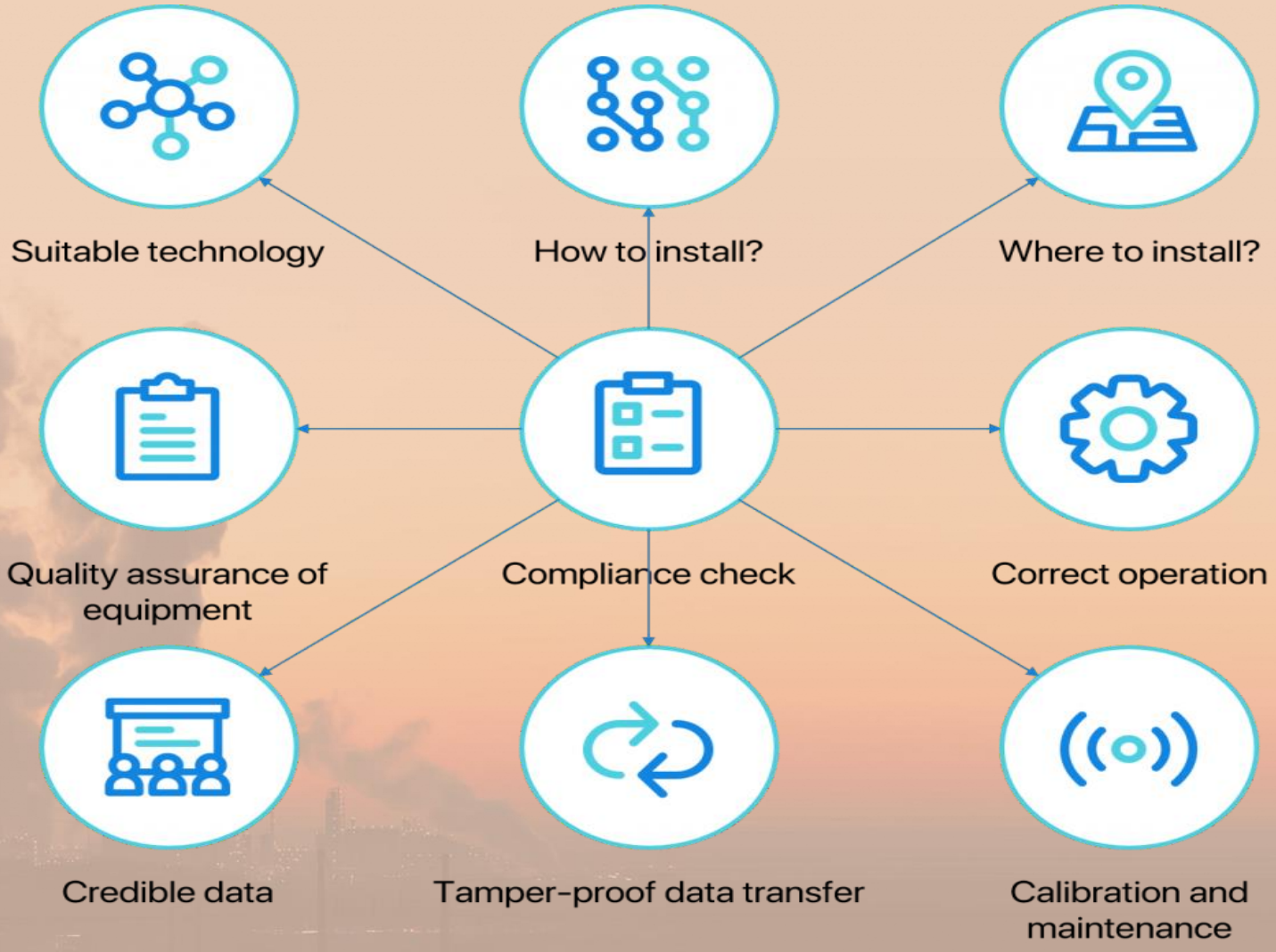
- ✓ *To ensure that correct implementation of CEMS being done*
- ✓ *That the stated standards and other regulatory requirements are being followed*
- ✓ *The industry is complying w.r.t. to its permit conditions*
- ✓ *To ensure that the data is representative of actual emissions*

The audit methodology should be such that it should provide guidance to inspecting officials:

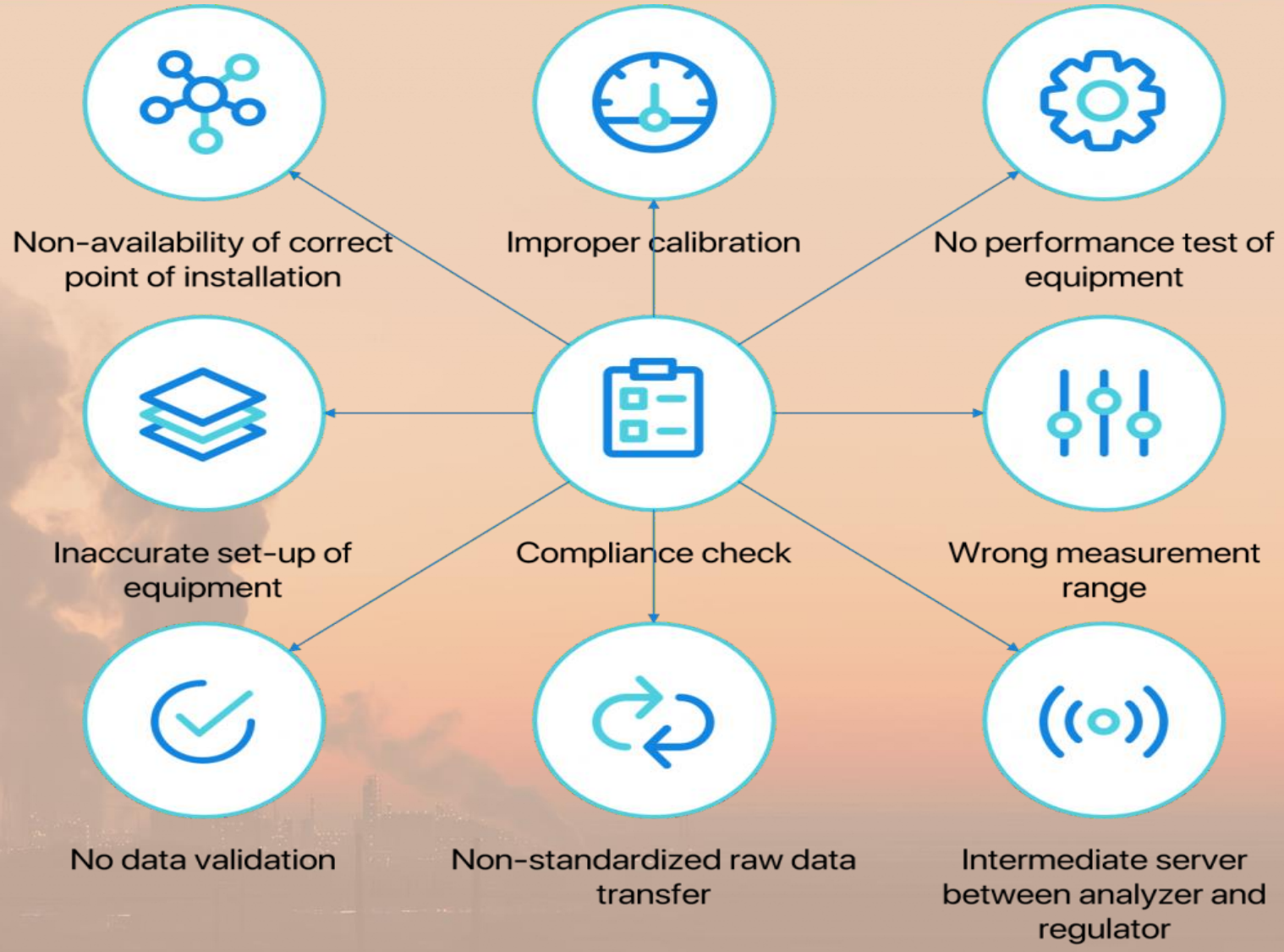
- ✓ *In carrying out proper inspection of CEMS*
- ✓ *To verify whether suitable technology is selected*
- ✓ *To inspect the calibration of the system*
- ✓ *To check the performance of the O & M of CEMS*
- ✓ *Assessing the gaps in the implementation of CEMS*

The audit report should also suggest adequate corrective measures to rectify the identified issues with CEMS installation.

Why CEMS Audit ???



Why CEMS Audit ???



Why CEMS Audit ???

Expert audit/assessment OR inhouse audit/assessment

- To assess the status of implementation
- To identify the issues in installation
- To understand the issues related to operation and maintenance
- To understand the data acquisition, processing and quality
- Assessment to drive towards corrective measures
- Action plan for future
- Training of employees

Parameters to be monitored

CEMS and CEQMS are required to be installed for a few selected parameters wherein proven technology is available.

Category	Effluent Parameters	Emission Parameters
Aluminum	pH, BOD, COD, TSS, Flow	PM, Fluoride
Cement	-	PM, NOx, SO2
Distillery	pH, BOD, COD, TSS, Flow	PM
Dye and dye	pH, BOD, COD, TSS, Cr, Flow	-
Chlor Alkali	pH, TSS, Flow	Cl2,HCl
Fertilizers	pH, flow, Ammoniacal Nitrogen, F	PM, Fluoride, NH3
Iron & steel	pH, Phenol, cyanide, flow	PM, SO2
Oil refinery	pH, BOD, COD, TSS, flow	PM, CO, NOx, SO2

Parameters to be monitored

Category	*Effluent Parameters*	*Emission Parameters*
Petrochemical	*pH, BOD, COD, TSS, flow*	*PM, CO, NOx, SO2,*
Pesticides	*pH, BOD, COD, TSS, Cr, As , flow*	-
Pharmaceutical	*pH, BOD, COD, TSS, Cr, As, flow*	-
Power Plants	*pH, TSS, Temperature*	*PM,NOx,SO2*
Pulp & paper	*pH, BOD, COD, TSS ,AOx, flow*	-
Sugar	*pH, BOD, COD, TSS, flow*	-
Tannery	*pH, BOD, COD, TSS, Cr, flow*	-
Zinc	*pH, TSS, flow*	*PM, SO2*
Copper	*pH, TSS, flow*	*PM, SO2*
Textile GPI	*pH, COD, TSS, flow*	-
Dairy (GPI)	*pH, BOD, COD, TSS, flow*	-
Slaughter house	*pH, BOD, COD, TSS, flow*	-

Types of Assessments under Audit

❖ ***According to emissions to be monitored***

A. For Continuous Emissions Monitoring System (CEMS) – flue gas emissions

B. For Continuous Emissions Monitoring System (CEMS) – gaseous emissions

C. For Continuous Effluent Quality Monitoring System (CEQMS) – wastewater emissions

❖ ***According to attributes***

✓ *Assessment of Monitoring Technologies*

✓ *Assessment of Location*

✓ *Assessment O & M and Calibration Practices etc.*

Assessment of Monitoring Technologies

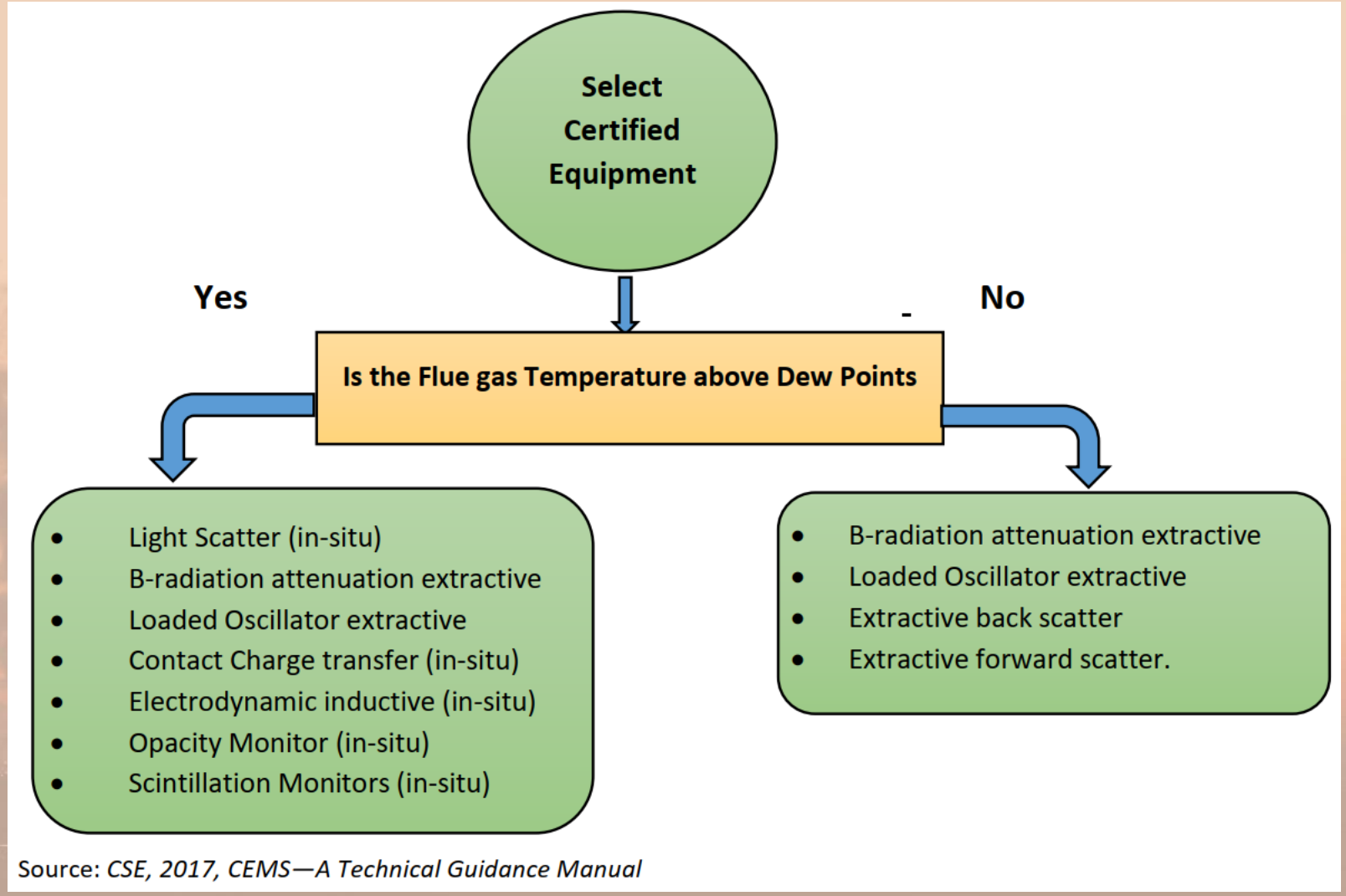
Selection of suitable and quality assured technology is very important for accurate pollution monitoring. The technology selected for PM CEMS depends upon stack characteristics, process parameters and air pollution control devices (APCDs) installed.

***The key factors for PM CEMS are** :*

- *Characteristics of flue gas-velocity, moisture and dew point.*
- *If flue gas temperature is below dew point, select B-radiation attenuation extractive, oscillator extractive, extractive back scatter and extractive forward scatter CEMS technologies.*
- *Ensure that selected analyser is certified and capable for accurately monitoring the desired range of pollution concentration. Range should be 2.5-3 times of Emission limit value (mentioned in guidelines)*
- *Pollution control equipment- so that APC technology doesn't interfere in the functioning of PM CEMS technology.*
- *Ensure that the moisture content doesn't affect the accuracy of PM monitoring.*
- *Primarily ensure that the probe of the analyser is reaching the middle of the stack diameter for representative sampling.*

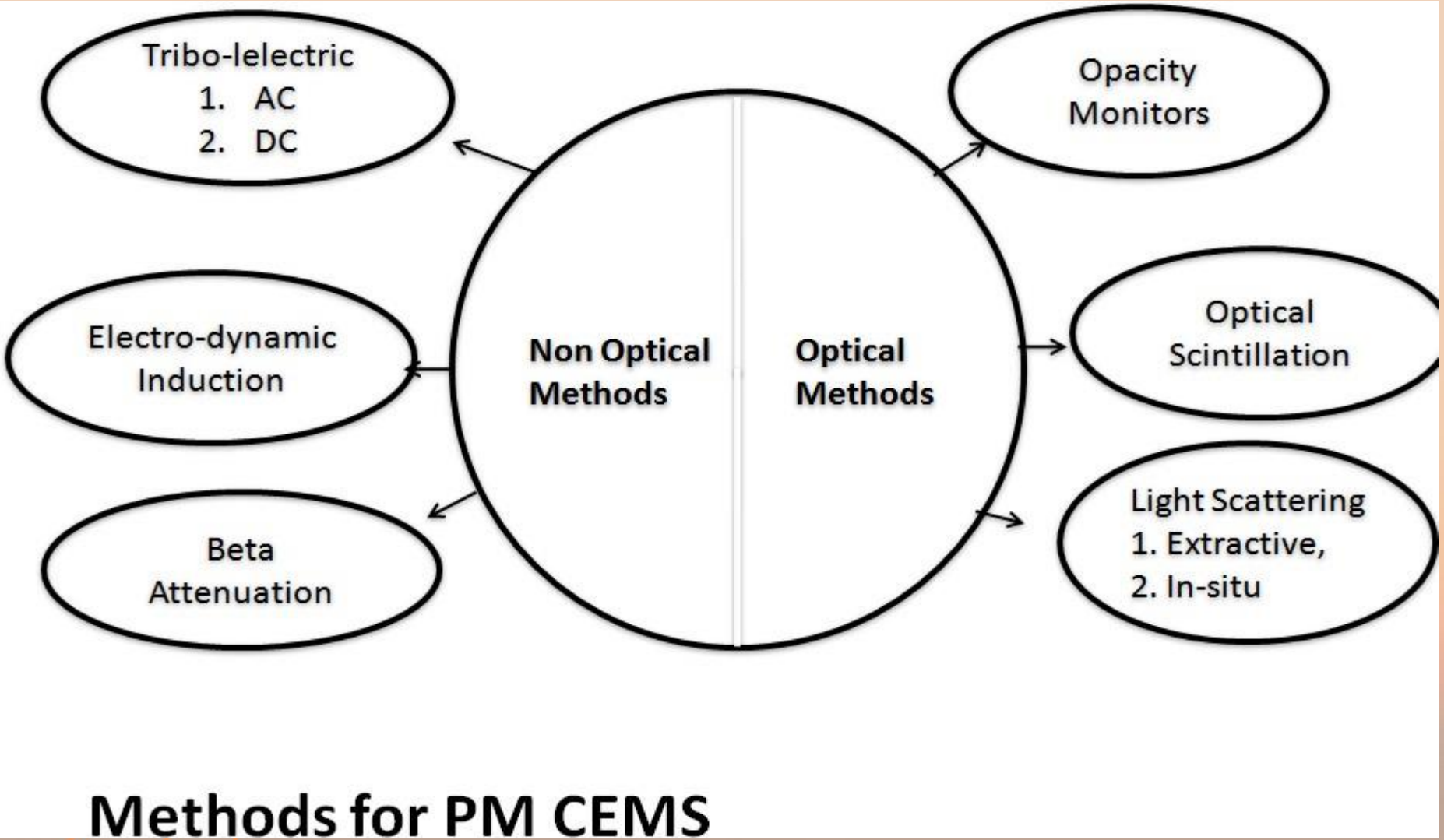
Assessment of Monitoring Technologies

Flow chart for selection of PM CEMS Technology



Source: *CSE, 2017, CEMS—A Technical Guidance Manual*

Assessment of Monitoring Technologies



Methods for PM CEMS

Assessment of Monitoring Technologies

PM CEMS Technology Matrix

Sr. No	Measurement Technology	Principle	Concentration range (mg/m3)	Stack Condition	Stack Dia.(m)	Filter Type	Velocity Dependent
1.	Transmisometery						
i.	Dynamic opacity	Ratio metric opacity	10-1000	Dry Stack	1-15	Bag, Cyclone, ESP, None	No
ii.	Opacity	Opacity	30-1000	Dry Stack	2-10	ESP, None	No
2.	Scattered Light						
i.	Foreword Scatter	Light scattering	0.1-200	Dry/Wet/ Humid	1-3	Bag, Cyclone, ESP, None	No
ii.	Backward/Side Scatter	Light scattering	25-500	Dry	1-4	Bag, Cyclone, ESP, None	No
3.	Probe Electrification						
i.	Electro Dynamic	Charge Induction (AC)	0.05-1000	Dry/Humid	0.2-4	Bag, Cyclone, Drier, None, Scrubber	No
ii.	DC Triboelectric	Contact Charge (DC)	1-1000	Dry	0.2-2	Bag, Cyclone, ESP, None	Yes
iii.	Combination AC / DC Tribo	Combination AC/DC	1-1000	Dry		Bag, Cyclone, None	Yes
4.	Extractive Beta						
	Extractive Beta		0.5-150	Dry / Wet / Humid	0.5-10	Wet collector	N/A
5.	Extractive Light Scatter						
	Extractive Light Scatter		0.1-100	Dry / Wet / Humid	0.5-10	Wet collector	N/A

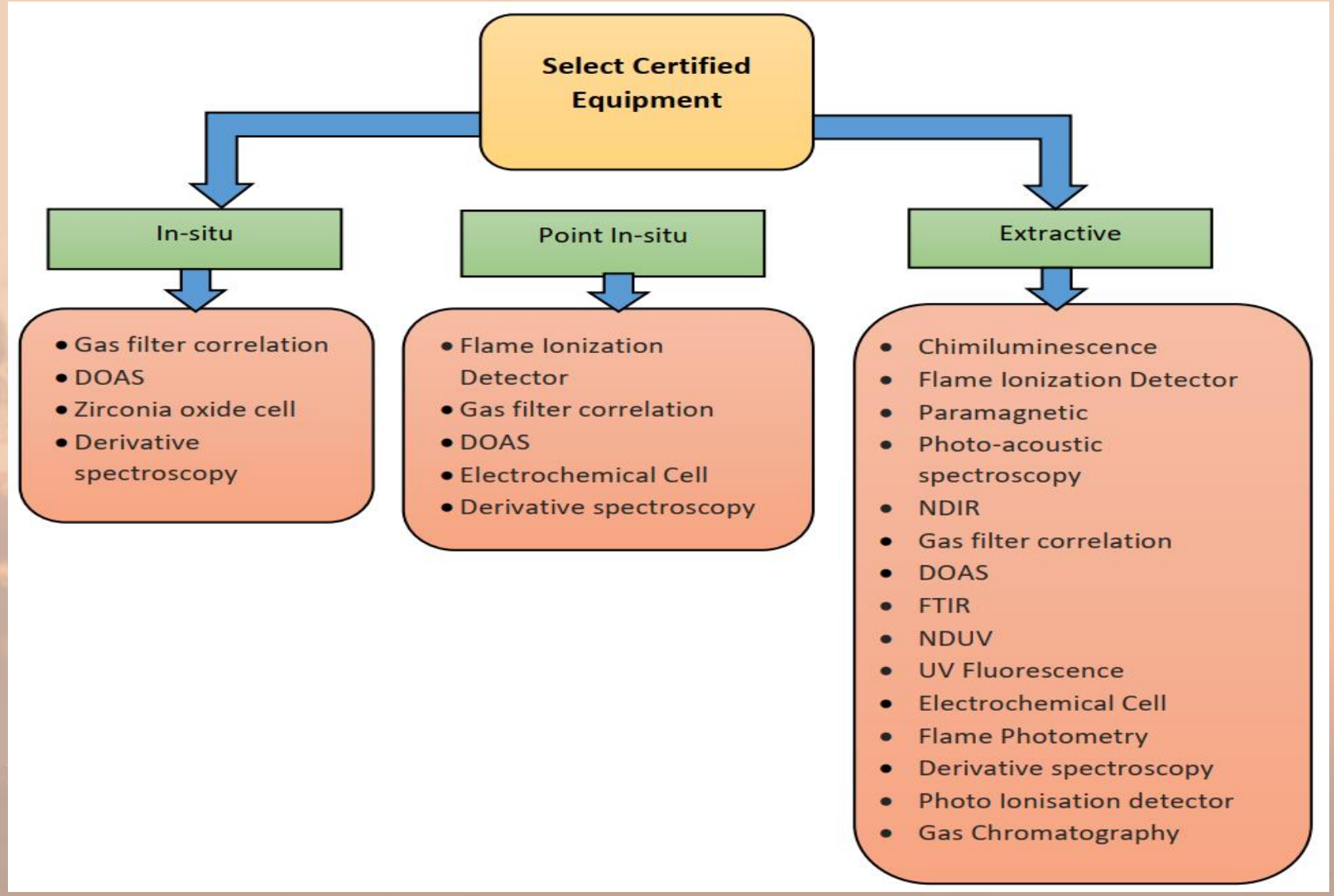
Assessment of Monitoring Technologies

The key factors for Gaseous CEMS are *:*

- *Certification and monitoring range of the analysers.*
- *Characteristics of flue gas-temperature, moisture and dew point.*
- *Presence of corrosive components in the gas.*
- *Dust content in flue gas.*

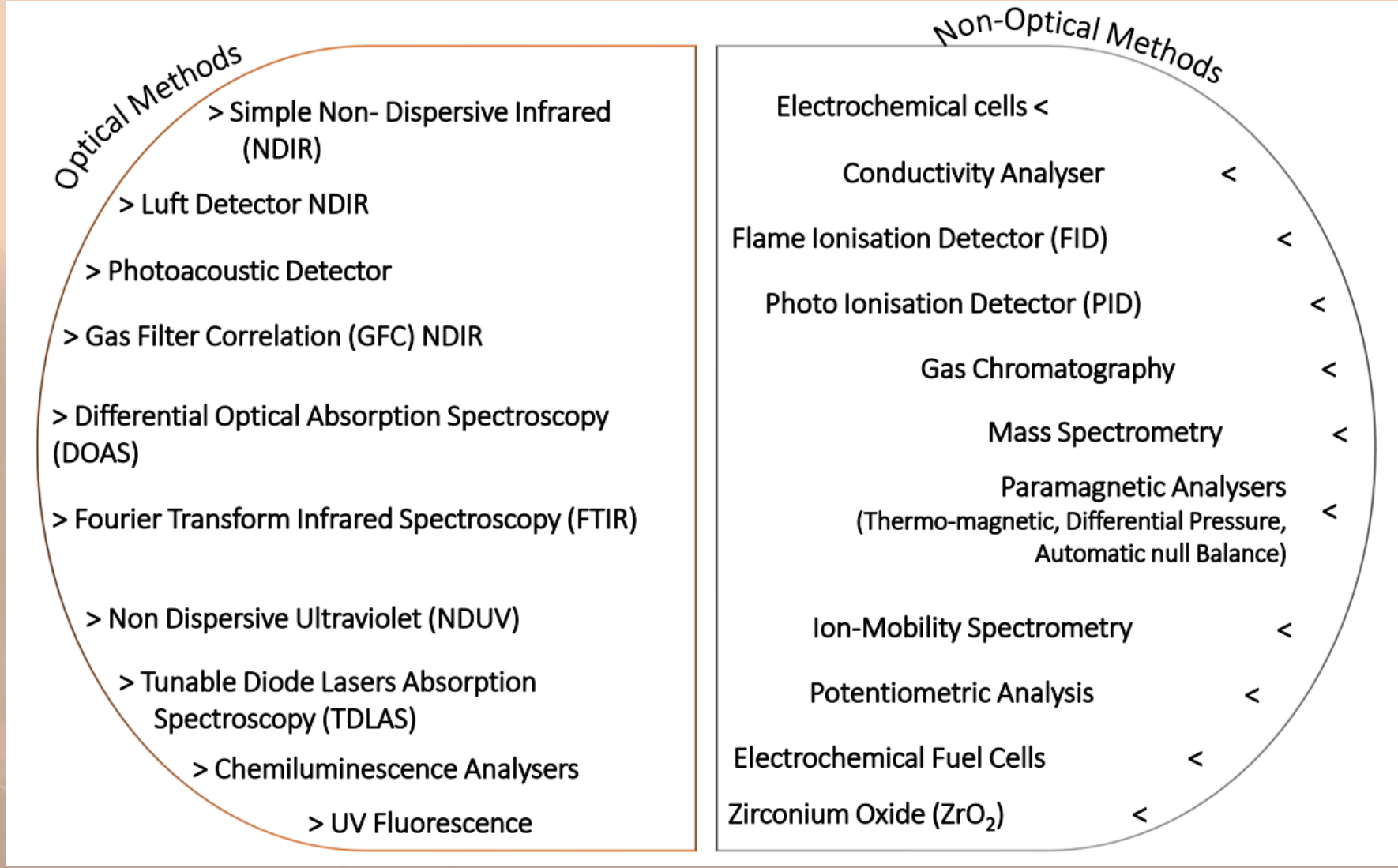
Assessment of Monitoring Technologies

Flow chart for selection of Gaseous CEMS Technology



Assessment of Monitoring Technologies

Methods for Gaseous CEMS



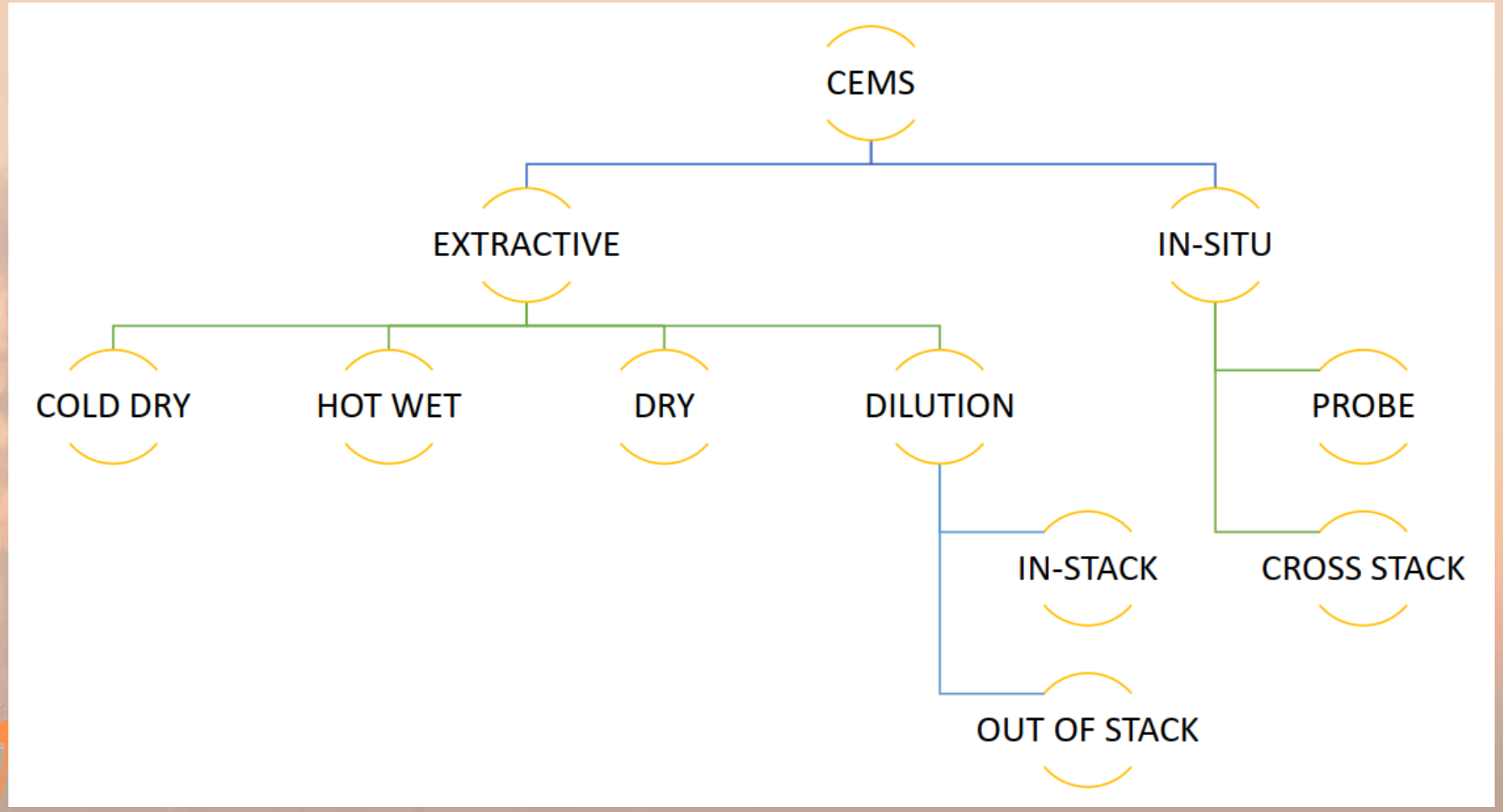
Assessment of Monitoring Technologies

Gaseous CEMS Technology Matrix

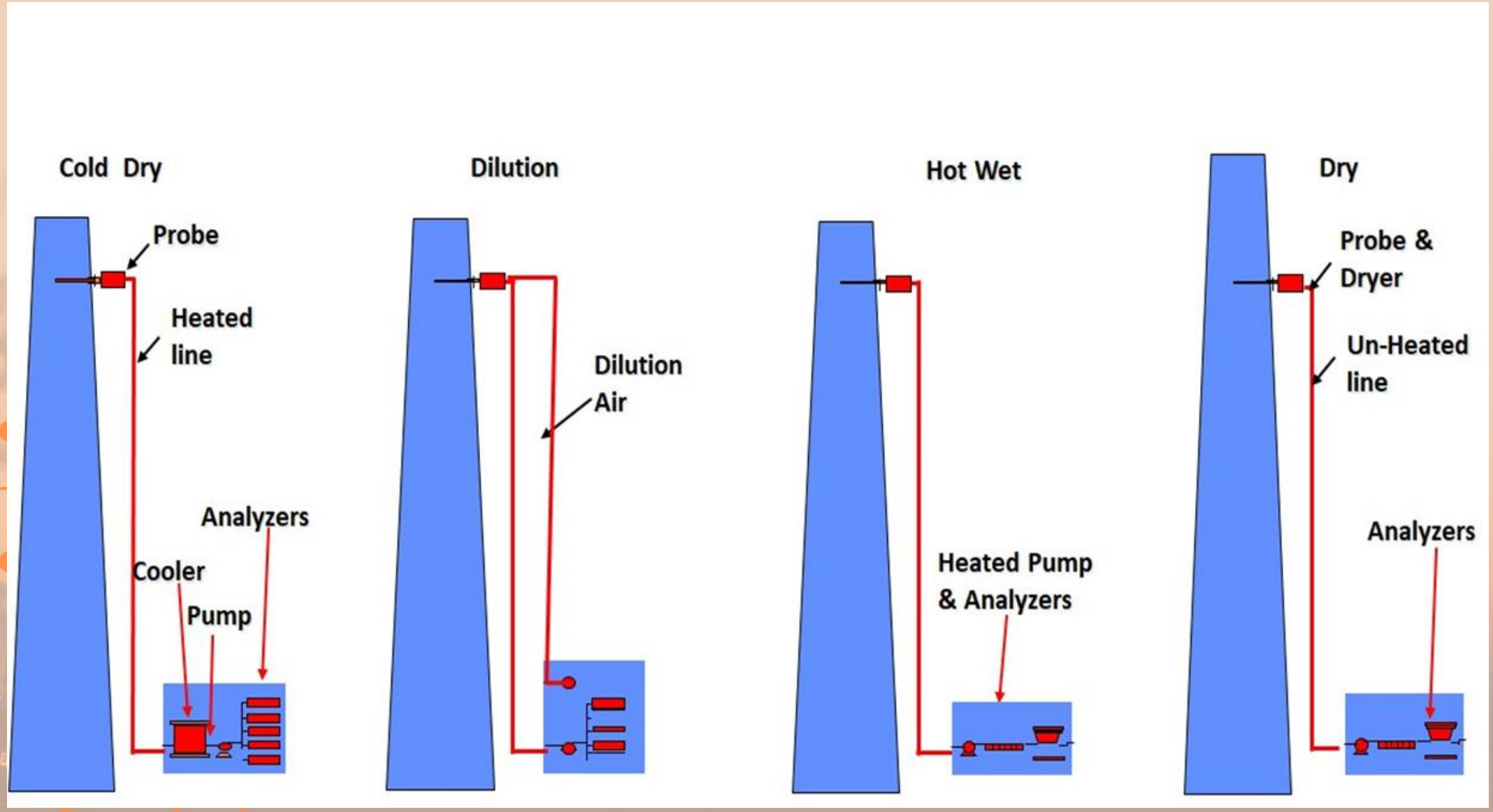
Technique	Type	Parameters	Comments & Limitations
Chemiluminescence	Dilution extractive	NO, NOx, NO2	NO2 estimated as calculated (NOx-NO)
UV Fluorescence	Dilution extractive	SO2, H2S*, TRS* (Total reduced sulphur)	H2S and TRS cannot be measured simultaneously. Advantageous in industries where heating probe, transfer lines are avoided.
NDIR/ IR gas filter correlation (IR GFC)	In-situ & Extractive	CO, CO2, SO2, NOx, CH4, HCl, H20	Measure NO and not NO2. NO2 monitoring possible when convertor is used. Suitable-High level of Concentration.
NDUV	In-situ & Extractive	SO2, NO, NH3, NO2, Cl2, CS2 etc.	NH3-Hot wet extractive and dilution systems are suitable.
Fourier Transform Infra-red (FTIR)	Extractive	CO, CO2, SO2, NO, NO2, N2O, NH3, HF, HCl , CH4, VOC, H2O	Multi-parameter (5-12 gases) monitoring technique.
DOAS (Differential optical absorption spectroscopy)	Path	NO, N2O, NH3, SO2, HG with DOAS-UV. CO, CO2, HCl, CH4, H2O-DOAS IR.	Suitable-Low and high level of Concentration. If moisture above 40%, instrument gets effected.
Flame Ionization Detector (FID)	Extractive	Total HC (VOC), TOC, VOC	Requires H2 gas for flame and carrier gas.
Tunable Diode Laser	Path	CO, CO2, NH3, Moisture (H2O), HCL, HF,CH 4, O2 & H2S	Measurement of H2O for moisture correction is necessary.
Electrochemical	Extractive	O2,CO/CO2	Not accepted for online stack emission monitoring in industries.
Zirconia oxide cell	In-situ	O2	Widely used for boiler/stack -O2 correction.
Paramagnetic	Extractive	O2	Stable & accurate.
Photo-acoustic spectroscopy (PAS)	Extractive	CO,CO2,SO2,HCl,HF,NO,NO2, NH3,VOCs,H2 O	Can measure virtually any gas that absorb IR.

Assessment of Monitoring Technology

Sampling Architecture



CEMS Types


Cold Dry
Probe
Heated line
Analyzers
Cooler
Pump
Dilution
Dilution Air
Hot Wet
Heated Pump & Analyzers
Dry
Probe & Dryer
Un-Heated line
Analyzers

Assessment of Monitoring Technologies

The key factors for CEQMS are *:*

- *Parameters wise installed CEQMS technology as per the requirements-*
  - *pH, BOD, COD, TSS,*
  - *Any other sector specific parameters required to monitor*
  - *Temperature monitor*
  - *Flow meter*
  - *Video camera (Internet Protocol camera with Pan, Tilt, Zoom, 5x or above focal length, with night vision capability)*

- *As per CPCB guidelines, is the technology suitable for respective effluent quality?*

  It is very important that the sensors are properly installed and properly operated and maintained. Otherwise, it can give incorrect results. The auditor, during his/her visit should validate the sensor installation location to ensure representative sample.

Assessment of Monitoring Technologies

CEQMS Technology Matrix

Available technologies	Parameters measured	Applications
UV spectrophotometry (single/two/four wavelengths)	COD, BOD	Fresh water & waste water analysis with constant matrix in water source.
UV-Vis spectrophotometry 40 wavelength	COD, BOD, TSS	Fresh water & waste water analysis with constant matrix in water source.
UV-Visible spectrophotometry (single beam)	COD, BOD, TSS	Fresh water & waste water analysis (Without interference check and compen sation.)
UV-Vis spectrophotometry (double beam with entire spectrum scanning)	COD, BOD, TSS	Fresh water & waste water analysis (Interference check for color and turbidit y and compensation.)
Combine combustion catalytic oxidation at 680Deg C and NDIR Method	TOC (Co-relation with BOD &COD)	Fresh water & waste water analysis.
UV persulfate NDIR Detector	TOC (Co-relation with BOD &COD)	Fresh water & waste water analysis.
Persulfate oxidation at 116- 130degC NDIR detector	TOC (Co-relation with BOD &COD)	Fresh water & waste water analysis.
Measuring COD using Potassium Dichromate (K2Cr2O7) + calorimetric	COD	Fresh water & waste water analysis.
Electrode / electrochemical method	pH	Fresh water & waste water analysis.
Scattered light method (IR)	TSS	Fresh water & waste water analysis
Nephelometry method	NH3	Fresh water & waste water analysis.
Colorimetric	NH3	Process stream & waste water analysis
(645-655nm)		(Turbidity interference is there which can be overcome.)
Ion selective electrode method with temperature correction	NH3	
UV absorbance or multiple wavelength UV absorbance spectrophotometers (200- 4 50nm)	NH3	Process stream & waste water analysis (Turbidity interference is there which can be overcome.)
Colorimetric method reaction of Cr-VI with diphenyl carbazide in acid solution	Chromium	
Voltammetry (Anodic Stripping Voltammetry)	Chromium	Fresh water analysis.
Dual beam UV-Visible Spectrophotometry	Chromium (hexavalent & trivalent)	Fresh water & waste water analysis.
Voltammetry (Anodic Stripping Voltammetry)	Arsenic	Fresh water analysis.

Assessment of Monitoring Technologies

Assessment of Location

Location of CEMS installation

- ✓ *Correct installation of CEMS and CEQMS is very important to obtain reliable and representative pollution monitoring.*
- ✓ *It requires choosing suitable measurement sections, suitable measurement sites, and correct mounting locations in flues gas stack or ducts and also keeping in mind that the ease of accessibility for regular maintenance and other necessary activities.*
- ✓ *These are the important observation which must be considered during CEMS audit.*

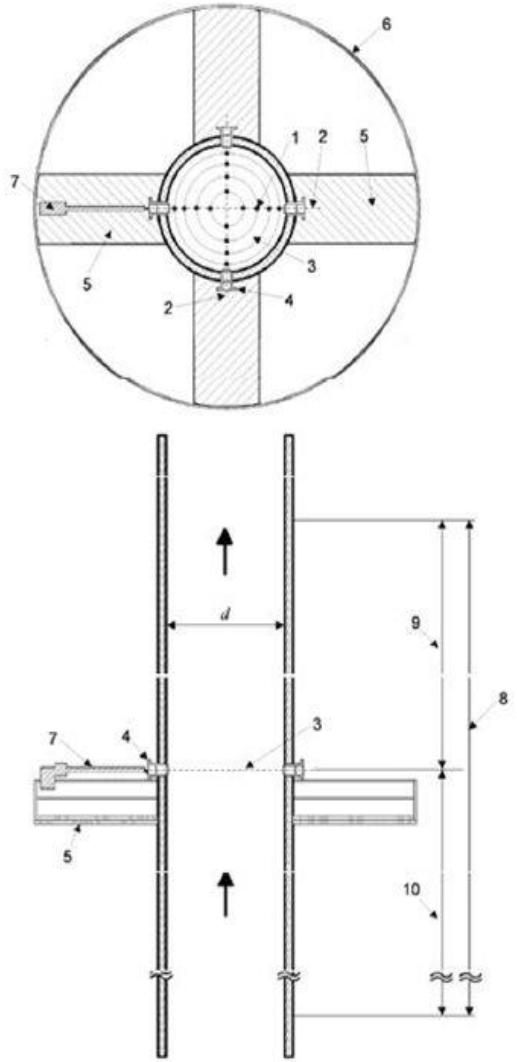
Assessment of Location

Sampling location for the analyser must be in accordance with Guidelines such as:

- ✓ *Laminar Flow: To ensure laminar flow, the PM monitoring systems shall be installed at a distance of at least eight times the stack diameter downstream and two times stack diameter upstream from any flow disturbance. In rare cases, the PM analyser can be installed at a distance at much as four times the stack diameter downstream from the flow disturbance, however correction for stratification shall be made.*
- ✓ *Tapping point for taking test samples or third party access should be from the top most point in the stack. (Above all existing tapping points for PM, CEMS, Flow/Temperature measurements in the stack).*
- ✓ *PM-CEMS device should be installed at least 500 mm below the manual port hole.*

Assessment of Location

Measurement site



Key

1	Measurement point
2	Measurement line
3	Measurement plane
4	Measurement port
5	Clearance area
6	Measurement site
7	Manual sampling train
8	Measurement section
9	Outlet section
10	Inlet section

Symbols

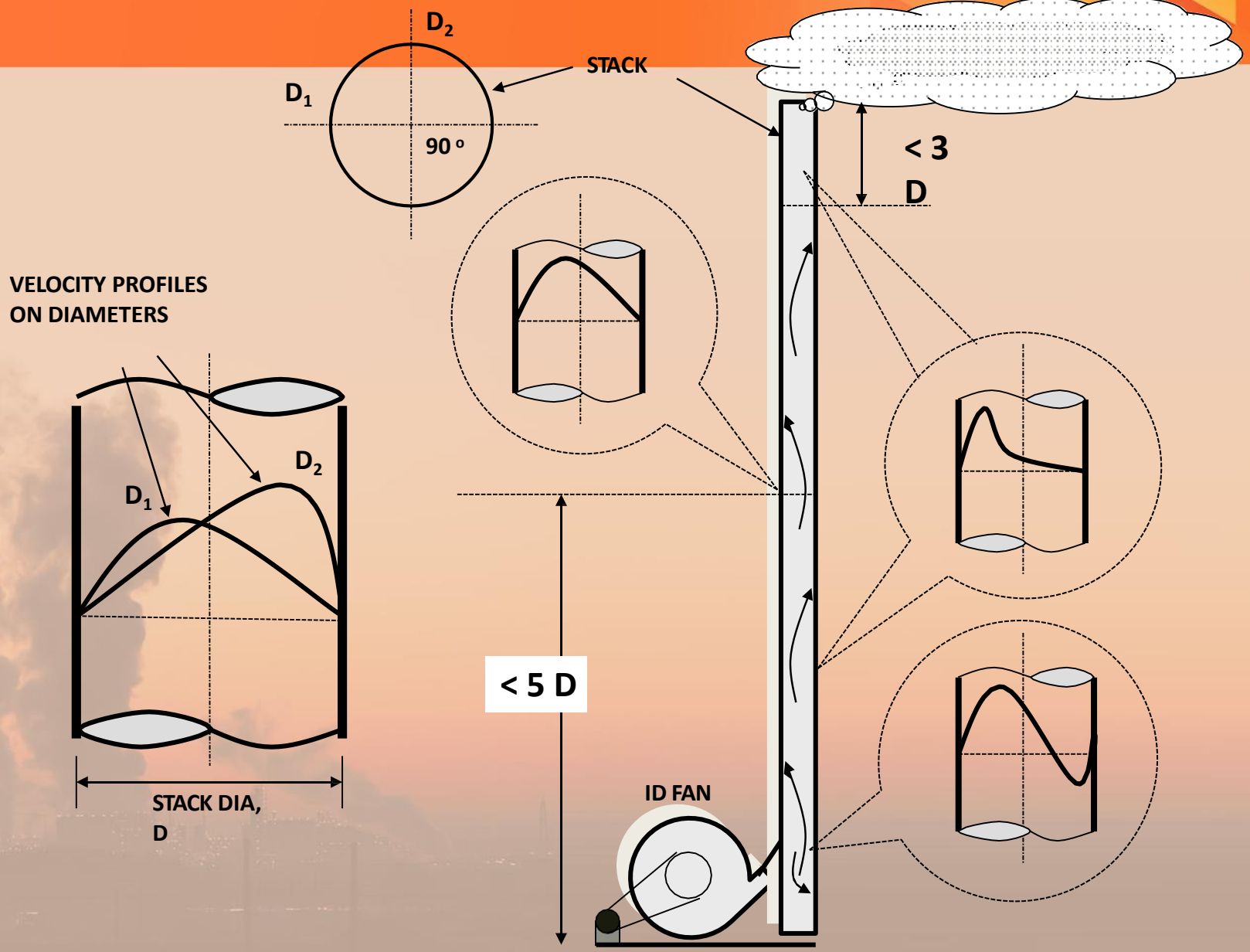
d	Internal duct diameter

Note: The figure is not to scale. In the India context, it should be considered 8D diameter downstream and 2D diameter upstream.

Source: STA

Assessment of Location

Stabilized Flow – Why 8D/2D or 4D/4D or 5D/5D



Assessment of Location

Infrastructure and Mounting

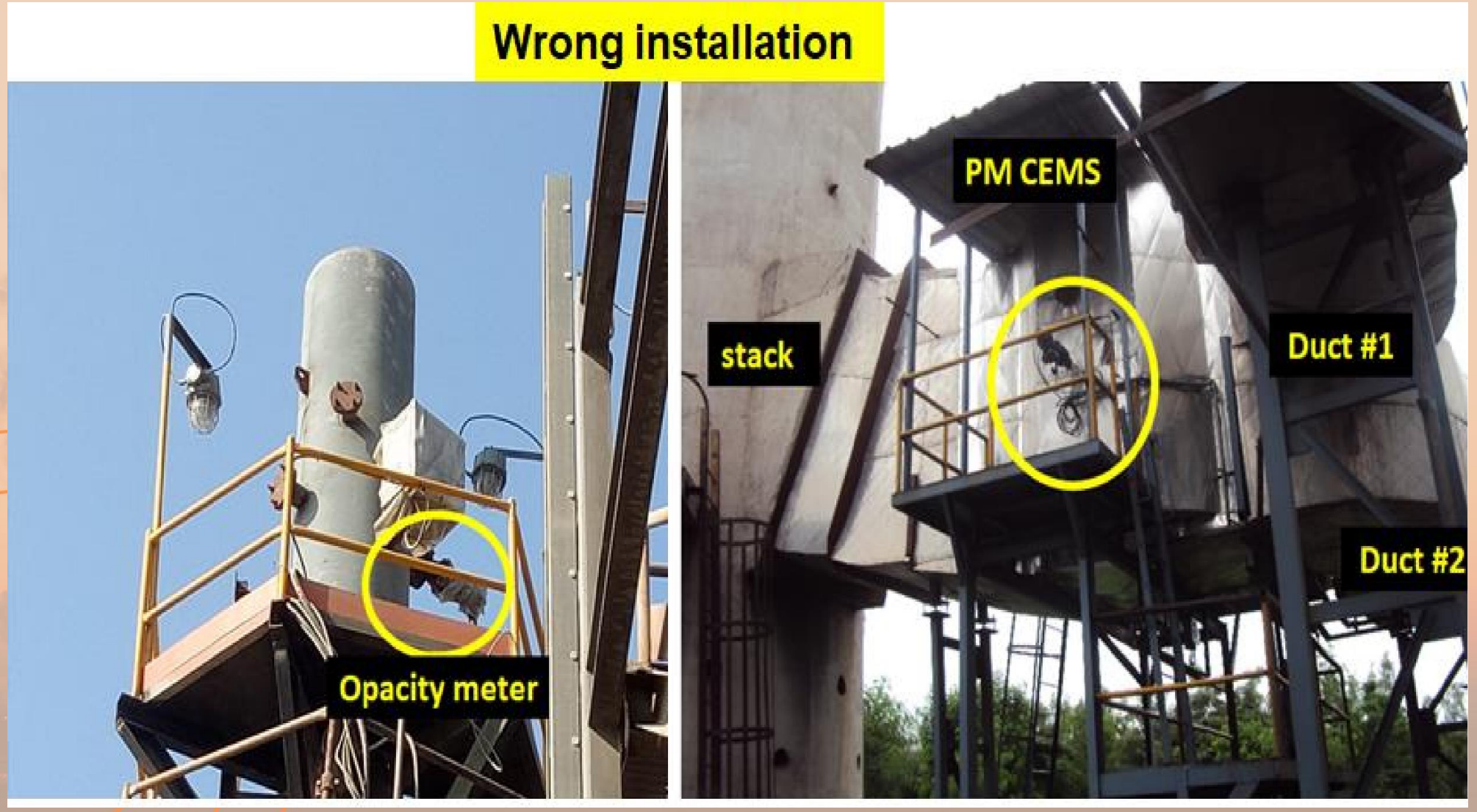
- *All the measurement ports in the stack/duct should have been made available as per CEMS requirements and are confirming the regulatory requirement.*
- *Ensure the availability of permanent, strong & reliable platforms at CEMs analyser mounting location with safe approach ladders or stair case (spiral) or elevator.*
- *Vertical ladders if provided, should have back guard, stair case if provided, should be with proper hand rail, and steps should be evenly distributed with adequate height, length & width. (Monkey ladder is not preferred in case the height of platform is more than 30 meter from the ground).*
- *Device should be installed such that it is accessible for regular maintenance.*
- *The stack platform width for metallic stacks should be 800mm minimum & for concrete stack platform, the width should be minimum of 1000 mm. All platforms should have hand rails.*

Assessment of Location

Safety

- *If the approach to the platform is via vertical ladder, then at every 10 - 12 meters landing platform should be provided. The entire length of the ladder must have protective back guard/cage.*
- *Ladder must continue through platform approach to some distance above such that landing on platform is easy.*
- *Ladder must be well maintained with all fasteners rigidly fixed in the stack wall.*
- *The completed ladder network and stack has to be regularly inspected for corrosion and must be painted periodically.*
- *Platform railing must be rigid and should at least reach 1.2 m in height from platform surface.*
- *If analyser mounting location is above 45 meter elevation then for the ease of maintenance and personnel safety, proper stair case or lift/elevator should be provided.*

Assessment of Location



Assessment of Location

Assessment O & M and Calibration Practice

Calibration is very important for any measuring equipment not only for CEMS. It ensures that equipment is working as per prescribed standards in order to produce correct and reliable data.

Particulate Matter CEMS (PM CEMS)

For PM CEMS calibration, the manual gravimetric sampling is the standard method.

- *The (PM-CEMS) should ideally be calibrated at three operational loads against isokinetic sampling method (triplicate samples at each load) with nine samples in three loads at the time of installation and thereafter, every twelve months of its operation, or after any change in solid fuels.*
- *The results from the particulate matter monitoring system should be compared on a monthly basis on a fixed day e.g. last Friday of the month, at fixed time (replicate sample) with standard isokinetic sampling method.*

Assessment O & M and Calibration Practice

Particulate Matter CEMS (PM CEMS) (Contd.)

- *In case deviation of the comparison values (dust factor) for 02 (two) consecutive monitoring is more than 10%, the system should be recalibrated against isokinetic sampling method (triplicate samples), if possible at three variable loads.*
- *The intensity of lamp should be checked once every fortnight.*
- *The data capture rate of more than 85% should be ensured.*
- *After any major repair to the system, change of lamp, readjustment of the alignment, change in fuel quality, and the system should be recalibrated against isokinetic sampling method (triplicate samples at each load).*
- *Adjustment of Calibrated Dust Factor (CDF) allowed only after full-scale calibration of PM CEMS. Change of CDF is permitted only after approval by the regulator.*

Assessment O & M and Calibration Practice

For Gaseous CEMS

The CEMS for gaseous emissions should be calibrated wrt their functioning, drift, linearity, detection limit, output, operating temperature and other relevant parameters:

- *Before installation*
- *After six months of operation, the system should be rechecked for its health and data accuracy and reliability—following multi point calibration (at least 03 span concentrations) using standard methods and certified reference materials.*
- *The data comparison and calibration verification should be done once in 06 months by empaneled laboratories.*
- *There are specific limits on allowable drifts, exceeding these levels requires CEMS maintenance to bring it back into control e.g. in case zero drift condition fails continuously for 5 days.*

Assessment O & M and Calibration Practice

For Gaseous CEMS (Contd.)

- *For Differential Optical Absorption Spectroscopy (DOAS), Non Dispersive Ultra Violet (NDUV)/Non Dispersive Infra-Red lamp/laser based systems / FTIR based systems, the calibration should be revalidated once in 06 months, and after replacement of lamp.*
- *The instrument/ analyser should be recalibrated after any major repair/replacement of parts/lamps or readjustment of the alignment using standard methods and certified reference materials.*
- *The instrument/analyser system should have provision of remote calibration, for verification of the system performance by SPCBs/PCCs whenever, felt necessary.*
- *The intensity of the lamp should be checked once every fortnight.*

Assessment O & M and Calibration Practice

For Gaseous CEMS (Contd.)

- *Data capture rate of more than 85% should be ensured.*
- *Using Ambient Air for Zero/Span calibration is not acceptable, Zero air, instrument air, Span Gas/Gas filled Cuvette should be used with required certifications.*
- *It is recommended to use two point calibration – One for the Zero and another one for Span. Please note the span gas used should be around 80% of the operating Span.*
- *Zero drift should be carried out every day at fixed timings (e.g. 9:00am), and zero and span should be carried out every week at fixed timings (e.g. every Monday, 9:00 am).*

Assessment O & M and Calibration Practice

For Continuous Effluent Quality Monitoring System (CEQMS)

Following key factors should be considered while auditing CEQMS

- *COD, pH, BOD, TOC, TSS – once every week or as specified by manufacturer whichever is earlier.*
- *Temperature – once every month or as specified by manufacturer whichever is earlier.*
- *After six months of operation, the system shall be rechecked for its health, data accuracy and reliability.*
- *Daily Check – GPS Transmission, System Diagnostic alarms.*
- *System validation should be evaluated using the known standards.*
  - *When the variance is outside of the set points, this can be an indication the monitor requires calibration & service*
  - *In case of deviation of comparison value (pH, color, COD, BOD, TSS and TOC done fortnightly) exceeds the accuracy (pH ± 0.2% and BOD/COD/TSS ±10%) for 02 consecutive days.*

Assessment O & M and Calibration Practice

Europe has well-established CEMS quality assurance system as per EN-14181 standards. It includes quality assurance levels QAL-1 (certification of measuring system), QAL-2(proper installation, functional testing and calibration) and QAL-3 (quality assurance during operation) and an annual surveillance test (AST). MCERTS in UK and TUV in Germany are the certification agencies for CEMS.

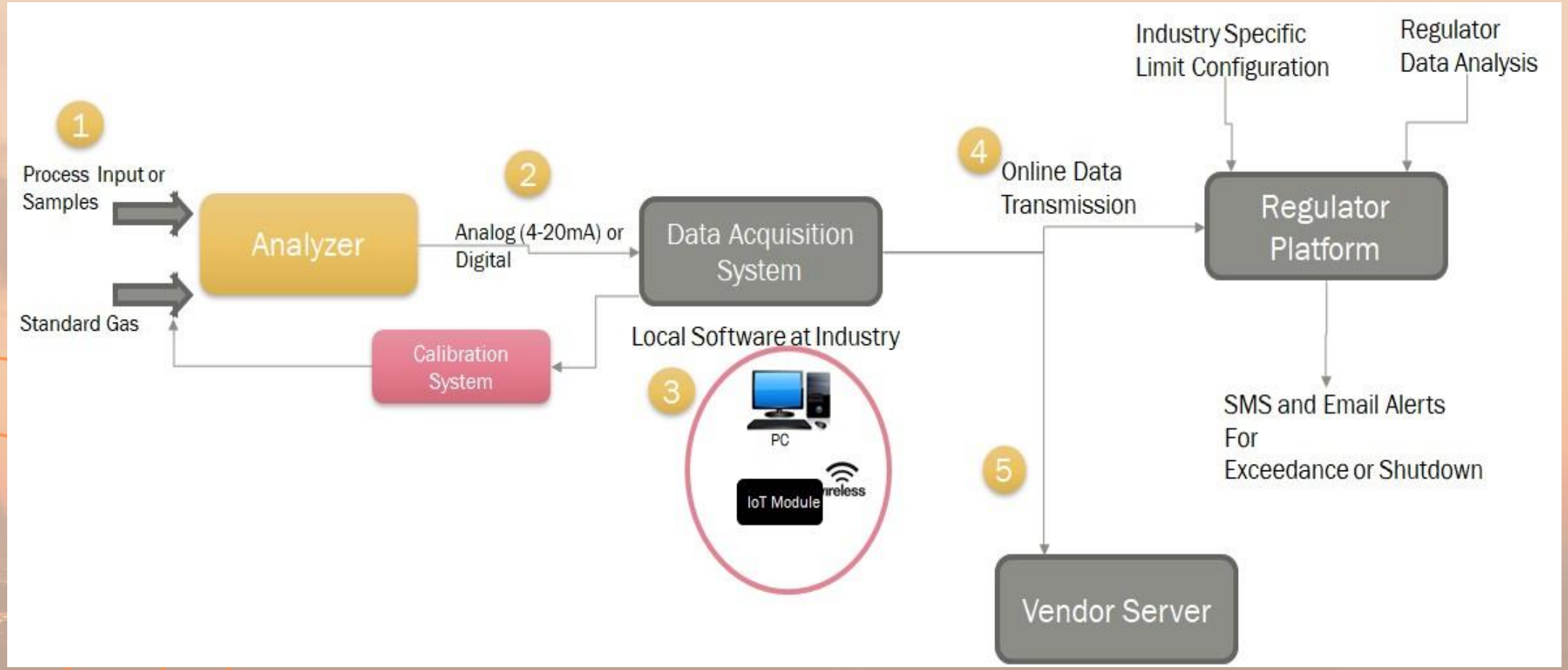
For quality assurance, CPCB recommends use of USEPA, TUV and MCERTS certified and approved analysers.

- ✓ *Certificate of analysers / instruments for CEMS / CEQMS must be checked at time of installation*
- ✓ *Quality control measures needs to be checked periodically in the installed CEMS to ensure stability, calibration and ongoing linearity and drift checks as per the regulations.*
- ✓ *Quality assurance requirement for PM CEMS are Daily zero and upscale drift check and for gaseous CEMS are zero drift (daily) and span drift (weekly).*

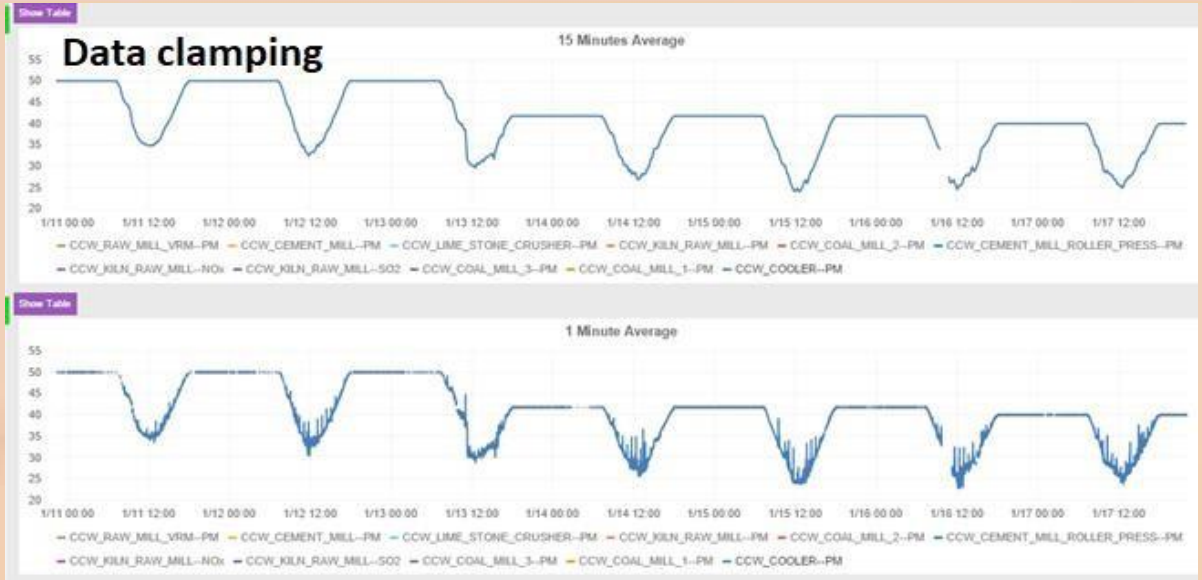
Assessment of Online Reporting System

Important requirement-

- ✓ **Direct data transmission- both to central and state regulator, no chance of manipulation**
- ✓ **Remote calibration for Gaseous CEMS- regulator can trigger remote calibration of gaseous CEMS**



Assessment of Online Reporting System



Data tampering

Basic Requirements for CEMS Audit

The objective or purpose of the Assessment/inspection.

Required to have prior knowledge of CEMS before visiting the facility.

- *About plant- operation, pollution issues and control practices*
- *Regulatory requirement for plant- CEMS requirement, parameters, performance history, manual monitoring data*
- *CEMS installed- CEMS technology, components, working principle, suitability, limitations.*
- *Installation guidelines- Correct installation requirement*
- *Data handling- Data acquisition and transfer system, standardization*
- *Calibration and Maintenance requirements- calibration, zero and span drift and other maintenance*

Overview of CEMS Installations during Audit

To start with some visual observation can cover overview of CEMS installation in the plant	
Need of CEMS installation	• Number of units in plant • Parameters to monitor- unit wise • Number of installation done • Installation incomplete/ to be done • Reason of incomplete installation, plan of action
Stack or duct installation	• Installation carried in stack • Installation carried in duct • Manual monitoring point?- duct or stack? • Reason for installation in duct?
Working/non-working units	• CEMS working in working units? • Is CEMS working and data available in non-working units?
CEMS installation maintenance	• Is CEMS protected from weather conditions? • CEMS in shelter (if extractive) ? • Gas cylinders (if applicable) are available and properly connected? • Remote calibration system available
Data handling	• Analog or direct digital data transfer • Direct data transfer or server/PC in-between • Visual dust emission comparison to PM CEMS data

Location Assessment of CEMS Installations during Audit

PM CEMS installation location must ensure stabilised and un-interrupted flow to get representative sampling.

If installation in stack	• Stack material, height, diameter (at last disturbance point in upstream and downstream) • Height of the point of manual monitoring and CEMS • Does manual and CEMS installation fit in 8D/2D formula? • If fits in 4D/4D formula, during calibration requires 12 samples instead of 9. • If not, whether stratification study carried? • CEMS at-least 500mm below manual monitoring? • Other analysers/monitors should be in proper position, not affecting each other. • PM CEMS installation in Horizontal plane • Gaseous CEMS, protruding downwards facing the direction of flow
If installed in duct	• Standalone duct or combined duct? • If a combined duct (two or more ducts joining)- ➢ Each duct has separate installation ? ➢ Installation is in common duct? • Shape of duct, duct diameter/equivalent diameter • Does installation fit in 8D/2D or 4D/4D? • If not, whether stratification study carried?
Platform and approach	• Is the platform approachable for regular maintenance? • Is the platform safe?- Width, Guardrail, Safe ladder etc. CPCB guideline: "stack monitoring – material and methodology for isokinetic sampling http://www.cpcb.nic.in/newitems/15.pdf

Assessment of PM CEMS Installations during Audit

Right equipment selection- Refer “CEMS guidelines”

- **Technology fits as per the guidelines ?**
  - Suitable with installed pollution control equipment?
  - Suitable with pollution concentration?
  - Measuring range- 2.5-3 times of limit?
  - Suitable with moisture condition?
  - Suitable with diameter of stack (reached to centre of stack)?
  - Suitable with vibration level (if cross duct, specially in duct installation)?
  - O2 monitor installed?
  - Temperature, moisture, pressure monitor installed?
  - Performance specification ±2%, performance accuracy ±10% of reference measurement

- **Quality assured?**
  - Certified under MCERTS, TUV?
  - If not certified, performance test carried during installation?
  - Certificate available?
  - Certificate of calibration or performance check carried during installation available? Required for setting dust factor?

Assessment of Gaseous CEMS Installations during Audit

Right equipment selection- Refer "CEMS guidelines"

- **Technology fits as per the guidelines ?**
  - In-situ or extractive?
  - If extractive what is gas conditioning and transport architecture (Hot-wet, Cold –dry, Hot?
  - Check heated line, termination, functioning?
  - Measuring range- 2.5-3 times of limit?
  - Suitable with moisture condition?
  - O2/CO2 monitor installed?
  - Temperature, moisture, pressure monitor installed?
  - For extractive type- Temperature, gas flow rate measurement?
  - For extractive- Shelter condition?
  - Zero/Span/Linearity specification ±1%, performance accuracy ±10% of reference measurement
  - Gas cylinders (zero, span)- valid calibration certificate, not expired, connected?
  - Gas cylinder concentration 80% of measuring range?

- **Quality assured?**
  - Certified under MCERTS, TUV?
  - If not certified, performance test carried during installation?
  - Certificate available?
  - Certificate of calibration or performance check carried during installation available?

Assessment Calibration & Maintenance during Audit

Calibration

- By NABL/EPA accredited lab?
- Full Calibration carried during installation? How many points/load (number of readings)?
  - PM CEMS- Full calibration is not only comparison on manual and CEMS value. Not only one point?
  - Gaseous CEMS- Includes functioning, drift, linearity, detection limit, output, operating temp etc.
- Calibration certificate (showing the entire process and calculation) available?
- Calibration frequency, post installation?
- Any repair/replacement? If any major repair/lamp replacement, calibration carried or not?
- When was lamp changed last time? If yes, calibration carried?
- When last calibration carried? Record available?
- PM CEMS- Any dust factor change? Reason? Prior permission from regulator?
- Gaseous CEMS- using zero and various span gas concentration cylinder/cuvette?
- O2 consecutive deviation >10%, recalibration

Drift check and Data comparison

- Frequency of drift check?- Zero, Span
- Timing for one cycle of zero and span?
- Post drift any correction done? How much was the drift when correction done?
- Frequency of data comparison from SRM- fortnightly, replicate?
- Any deviation above ±10% ? If so, was it recalibrated?

Assessment of DAHS

- **DAS architecture , compare the real installation on the spots**
  - Direct transmission to CPCB/SPCB?
  - Any PC/server in-between?
  - Any other foreign object/cheating device between analyser and data transmitter (IoT/Data logger)?
- **Data standardization**
  - Unit of output of analyser- ppm or mg/m3? Is same data is sent as mg/Nm3?
  - How data conversion process takes place- from mg/m3 to mg/Nm3 (temperature, moisture, pressure correction)
  - How NOx (NO+ NO2) is monitored?
  - How O2/CO2 correction happens?
- **Data check**
  - Data availability of 85%
  - Any shut down analyser showing data?
  - Calibration, zero/span process, reflects in data records?
  - Unrealistically low data- if PM, compare with visible emission, technology feasibility, fuel quality and APC efficiency.
  - Unrealistically low data- if SO2, compare with S concentration in fuel and APC, if NOx compare with fuel type and combustion technology, APC?
  - Stagnant data/clamped data/scientifically absurd data- review the analyser and range fixed?

Assessment for Standardisation of Data

$$C_{dry}\ [ppm] = C_{wet}\ [ppm] \times \frac{1}{1 - [\%H_2O]/100}$$

Conversion from Wet to Dry

$$C_{dry}\ [mg/m3] = \frac{ppm \times MW}{24.45} = f$$

Conversion from ppm to mg/m3

PV= nRT

P (Pressure) x V (Volume)= n (amount) x R (constant) x T (Temperature)

N= PV/RT

Temperature and Pressure correction

$$C_{dry}\ [mg/Nm^3] \text{ @ Reference O2} = \frac{21\% - 10\%}{21\% - \text{Measured O2}}$$

Oxygen correction

Assessment for Standardisation of Data - Example

Example: SO_2 = 120 [ppm, wet]; Moisture content = 15% wet

$$SO_{2dry}\,[ppm] = 120 \times \frac{1}{1 - [15/100]} = 141\ [ppm/dry]$$

Conversion from Wet to Dry

$$SO2_{dry}\,[mg/m^3] = \frac{141 \times 64.07}{22.4} = 403.3 mg/m3\ dry$$

Conversion from ppm to mg/m3

If Stack Temp. 150°C and Stack Pressure 740mmHg

$$SO2_{dry}\,[mg/Nm^3] = \frac{423 \times 760}{298 \times 740} \times 403.3 = 587.9\ mg/Nm3\ dry$$

Temperature and Pressure correction

If O2 = 8.8%

$$SO2_{dry}\,[mg/Nm^3] \text{ @ Reference } O_2 = \frac{21\% - 10\%}{21\% - 8.8} = 0.902$$

$$SO2_{dry}\,[mg/Nm^3] \text{ @ } 10\%\ O_2 = 0.902 \times 587.9 = 530\ mg/Nm^3{}_{dry} \text{ @ } 10\%\ O_2$$

Oxygen correction

Assessment for Standardisation of Data - Example

Reporting Value should be NOx as NO2

NOx Conversion formula

Total NOx = NO x 1.53 + NO2 (if NO2 is measured)
Total NOx = NO x 1.53 + (NO x 5%) (If only NO is measured)

NOx Conversion - Example

NO =**400ppm[ppm, dry] and NO2 = 20ppm**

$$\text{NO to NO2 [ppm, dry]} = 400 \times \frac{46}{30} = 613\text{ppm, dry}$$

NOx_{dry} [ppm] = 613 + 20 = 633ppm, dry

Conversion from ppm to mg/Nm3

Parameter	Molar Mass M [kg/kmol]	Conversion Factor f
SO2	64.07	2.86
NO as NO2	46.01	2.05
NO2	46.01	2.05
CO	28.01	1.25
HCl	35.40	1.58
HF	20.01	0.89
NH3	17.03	0.76
VOC	12.01 36.03	0.54 1.61

Contents of Checklist for CEMS Audit

- ✓ Check stack height As per Consent (m) / Actual (m)
- ✓ Check distance of CEM installed from the point of disturbance from the downstream (m).
- ✓ Check distance of CEM installed from the point of disturbance from the upstream (m).
- ✓ What is the height of gravimetric sampling port (m)? Does it meet 8D/2D criteria?
- ✓ Is there any stratification study done if it is not meeting 8D / 2D criteria?
- ✓ Is Manual sampling port at-least 500mm above the PM-CEMS port?
- ✓ Is heated sample line having cold spots? Sampling line in analyser shows water droplets?
- ✓ If Cross duct analyser is installed, check if the stack or duct vibration is very high which can affect the reading.
- ✓ Was analyser calibrated during installation?
- ✓ Is it a certified analyser? Is certificate available? Check.
- ✓ Is O2/CO2 correction done for measurement? Calculate.
- ✓ Is Pressure & Temperature correction carried? Calculate

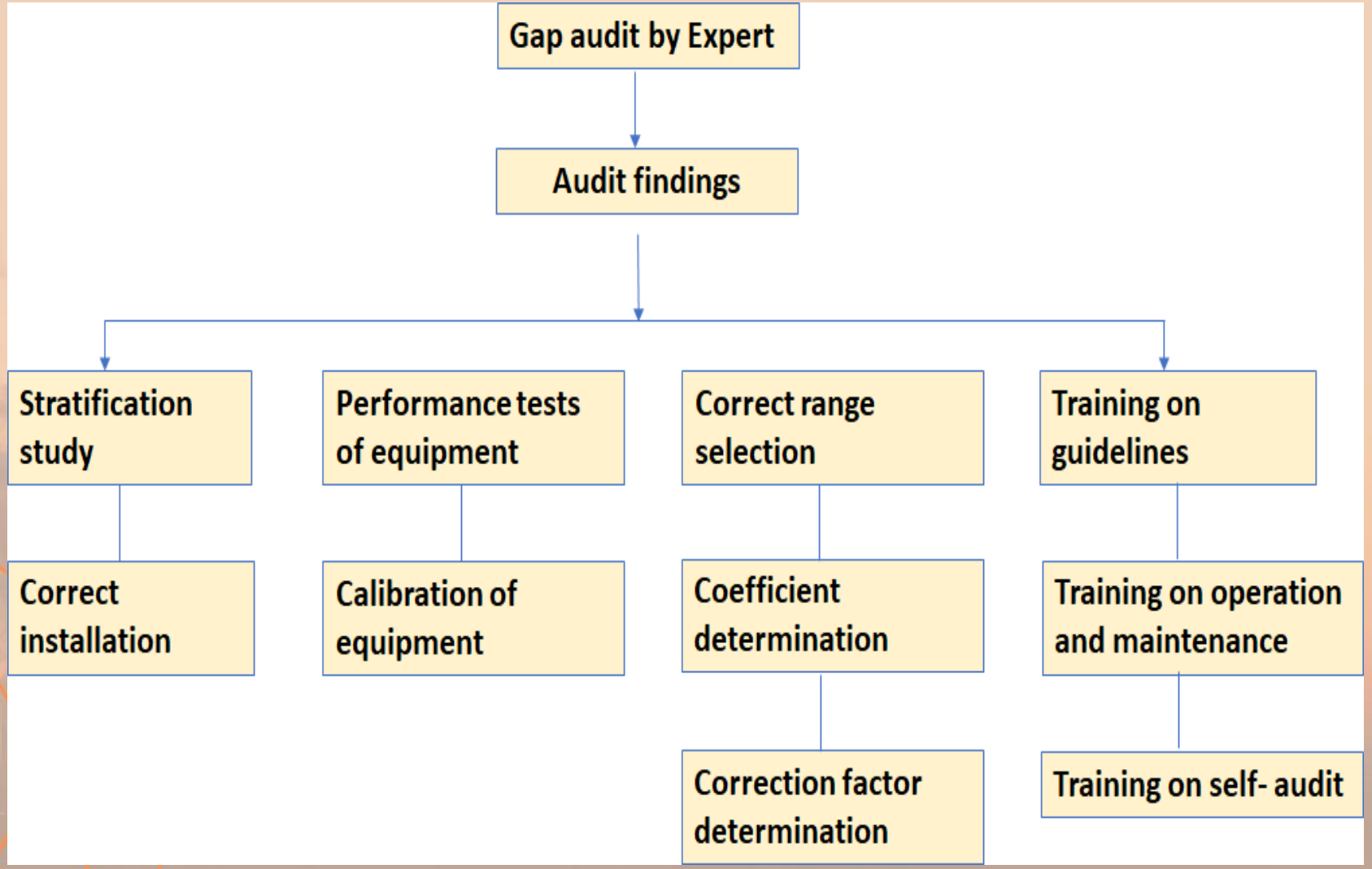
Contents of Checklist for CEMS Audit

- ✓ Is the Remote calibration facility available? Check if zero and span gas cylinders are connected , if so?
- ✓ Is it calibration cylinder available with valid calibration certificate and required concentration.
- ✓ What is the technology of the PM analyser? Is it as per the guidelines?
- ✓ What is the technology of Gaseous analysers? Is it as per the guidelines?
- ✓ What is the Range of Analyser? It should be 2.5 to 3 times of Emission Limit Value.
- ✓ For extractive CEMS, what is the Gas flow rate? Temperature?
- ✓ What is the dust factor and whether is it calibrated during installation? Is calibration certificate available and showing correct estimation.
- ✓ What is the calibration frequency?
- ✓ What is zero drift check frequency?
- ✓ What is span drift check frequency?

Contents of Checklist for CEMS Audit

- ✓ When was the PM CEMS calibration factor changed last time? Was it permitted by SPCB?
- ✓ What is data transmission frequency?
- ✓ Is there any intermediate PC/server between analyser and data transmission to CPCB/SPCB? There should not be any. Data should be directly transmitted to the regulator.
- ✓ Is there maintenance log book for the instruments?
- ✓ Is there any check of lamp after the installation and what will be the life time of lamp?
- ✓ Do you see any analyser in shutdown and data still coming? Notice that.
- ✓ Do you see emission from stack visible and PM data unrealistically low? Notice that.
- ✓ Ask for S content in the fuel, notice if the SO2 emission is unrealistically low and enquire.
- ✓ Check the data and notice if the data is stagnant, clipped from the top, availability is low, and changing during calibration period.

Way Forward


Gap audit by Expert
Audit findings
Stratification study
Correct installation
Performance tests of equipment
Calibration of equipment
Correct range selection
Coefficient determination
Correction factor determination
Training on guidelines
Training on operation and maintenance
Training on self- audit

THANK YOU

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