Study of Air Pollution Carrying Capacity of Satna Region

Study conducted by

Envirotech Instruments Pvt. Ltd

in 1999 - 2000

SATNA STUDY

Air Assimilative Capacity

- The Study was carried out in the Satna, Reva, Maiher region of Madhya Pradesh
- The region is by and large flat terrain with some hillocks
- This region is rich in Limestone and besides several Cement Plants has scores of Lime Kilns.
- Towns in the region:
  - Satna
  - Reva
  - Maiher
  - Katni

Air Assimilative Capacity

- The atmosphere is a finite medium.
- Concentration of activities such as:
  - Urban settlements
  - Cluster of small sources like Kilns - Jukehi
  - Grouping of units with massive capacities & having several activities with air pollution potential such as:
    - Mining
    - Handling & transport of pulverized material
    - Stack emissions
- Capacity to disperse / transport away material released into the atmosphere is proving to be limited in comparison to the scale of operations

Air Assimilative Capacity

the concept of Air Shed

- **What constitutes the boundaries of an Air Shed**
  - Topographic features like a range of hillocks
  - In the vertical plane Mixing Height
- Within an Air Shed Capacity to disperse / transport away material released into the atmosphere.
  - Basically governed by:
    - Micrometeorology of the region
  - Air quality also a function of Other removal mechanisms like settling or absorption by vegetation.

Air Pollutants Disperse by a Variety of Mechanisms

Horizontal Dispersion is primarily dependent on

- Wind Speed & Direction
- Atmospheric Stability

Dispersion in the Vertical Plane is mainly governed by:

- Vertical Turbulence - Stability
- Mixing Height

Stable Layers or Inversions restrict Vertical spread of Pollutants

Met Parameters monitored as part of Satna Study

Mixing Height and Inversion layer

- Lapse rate via tethered baloon
- Monostatic Sodar
- Different Seasons and different locations in the region

Change of Met Parameters with Height

- Temperature
- Wind Speed
- Wind Direction
- Sigma Theta

Satna Study
Lapse rate data Findings & Implications

- Findings:
  - Upper layer (above 95m) remains super-adiabatic / unstable all through.
  - In September ground based Inversion from early night (8 PM) onwards.
- Implications:
  - Good dispersion capacity available for elevated emissions.
  - Emissions from elevated stacks may not contribute significantly to ground level concentrations
  - Low level sources from crushers, kilns, material handling and transportation activities will be critical for Ambient Air Quality.

Mixing Height Varies from place to place and with change of Season

Mixing Height is controlled by:

- Incoming Solar Radiation
- Albedo - Rate of Radiative cooling

  Function of
  - Land use
  - Vegetative cover
  - Nature of Rocks / Soil etc of the site
- Climatic factors such as Winds, Hot and Cold Fronts etc.

Mixing Height is often considered to be Site Specific.

In the Satna Study Monostatic SODAR was used to get Vital Data for Dispersion Modeling

- SODAR Echograms can be interpreted to give hourly values of **Atmospheric Stability**
- **Stability Class affects:**
  - Extrapolation of Wind Speed
  - Plume Rise
  - Horizontal & Vertical Dispersion
- Heights of Nocturnal Stable Boundary Layer can be read from the echograms without any ambiguity.
- Pictorial representation of atmospheric phenomena helps in understanding them.

Satna Study
Implications of Sodar Data

- Findings:
  - Sodar data indicates that a ground based inversion layer forms early in the night and persists till morning.
  - Evening period from 19 to 21 hours has the lowest mixing height ~ 85m.
  - September data shows a rising layer and fumigation conditions forming on about 50% of the days between 7am to 10am.
- Implications:
  - Emissions from sources at ground level such as from Kilns, transportation, and fugitive sources in industry will be critical
  - Estimation of the nocturnal inversion height can have an important bearing on the recommended minimum stack height.
  - Short term Air Quality monitoring during the fumigation period may be desirable at selected locations.

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Peculiarities in Wind Direction Data

- Comparison of Wind Directions observed at 10m with those at 105m indicates the following trends:
  - **On an overall basis** Wind Direction at 10m is within +/- 20^{o} of the wind direction observed at 105m for only 60% of the time.
  - **During Convective / Neutral** conditions, 80% of the time 10m Direction is within +/- 20^{o} of the direction at 105m.
  - **During Stable Conditions**

    10m Wind Direction more than 40^{o} different from the Direction at 105m for 40% of the time and for almost 20% of the time more than 90^{o} off.

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Wind Speed Data - Trends

- Duration and value of wind speed is significantly higher in summer as compared to winter months.
- Shift in Diurnal pattern in Wind speed with change in season:
  - During Winter high wind speeds observed mainly in the evening period 17hrs - midnight
  - In the Spring season high wind speeds observed from 14hrs to 2am.
  - In Summer High Wind Speeds observed almost all through the day and night.

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Peculiarities in Wind Speed Data

- Wind speed is normally expected to increase with height. A power law is thus used to scale up and estimate elevated wind speeds on the basis of observed speed at a reference height.
- At Satna - Tower data indicates that for significant periods of time surface (10m) wind speeds exceed the wind speed measured at 105m.
- During April & May periods of abnormal wind profile coincide with the morning transition from Inversion to Convective conditions.

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Extrapolation of Wind Speed

- Tower Lapse rate and two height Wind Speed data was used to determine the Ratio of Wind Speed at 105m and 10m.

- Satna data shows that Irwin's Wind Scaling formula (recommended in CPCB guidelines) may be used to determine Wind Speed at elevated heights.

Satna Study
Wind Data Findings

- Findings :
  - The overall trend observed during August co-relates reasonably well with historical IMD data.
  - In September ‘99 winds have veered towards North - East sector.
  - Evening & night time shows a calm percentage of almost 30%.
  - Wind Directions near the Surface can be significantly different from the directions at elevated levels.
- Implications :
  - Continuous site-specific data will be necessary for realistic dispersion modeling.
  - It would be best to locate Wind Sensors at a height comparable to the stack top.

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Peculiarities in Sigma Theta Data

- **During periods of high wind speed** or when Lapse rate is near adiabatic - atmosphere may be assumed to be Neutral - Sigma Theta is close to 10^{o} both near the surface and at 105m.
- **During Stable Periods** - Lapse rate inverted
  - Sigma Theta only sparingly below 10^{o}.
  - Two height data indicates that the layer near the surface is more turbulent than the upper layer.
- Seasonal data indicates that during Spring and Summer months atmosphere is significantly more turbulent as compared to the Winter period.

Satna Study
Implications of Stability Data

- Findings :
  - During August Turner classification indicates Stability Class D for most of the day & night.
  - Lapse rate shows Stability class A or B for most of the day & night.
  - In September Turner classification shows Stability Class F during most of the night.
  - Lapse Rate & Sodar show much higher occurrence of E class at night and A during the day.
  - Sigma Theta based classification shows significant presence of A class at night.
- Implications :
  - Greater dispersion in the horizontal plane will produce overall a lower GLC.
  - Important to use practical data obtained from site specific measurements.

Implications of data from the Satna Study

- Vertical Stratification of the atmosphere evident from:
  - Lapse rate data
  - Sodar Echograms
- Elevated sources appear to be emitting above the ground based layer and may not contribute significantly to GLC.
- Low wind speeds with Stable conditions near the surface observed in the night.
  - Low level sources such as Lime Kilns, crushers, material handling operations, transportation etc. will have a significant impact on GLC.
- Large fluctuations in Wind Direction observed.
  - The pollutants will be spread over a wide area.
  - Modeling techniques should adopt suitable methodologies to account for large horizontal dispersion.

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Air Quality Assessment

- Ambient Air Quality was monitored by Envirotech
  - Temporal and Spatial trends
  - Identification of hot Spots
  - Background concentration
- Comprehensive inventory of emission sources
  - Stack emissions from the cement units & Lime Kilns
  - Traffic Census – Vehicle Kilometers cross referenced with data on sale of Petroleum Products in the region
  - Road Lifted dust
- Air Quality Modelling

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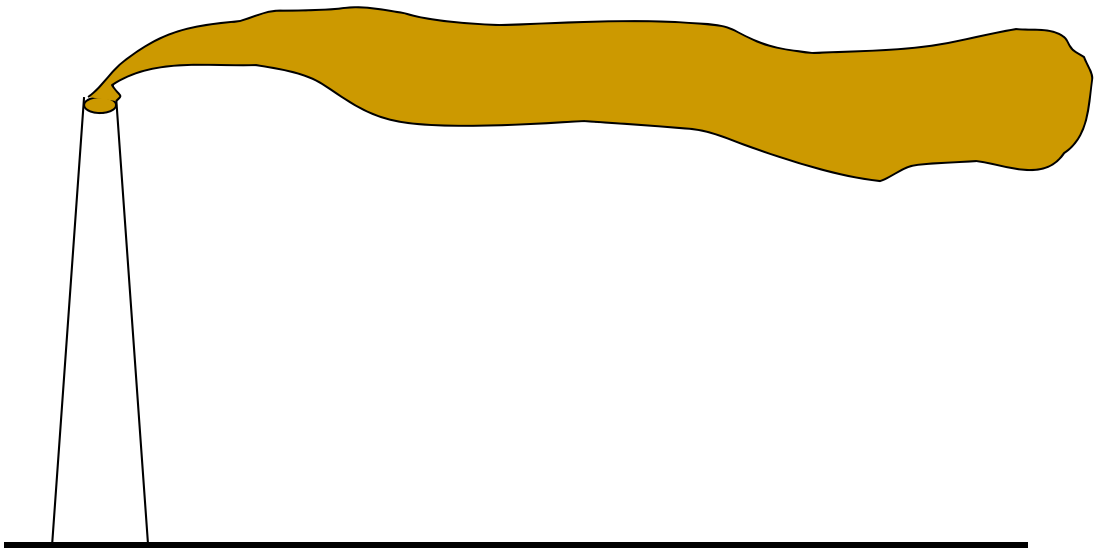
Ambient Air Quality

- Spring Season Ambient SPM and RPM concentrations
  - Comparable to Winter values at most places but higher at several locations.
  - Higher than summer values for most of the stations monitored.
- All the poor Air Quality areas are located in Air Shed 1
  - Jukehi RPM 400, SPM 650
  - Jaitwara RPM 200, SPM 800
  - Semaria Ch. RPM 250, SPM 550
  - Ghoghar RPM 200, SPM 550
- Each of these appears to be affected by local factors.

Modeling Elevated Emissions

- Elevated emissions released above the Nocturnal Stable layer will remain aloft all through the night and will not contribute to Ground Level Conc. (GLC)



- Increment to GLC from elevated sources needs to be modeled only for the Convective day-time period.

Understanding from the Satna Study – Realistic Emission Inventory is often missing

- Not much point in concentrating on the elevated sources alone.
- Low level sources often neglected can be more significant contributors to deterioration in Air Quality
    - Material handling – fugitive emissions
    - Road lifted dust from haul roads
    - Emissions from vehicle fleet deployed for material movement.
    - In Satna region small kilns were a significant source unrelated to the major cement plants.
- In rural India domestic / non industrial emissions can be significant as use of bio-mass based fuels for cooking is widespread.

For improvement in Air Quality in the Satna Region

- Elevated Stack Emissions are only a fraction of the total pollution load.
- For the Cement Plants:
  - Try to curtail fugitive emissions
    - Transport - Maiher's covered belt conveyor is a good alternative.
  - Use green belts to minimize impact of operations where dust generation is unavoidable.
  - There is no substitute for good housekeeping.
  - Identify process / plant modifications to reduce emissions.
- For local hot-spots such as Jukehi
  - Improve road conditions.
  - Schedule operations in periods favoring good dispersion of air pollutants.

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How can it benefit project proponents

- Establish background air quality in the region
  - Identify areas where activities with Air Pollution potential must be discouraged.
  - Form a basis for rational emission standards.
- Provide detailed site specific data on all Met. Parameters important for Air Pollution Dispersion
  - More realistic Modeling of Air Pollution Dispersion from different sources
  - Help in apportioning responsibility for deterioration in air quality of local hot spots.
- Assess the impact of adverse air quality on local flora & human health
  - Put to rest apprehensions of local populace leading to congenial community feelings.

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The Indirect - Social Benefits

- Promote Scientific Research in critical areas of Air Pollution Dispersion Modeling
- Increase local awareness and reassure local communities.
- Through exchange of information amongst plants in the region adopt best practices.
- Develop a deeper understanding of Air Pollution phenomena and train manpower.

Thank You

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