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Anil Agarwal Environment Training Institute

Alternative Monitoring Technology

Digvijay Singh Bisht
Deputy Programme Manager, Complaince Monitoring
Email – digvijay@cseindia.org, Ph: (+91) 9891921959

Source: https://www.youtube.com/watch?v=e6rglsLy1Ys

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BACKGROUND

- Environmental monitoring is an indispensible part of government's functioning in the contemporary setup.
- However, effective regulatory monitoring of the environment has the following drawbacks-
  - It is costly (Set-up as well as O&M)
  - Requires greater number of man hours (for O&M operations like calibration, regular checks, etc.)
  - Requires technically skilled personnel
  - Resource intensive
- The offset of the above being that the data generated is of high quality and useful for the policy makers.
- However, these drawbacks make real-time regulatory monitoring unfeasible, especially in the low income countries.
- This has resulted in a much slower and more unsustainable development in the low income countries.

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AAETI NATIONAL AMBIENT AIQ QUALITY STANDARDS

Pollutant	Time Wtd. Average	Ind., Resd., Rural & other areas	Ecologically sensitive areas	Methods of Measurement
Sulphur Dioxide (SO_2 in µg/m³)	Annual	50	20	Improved West and Gaeke Method
	24 hours	80	80	Ultraviolet fluorescence
Nitrogen Dioxide (NO_2 in µg/m³)	Annual	40	30	Modified Jacob & Hochheiser
	24 hours	80	80	Chemiluminescence
Particulate Matter (PM_{10} in µg/m³)	Annual	60	60	• Gravimetric • TOEM • Beta attenuation
	24 hours	100	100	
Particulate Matter ($PM_{2.5}$ in µg/m³)	Annual	40	40	• Gravimetric • TOEM • Beta attenuation
	24 hours	60	60	
Ozone (O_3 in µg/m³)	8 hours	100	100	• UV photometric • Chemiluminescence • Chemical Method
	1 hour	180	180	
Lead (Pb in µg/m³)	Annual	0.50	0.50	• AAS/ICP method • ED-XRF using Teflon filter
	24 hours	1.0	1.0	
Carbon Monoxide (CO mg/m³)	8 hours	02	02	NDIR spectroscopy
	1 hour	04	04	

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NATIONAL AMBIENT AIQ QUALITY STANDARDS

Pollutant	Time Wtd. Average	Ind., Resd., Rural & other areas	Ecologically sensitive areas	Methods of Measurement
Ammonia (NH_3 in µg/m³)	Annual	100	100	Chemiluminescence
	24 hours	400	400	Indophenol Blue Method
Benzene (C_6H_6 in µg/m³)	Annual	5	5	Gas Chromatography
	24 hours	1	1	Adsorption and Desorption followed by GC
Benzo(a) Pyrene (BaP) particulate phase only (ng/m³)	Annual	1	1	Solvent extraction followed by HPLC/GC
Arsenic (As in ng/m³)	Annual	6	40	AAS/ICP of the filter paper
Nickel (Ni in ng/m³)	Annual	20	20	AAS/ICP of the filter paper

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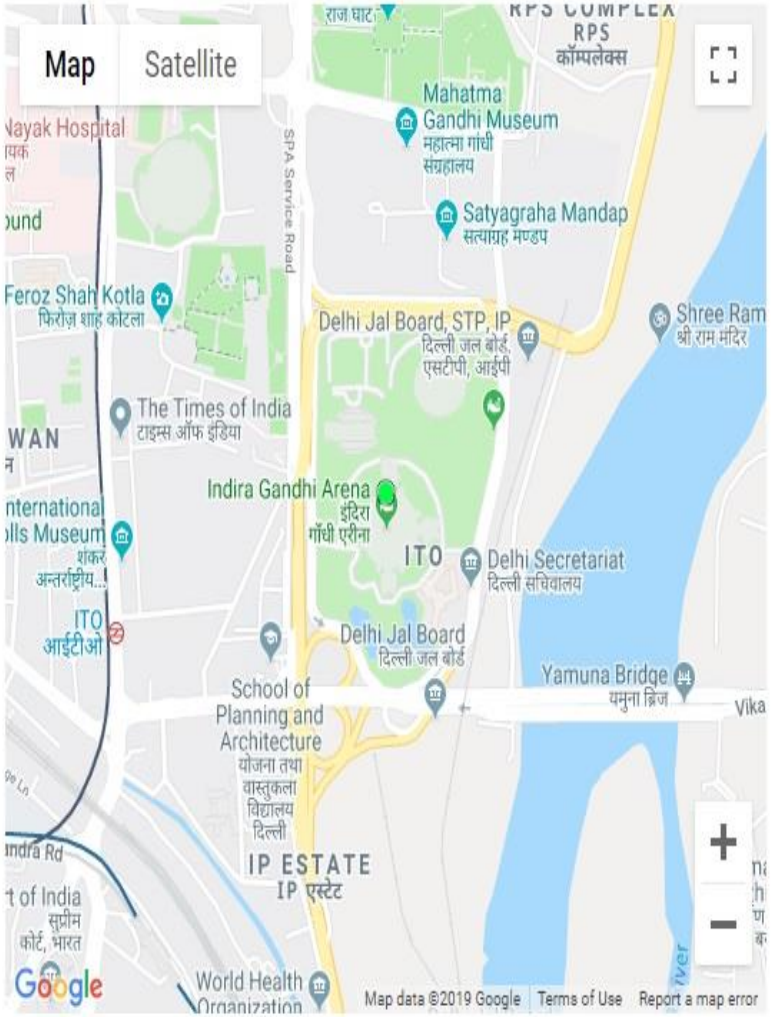
AQI (ITO, New Delhi)

National Air Quality Index

Central Pollution Control Board,
Ministry of Environment, Forests and Climate Change



Moderate

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0

500

ITO, Delhi - CPCB

Prominent Pollutant is PM2.5

On Tuesday, 20 Aug 2019 02:00 PM

Pollutant	Timeline	Avg	Min	Max
PM2.5		107	46	192
PM10		89	47	137
NO2	24	24	14	44
NH3	2	2	1	3
SO2		3	1	5
CO		34	23	107
OZONE		40	11	62

4PM, Mon 8PM, Mon 12AM, Tue 4AM, Tue 8AM, Tue 12PM, Tue

GAPS & CHALLENGES IN CURRENT MONITORING REGIME

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LIMITATIONS IN ENVIRONMENTAL QUALITY MONITORING IN INDIA

Improved monitoring methodologies and network, however, still has a long way to go. Some of the limitations that the current monitoring paradigm faces are-

- Significant growth of air and water monitoring networks in the last decade, but coverage is still comparatively less than required.
- Lower investment in environmental monitoring by the government than what's required.
- Ambient standards for air and water crossed on a daily basis, exposing the shortcoming in the current enforcement measures in place.
- Lack of extensive and specialied studies limits the performance of the monitoring network.
- Extensive monitoring limited only to major cities; barely covers other urban & rural areas.
- Majority of the monitoring is manual; only few places have continuous monitoring.
- Majority of the monitoring stations do not cover some of the important parameters.
- In many cases, data from a specific location is extrapolated using models to create monitoring map of the area – not a correct depiction of the real and actual conditions.
- No well-defined protocols and methodology for measurement of various parameters (standard methods), data verification and validation, and calibration and certification that can be used for carrying out a comprehensive and well defined monitoring programme.
- Inter-departmental cooperation needs more strengthening
- Lack of proper citizen monitoring initiatives and the relevance of data generated thus.

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COUNTRY INDICATORS	INDIA	SRI LANKA	BANGLADESH	ETHIOPIA	GHANA	NAMIBIA	NIGERIA
Legislation	**Yes**	**Yes**	**Yes** (No separate legislation for water & air)	**Yes** (No separate legislation for water & air)	Air: No Water : Yes	**Yes**	**Yes**
Standards	Air: Yes Water: Yes	Air: Yes Water: No	Air: Yes Water: Yes	Air: Yes Water: Yes	Air: Yes Water: No	Air: Yes Water: No	Air: Yes Water: Yes
Presence of monitoring network	**Yes**	**No**	**Yes**	**No**	**No**	**No**	**No**
Coverage of monitoring network	Not very comprehensive	No	Limited coverage	No	No	No	No
Testing facilities	Yes, however, it lacks proper instrumentation	Yes, however, it lacks proper instrumentation	Yes, however, it lacks proper instrumentation	No	No	No	No
Investments/ funding	Moderate Low	Negligible	Low	Negligible	Negligible	Negligible	Negligible
Type of Monitoring	Manual and Continuous, but the former is more prominent	Only one CAAQMS and rest all manual for both air and water	Mostly manual and a few places has continuous	Only one CAAQMS and rest all manual for both air and water	Only one CAAQMS and rest all manual for both air and water	Only one CAAQMS and rest all manual for both air and water	Only few CAAQMS and rest all manual for both air and water
Parameters monitored	All major parameters monitored; monitoring frequency of advance parameters is relatively low	All basic parameters; frequency of monitoring of advance parameters is very low	All basic parameters; frequency of monitoring of advance parameters is very low	All basic parameters; frequency of monitoring of advance parameters is very low	All basic parameters; frequency of monitoring of advance parameters is very low	All basic parameters; frequency of monitoring of advance parameters is very low	All basic parameters; frequency of monitoring of advance parameters is very low
Citizen monitoring	On the lower side and very localised	Negligible	Negligible	No	No	No	No
Methodology and protocol for monitoring	**Yes**	**No**	**Yes but not well defined**	**No**	**No**	**No**	**No**
Data extrapolation	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Specialised studies including Source Apportionment studies	Yes (in most cases)	No	Very limited	No	No	No	No
Equipment Safety	High	Moderate	Moderate	Low	Low	Low	Low

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IMPORTANT INFORMATION

- **What is at stake?**
  - **4.2 million –** Deaths every year from exposure to ambient (outdoor) air pollution
  - **3.8 million –** Deaths every year from household exposure to smoke
  - **91% –** World's population that lives in places where air quality exceeds WHO guideline limits
- **What has to be understood?**
  - Current Health Status of the people
  - Type of Pollutant(s) and their concentration
  - Duration of Exposure – which decides whether its Chronic OR Acute
  - What else besides Lungs – Heart, Brain and Arteries (How?)
  - Difference in the Urban and the Rural setup
  - Approach in Environmental Governance and Public Practice

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Source:
https://www.youtube.com/watch?time_continue=172&v=vYSAPwQwMTk

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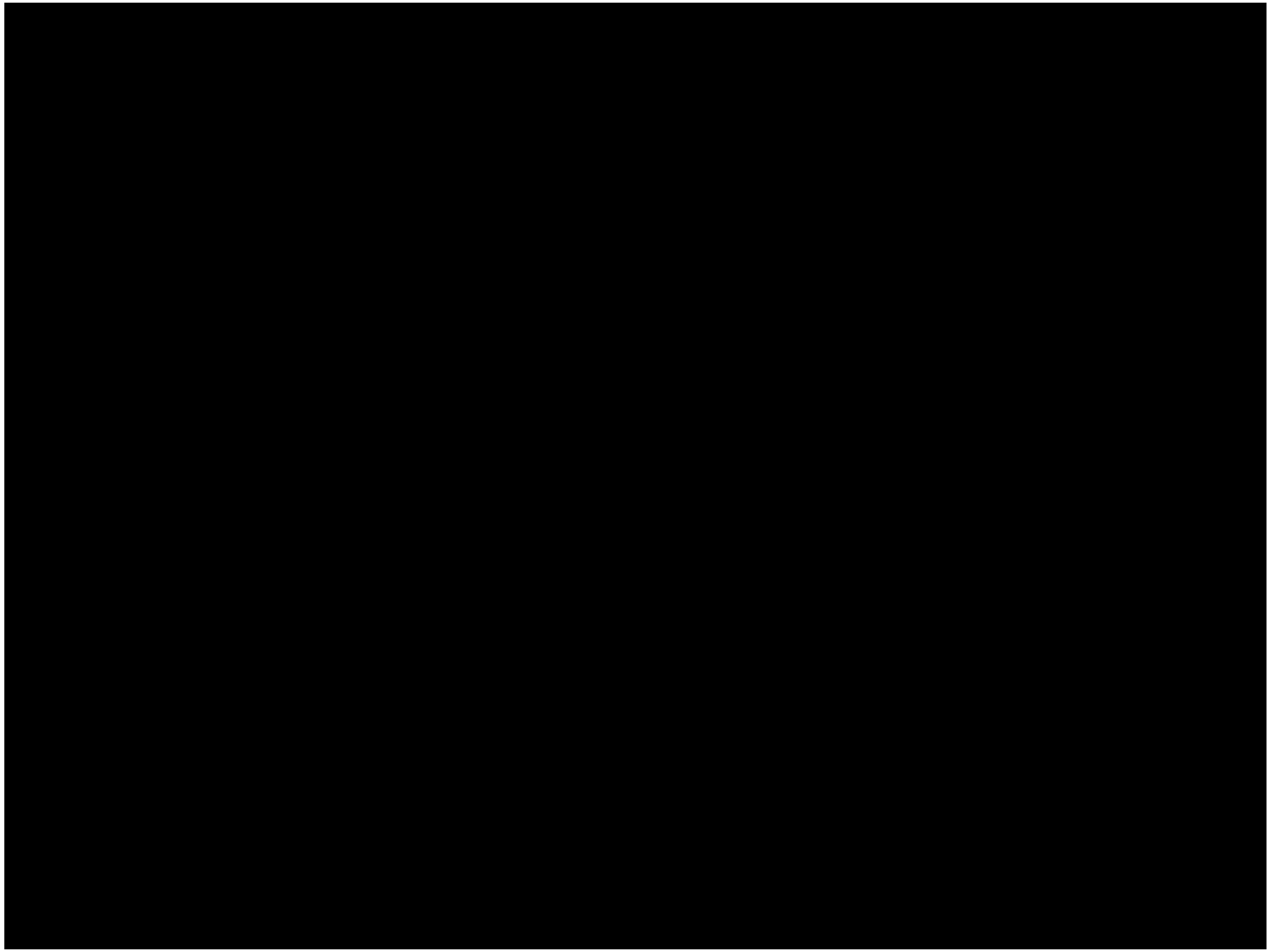
Source:
https://www.youtube.com/watch?v=GVBeY1jSG9Y



SMART & AFFORDABLE MONITORING

AN OVERVIEW

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WHAT IS IT SMART & AFFORDABLE TECHNOLOGY?

- A portable technology that is capable of measuring various air and water quality parameters in real time scenario (in-situ)
- **SMART -** Self-monitoring, analysing, and reporting/recording technologies
- Cost of monitoring is relatively much lesser compared to regulatory monitoring
- This technology has potential to address the gaps of the conventional monitoring system.
- These can be classified based on -
  - Monitoring system
  - Monitoring Network

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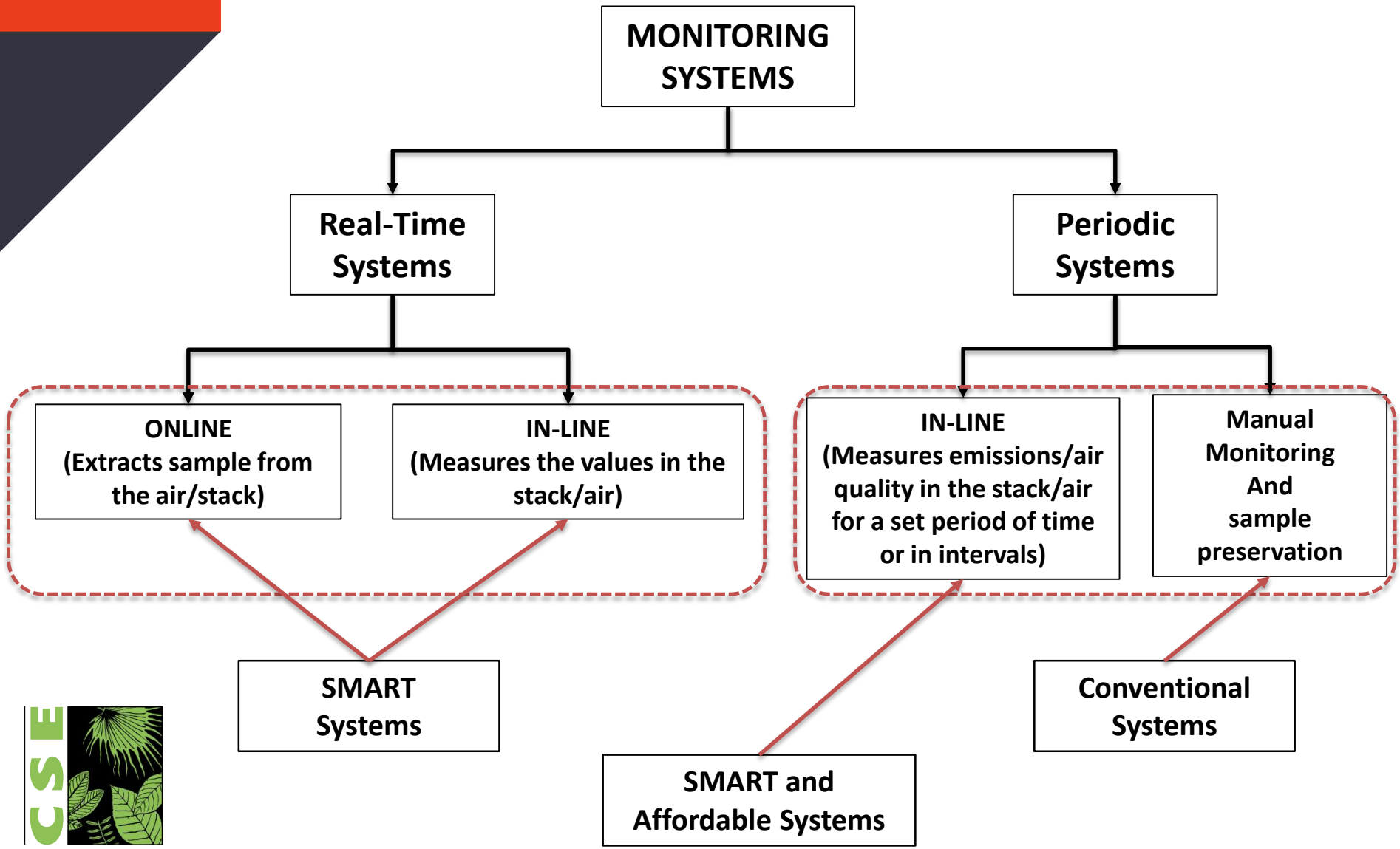
CLASSIFICATION BASED ON TYPE OF MONITORING SYSTEM



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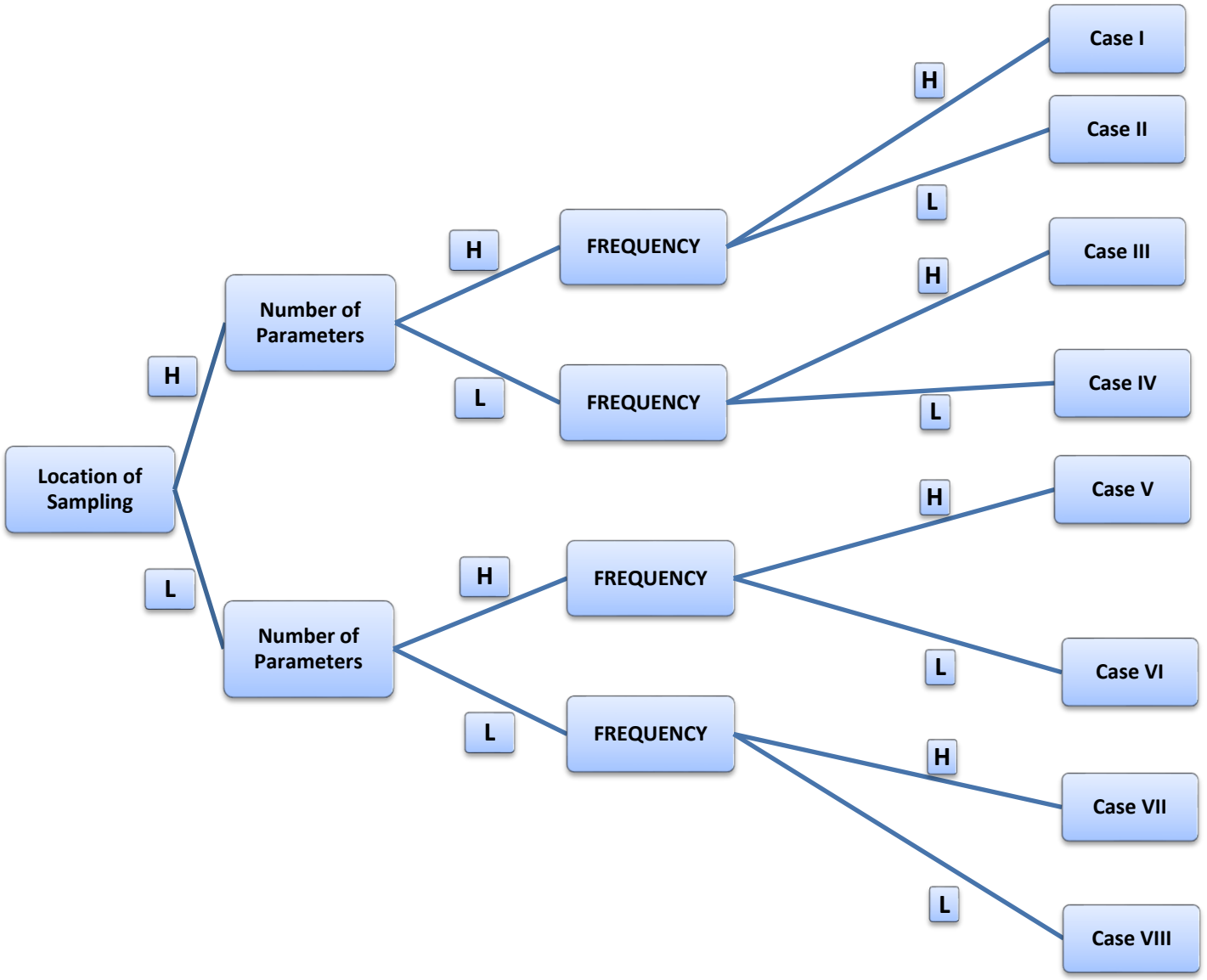
CLASSIFICATION BASED ON TYPE OF MONITORING NETWORK



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BENEFITS – SMART & AFFORDABLE MONITORING

- Relatively **lower cost**
- **Not** very **sophisticated**
- Portable
- **Deployed in networks** - Produce detailed pollution mapping
- Not for regulatory monitoring - Data **capable of providing good indicative values**.
- Useful as **screening tool** to -
  - **Identify problem areas, emergency situations, etc.**
  - **Identify** the **best location** for setting up a **regulatory type monitoring station**
- If **testing and calibration are done correctly**, can be useful in
  - **Generating** a **near real-time trend** of the ambient environment in any given area.
  - **Provide data to help validate adherence** to given **ambient standards** for air and water
  - **Health impact studies**
- **Enhancing** the **existing** regulatory **monitoring network**
- Can give **better coverage** with **limited funding**
- **Exposure studies** for individuals
  - living or working in a **possible impact area/place**
  - **Vulnerable groups**

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CHALLENGES
SMART & AFFORDABLE MONITORING

- There **aren't any set global standards methods** for the **development and testing of "low-cost" SMART systems**.
- There is **no proper mechanism for quality control and quality assurance** in place for such systems in developing countries.
- There **aren't any certification bodies** that would certify such technologies in **developing nations**.
- The **measurements** with low-cost and SMART are **often of lower and more questionable data quality** than the results from official monitoring stations
- The **performance** of these devices **vary with location**
- **Need for regular calibration** because of the **drift in the devices**
- **While considering the cost** of the device, **the O&M cost, labor** and **spare parts cost** is **not always considered**.

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BASIC PRINCIPLES INVOLVED AIR QUALITY MONITORING

PARTICLE BASED SENSORS

- This technology detects the particulate pollution by measuring the chances in the light properties by the particulate matter particles.
  - Scattering (Aerosol particles)
  - Absorption (Black carbon)
  - Light excitation (diesel emissions)

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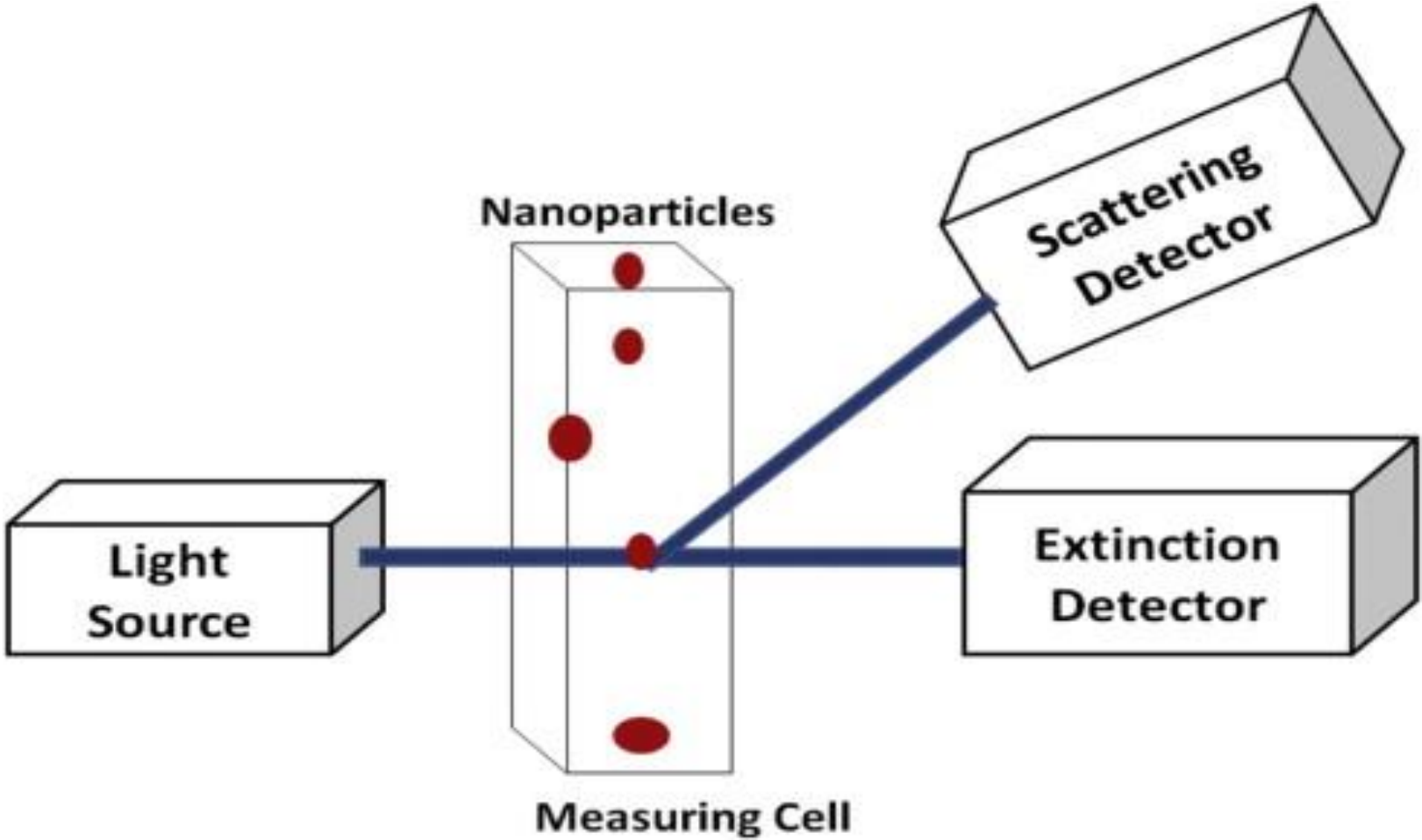
BASIC PRINCIPLES INVOLVED AIR QUALITY MONITORING



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BASIC PRINCIPLES INVOLVED AIR QUALITY MONITORING

GAS BASED SENSORS

- **Electrochemical Sensors** - These devices/systems are based on the principle of **a chemical reaction between gases in the air and the electrode in a liquid inside a sensor** i.e. they apply the potential difference of the working electrode house.

- **Metal Oxide Sensor (MOS)** – Also called resistive sensor and semiconductors, the **ambient gaseous pollutants react on the sensor surface and modify its resistance** which is recorded as a electric signal.

- **Photo Ionization Detector (PID)** – The principle of working for this is based on the **ionization of volatile organic compounds (VOCs) that generates an electrical current** which is subsequently measured.

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TECHNOLOGY
AIR QUALITY MONITORING

Sensors Type	Pollutants	Sensitivity	Response time	Sensitive (temperature/ humidity)	Remarks	Cost (in ₹)
Electrochemical sensors	NO_2, SO_2, O_3, NO, CO	mg/m^3 to $\mu g/m^3$	30-2005	Highly dependent on electrolytes	Cross connectivity with similar molecular type	150
Metal oxide sensors	NO_2, O_3, CO	mg/m^3 to $\mu g/m^3$	5-50 mins	Affected	Instability	900 — 1500
Photo Ionisation detector	VOCs	mg/m^3 to $\mu g/m^3$	Few seconds	Limited temp dependence and humidity affect	Significant drift	400-5000
Optimal particulate counter	PM_{10}, $PM_{2.5}$	$\mu g/m^3$	Fast response	-	Conversion of particulate count to PM was on theoretical basis	3000
Optical sensors	CO, CO_2	350-2000 ppm	20-120 sec	Limited drift of the sensor over time	Measured signal depends on shapes, colour, density, humidity and refractive index.	100-350

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- **Devices Available in the Market**

AIR Quality Measurements

Name of the Equipment	Equipment Description	Manufacturer	Operating Principle	Setup	Parameters Measured	Range	Interference	Remarks
AEROCET 531S	Full–featured, battery operated, handheld particle counter or mass monitor	Met One Instruments, Inc	Optical Particle Counter method. Specifications are mentioned in the product manual.	Handheld and portable	Particulate Matter in the following categories:- · TSP · PM_{10} (10 µm) · PM_{7} (5 µm) · PM_{4} (1 µm) · $PM_{2.5}$ (0.5 µm) · PM_{1} (0.3 µm)	**Concentration Range** 0 to 3,000,000 particles/ft^3 **Sensitivity** High – 0.3 µm Low – 0.5 µm	Temperature Range (0°C to 50°C) Storage Temperature (-20°C to 60°C)	· Annual calibration in the company laboratory · Done as per ISO, IIS and NIST Manual can be found at this link.
EVM-7/ CO	Full–featured, battery operated, handheld particle counter or mass monitor	3M (USA)	· **PM** – 90 Light scattering/ Integrating photometer/ Particulate size range · **CO_2** – Non-Dispersive Infrared · **CO** – Electrochemical Sensor · **NO** – Electrochemical Sensor · **NO_2** – Electrochemical Sensor · **SO_2** – Electrochemical Sensor · **Temperature** – Junction diode · **Relative Humidity** – Capacitive · **Air Velocity** – Omni-directional Heated Thermistor Wind probe	Handheld and portable	**PM** **CO_2** **CO** **NO** **NO_2** **SO_2** **Temperature** **Relative Humidity** **Air Velocity**	0.00 – 200.0 mg/m^3 0 – 20,000 µg/m^3 0.1-10 µm 0 – 5,000 ppm 0 – 1,000 ppm 0.0 – 100 ppm 0.0 – 50 ppm 0.0 – 50 ppm 0°C – 60°C 0.0 – 100 % humidity 0–20 m/sec	**Temperature Range** (0°C to 50°C) **Pressure Range** (65 kPa to 108 kPa) **Relative Humidity** (10% to 90% non-condensing)	· Cl_2 – Chlorine Sensor, · EtO – Ethylene Oxide Sensor, · HCN – Hydrogen Cyanide Sensor, · H_2S – Hydrogen Sulfide Sensor, · O_2 – Oxygen Sensor **Flow Rate** – 1.67 l/min CE Mark and RoHS compliant Manual can be found at this link.
Aeroqual 500	Full–featured, battery operated, handheld particle counter or mass monitor	Aeroqual Ltd. (NEW ZEALAND)	· **PM (2.5 & 10)**-Laser Particle Counter · **CO2** – Fan-sampling using NDIR · **CO**-Electrochemical Sensor · **O3**-Electrochemical Sensor · **NO**-Electrochemical Sensor · **NO2**-Electrochemical Sensor · **SO2**-Electrochemical Sensor	Handheld and portable	**PM (2.5 & 10)** **CO_2** **CO** **O3** **NO_2** **Temperature**	0.00 – 1000 mg/m^3 0 – 5,000 ppm 0 – 25 ppm 0 – 10 ppm 0 – 1 ppm -40°C to 124°C	**Temperature Range** (-5°C to 45°C) **Pressure Range** (65 kPa to 108 kPa) **Relative Humidity** (0% to 95% non-condensing)	The simultaneous measurement of PM and gases is not possible with this model. Manual can be found at this link.
VPC 300	Full–featured, battery	EXTECH Instruments	Optical Particle Counter method using an isokinetic probe. Specifications are		Particulate Matter in the following categories:-	**Particle Count Modes** Cumulative,	**Temperature Range** (-0°C to 50°C)	

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Review of Environmental Legislation W.R.T Environmental Monitoring – India Context

POSSIBILITY OF INCORPORATING SMART & AFFORDABLE MONITORING

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CURRENT SCENARIO – AIR (INDIA)

- Steps taken by the government to address Air Pollution
  - National Ambient Air Quality Standards (NAAQS)
  - Sector specific emission and standards for industries;
  - Setting up of ambient air monitoring network;
  - Introduction of cleaner fuels like CNG, LPG as well as ethanol blending;
  - Launching National Air Quality Index (AQI);
  - Universalization of BSIV for vehicles; leapfrogging from BS-IV to BS-VI standards
  - Banning of burning of biomass;
  - Promotion of public transport network;
  - Pollution Under Control Certificate;
  - Issuance of directions under Air (Prevention and Control of Pollution) Act, 1981;
  - Installation of CEMS for 17 highly polluting industrial sectors;
  - Ban on bursting of sound emitting crackers between 10 PM to 6 AM;
  - Notification of graded response action plan for Delhi and NCR

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CURRENT SCENARIO – AIR (INDIA)

- Current status is encouraging with the impacts due to multiple government introduced programmes/initiatives.

- Nation-wide programme of ambient air quality monitoring - National Air Quality Monitoring Programme (NAMP).

- Network consisting of -
  - 691 manual operating stations in 303 cities/towns in 29 states & 6 UTs
  - 4 pollutants - SO_2, NO_2, PM_{10}, and $PM_{2.5}$
  - 101 real-time Continuous Ambient Air Quality Monitoring stations (CAAQMS) in 57 cities
  - 8 pollutants - PM_{10}, $PM_{2.5}$, SO_2, NOx, NH_3, CO, O_3 and C_6H_6.

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- However, the situation remains dire since the list of non-attainment cities, towns, areas increase rapidly and many places do not have monitoring.

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LEGISLATIVE PROVISIONS – AIR (INDIA)

- **National Clean Air Programme (NCAP)**
  - To address the gaps of the current initiatives
  - Has provisions for
    - Inclusion of SAAM
    - Development of Certification system
    - Initiating citizen monitoring
- **Section 16(d)** of **Air Act** - Carry out and sponsor investigation and research relating to problems of air pollution, prevention, control and abatement of air pollution
- **Section 16(e)** of **Air Act** - Plan and organise the training of person, or to be engaged, in programs of prevention, control or abatement of air pollution
- **Section 16(f)** of **Air Act** – CPCB can organise through mass media a comprehensive programme regarding the prevention, control or abatement of air pollution'.
- The abovementioned functions of CPCB are also applicable to SPCBs under **Section 17** of the **Air Act**.

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RECOMMENDATIONS (INDIA)

- Provisions under **National Clean Air Programme (NCAP)** can be used to strengthen the monitoring network and develop the use of SAAM and community monitoring.
- Increase the inter departmental cooperation to formulate standards and protocols for the development of specifications, testing procedures, QA & QC analysis, and certification of SAAM devices.
- Seek collaboration with developed countries to set up facilities for testing, QA & QC and Certification.
- Promote community level groups for expanding the existing monitoring network for better spatial coverage
- Inventory development and source apportionment studies must be classified as important non-stop activities.

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LEARNINGS FROM OTHER COUNTRIES

Technology & Community Inclusion

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FEDERAL CLEAN AIR ACT, 1963 (USA)

Code of Federal Regulation

- Under the **40 CRF, Part 58** deals with the **ambient air quality surveillance**. Under **Part 58** –
  - **Subpart B** elaborate on the **establishment and working of monitoring networks**, which also includes monitoring plan and monitoring technical requirements.
  - **Subpart C** talks about **special purpose monitoring** which is designed by the agency in its annual monitoring network plan and air quality system (AQS), and which the agency does not show when showing compliance with the minimum requirements of this subpart.
  - **Appendix C and D** to **Part 58**, details out the **methodology for ambient air quality monitoring and the network design criteria** for the ambient air quality monitoring respectively.

Sensor Performance Evaluation and Application Research (SPEAR)

- An initiative of US EPA for supporting the advancement of air sensor technology by evaluating and testing commercial devices and developing and testing new instruments using miniature sensors and other technologies.

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FEDERAL CLEAN AIR ACT, 1963 (USA) (Citizen Monitoring Resources)

- Under **Section 103**, whereby, the **Administrator** is **authorised to cooperate** with **aforementioned agencies and individuals** on various **initiatives to execute the provisions under the Act and apply the standards** it sets forth.
- The emergence of SMART technologies have led to the identification areas in which these sensor devices can be used-
  - Research for scientific studies
  - Personal Exposure Monitoring
  - Supplementing existing monitoring data
  - Source Identification and Characterization
  - Education
  - Information and awareness
- **EPA has also developed an air sensor toolbox web page** - Provides information on various aspects of air sensors, the initiatives being undertaken by US EPA in this area and other useful resources.
- **Laboratory testing of sensor devices and then in-field studies** to help of citizen scientists. Some of the citizen science initiatives/ projects being undertaken like **AirMapper**, **RETIGO, Instruction guide and macro analysis** tool for citizen scientists

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EUROPEAN UNION (SMART & AFFORDABLE MONITORING)

Directive 2008/50/EC

- **Part 26** under **Article 1** of Directive 2008/50/EC - Defines '**Indicative measurements**'
- **Part 14**, **Part 12 (Article 1)**, **Part 2** & **3** (**Article 6**) **promulgate** the **use of indicative measurements** (air sensors, etc.) to supplement the regulatory monitoring.
- The Directive **allows the use of indicative measurements without restriction in the zones where the upper assessment threshold (UAT) is not exceeded**
- The Directive **does not specify any indicative method**
- Requires to **demonstrate that data quality objectives (DQO) can be met**
- Are about **twice less stringent than the one of reference methods**

Metrology for Chemical Pollutants in Air (MACPoll)

- Joint research project of the European Metrology Research Programme of EURAMET (deals with low-cost gas sensors for air quality monitoring)
- As part of the MACPoll project
- Has been decided to draft a protocol for the evaluation of gas sensors

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EUROPEAN UNION (CITIZEN MONITORING)

SEVENTH FRAMEWORK PROGRAMME FOR RESEARCH AND TECHNOLOGICAL DEVELOPMENT (FP7)

- **ENV.2012.6.5-1** - **Develop community-based environmental monitoring and information systems** by using innovative and novel earth observation applications
- Led to the **development of Citizen Observatories (CO)** that includes community based environmental monitoring with portable monitoring technologies (low-cost reliable micro-sensors).
- **CO combined participatory community monitoring with monitoring by policy-makers, scientists and other stakeholders,** and which further developed into five projects—CITI-SENSE, OmniScientis, CitClops, COBWEB, WeSenseIt.

Aarhus Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters, 1998

HORIZON 2020

- EU's biggest Research and Innovation programme facilitating public and private sectors to work together
- H2020 topic CSA-2017 ('*Coordination of Citizens' Observatories initiatives*'; EC, 2016–2017b)
- Various citizen Science Projects that are being implemented under the FP7 and Horizon 2020 like **DITOs, SPARKS, European Citizen Science Association (ECSA)**

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WAY FORWARD FOR SMART & AFFORDABLE MONITORING

LEARNINGS FOR INDIA

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WHAT'S THE SITUATION LIKE?

- Manufacturers Role –
  - To ensure that devices function on correct and verified principles and technologies,
  - Are reliable with proper calibration and tests,
  - Give data and results that are both comparable and indicative, and
  - Can be used for taking suitable measures and decisions at policy level.

- However, at this point because of issues related to –
  - lack of quality assurance,
  - No device/equipment certification process in place,
  - Questionable data quality of such devices,
  - No prior/limited quality checks and/or field testing before being used

- This technology has not found any support in the existing monitoring paradigm/monitoring framework in the developing countries.

- But developed counties are working towards making this technology work and complementing their existing monitoring.

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IMPROVE THE EFFECTIVENESS OF ENVIRONMENTAL QUALITY MONITORING PROGRAMME IN SCHOOLS

- Ensuring monitoring objectives are well defined and informed to the entire management and teachers
- Monitoring objectives are placed in the context of a broader environmental quality management programme within schools – focusing on achieving exposure reduction within the school premises as well as emission reductions from within and adjoining sources.
- Planning a roadmap and action plan for addressing any foreseeable challenges
- Documentation of success stories as well as lessons learned from your work
- Establishing partnerships between different stakeholders (schools, NGOs, regulators, etc.)
- Establishing the importance correct and coherent knowledge dissemination
- Having plans in place to ensure the smooth flow of monitoring work and timely resolution of any issues that might come up.

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CLASS EXERCISE

- In the given scenario kindly do the following
  - Identify the major sources of air pollution around the school area.
  - List down the initial steps that you will take to assess the impacts.
  - What measures can be taken in order to address these impacts from a –
    - Governance point of view
    - Cooperation/Collaboration point of view

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THANK YOU