Environmental Studies (ES 200, IITB)
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https://somphene.github.io/notes/

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A visitor remarked that the library at the newly constructed IHES was lacking. Grothendieck replied "We don't read books, we write them."

This is an **incomplete draft**. Please send corrections, comments, pictures of bad drawings, etc. to `somphene1@gmail.com`.

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Contents

1 Lecture Jan 13

§1.1 Course logistics

Meets Mon, Tuesday, Thursday Slot 2. 2 Assignments 7 marks each, Final. 80% attendacnce. Keep a soft copy for handwritten submissions. 3 Modules.

§1.2 Course objectves

Bareilly example of smoke coming out of industries. Black or white smoke.

- Be able to explain key concepts of air pollution and air quality management.
- Be able to have intelligent conversations and interpret articles.
- Can't become an expert in 6 hours.
- Not about being a good citizen. You could probably google for that or find 50 books.
- Whether you like it or not, being in a position to make tough decisions. This course gives you the wherewith all to go back to the resources and bring in scientific awareness of environmental factors in decision making.

This course is supposes to be in service of students. Its an honour for the students. Handing over the planet onto your hands. Give yourself a hand! (Claps ensue).

Prof. Archibala (father of Environmental studies) recently passed away. How was the Harvard experience?

- We were told that numbers must be put to every argument. (quantify)
- Library work- reading after classes.
- Apprenticeship - two months practical training. Invited to do work apart from the course. Encouraged to meet with local authorities in vacations to understand how they deal with air pollution.

Creating a Game
Accountable for Air Quality in city X. Where X is your city. Then ES 200 may occur more as an Opportunity and not just a required course. Examples from previous course offerings, where they went to NGT (National Green Tribunal) called the Chief Secretary for 15 cases in Rajasthan. The students gave a training workshop to District Magistrates. As a system Pollution control boards have been largely been managing industries- green, orange, red categories and large scale, medium scal and small scale. Haryana, Punjab only smoke from chimneys are counted as pollution. A large part of the problem in India is not in the Radar such as smoke from chulhas, trucks and buses. District magistrate of Gwalior- most polluted city in M.P. Intended to give us sleepless nights.

Anybody who can claim that their city is free of air pollution? NO. Went to Kerala and met the secretary for asking about air pollution status. She said can't guarantee.

Can you know where your city's air pollution stands in comparison to Delhi? Delhi people blame Haryana and Punjab. Argument about 15% and 60%.

Homework 1 Part A Study the movie "An Inconvenient Truth" before January 16th Class. Be convinced that Global Warming is being caused by Humans.

§1.3 To learn today

How much do I already know about air pollution.

§1.4 Quiz Pre-course

Marks not to be counted in the grades.

On top of a fresh sheet, write the name of your city.
Six questions (answer or make intelligent guess or OD- Oopsie doopsie, dont know:

1. What is air pollution?
   Contamination of natural air on planet

2 lecture Jan 14

Question 2.0.1. What is Air Pollution?

Perception:

- Visible
- Odour

Question 2.0.2. What is Clean Air?

- 78% Nitrogen + 21% Oxygen +1% Trace

§2.1 Lifecycles/ Statistics

- Capacity of the Earth system as a sink
  - Feasibility (thermodynamics)
  - Proximity
- Characteristic times
  - Kinetics- For instance,NO_2 has diffferent rates than other gases
  - Sulphur, Carbon, Nitrogen, Halogen Containing Compounds Cycles

Experiment for next time: start the measurement of CO_2 levels at the start of the class and then at the end of the class to check the change in levels.

§2.2 Scales

- *Local* > *Regional* > *Global* : the monthly average between different localities needs to be seen.
- Earth : Apple :: Atmosphere : Skin
- Ambient : Indoor (Yale report identifies **Kitchen** as the major source of pollution in India, making rural sources prominent 68% of the problem ascribed to rural sources.)

§2.3 Air Quality

Example 2.3.1

Listed as 172 or somewhere around in the international tables. PM 10 scaled to come to PM 2.5.

§2.4 CPCB

National Ambient Air Quality Standards (NAAQS)

1. Concentration
2. Exposure duration

Exercise 2.4.1. Given: Regulatory limit for SO_2 in Ambient Air is

- $80\mu g/m^3(0.03ppm)$ for anual average.
- $1300\mu g/m^3(0.05ppm)$ for 3 hour average.
- What is the actual value of Sulphur dioxide in the room to make it hazardous.

.

Results

- Range
  - 20 mg of Sulphur (panic buttons for no reason)

Exercise 2.4.2. What is the volume of this hall (LA 202) in m^3

Question 2.4.3. How do we manage Air Quality?

- At the source itslef
  - Industry (some amount allowed)
  - Vehicles (design the engine or fuel)
  - Dust
  - Home cooking (need to change cooking habits) People from LBNL (Lawrence Berkeley National Labs) got data that not more than 5% change from Chulhas. Provide solar sources or ventilation fan to avoid exposure to hazardous smoke.
- After the source
  - Dispersion and mixing

§2.5 Three kinds of sources

- Point source: chimney
- Line automobiles: moving source
- Plane : Larger areas

§2.6 Mixing/ Dispersion

- Metereology
  - Vertical
    - Lapse Rate
  - Horizontal
    - Wind
      - Speed
      - Direction

§2.7 Dispersion- Gaussian Plume

Insert image (later). Dilution with area increasing on going further and further away. Concentration is ok?

Example 2.7.1

Vadala has high buildings and top floors get more exposed to higher concentrations of pollutants.

Wind Rose

Insert diagram of Grand Rapids from Michigan(later). Each called a petal. Colour of the petal represents the speed. The radial length represents the frequency. Convention: you never know where the wind is going, only where it is coming from.

If all radial lengths are added, they **sum to** 100%.

Exercise 2.7.2. Find the wind rose for your city.

3 Lecture Jan 16

Practice drawing the wind rose diagrams for the exam, insert diagram (later) Wind roses provide

- xyz (later)

Volume of the Lecture Hall: The mixing height is known But in the atmosphere, the mixing height keeps changing.

Atmosphere cools with height

- What rate?
  - Dry (adiabatic) $10^0 C/km$
  - Wet (adiabatic) $6^0 C/km$

Insert diagram(later).
Move a parcel of air adiabatically (assumed to be dry) but the actual environment has different values (measure by a sensor placed in a balloon. (insert diagram (later)). if it is raised by 100m, surrounding temp is $18^0 C$, thus it continues to rise. **Lapse rate** of actual is higher slope angle than

Poorvi suggests the following calculation: For adiabatic process, assuming ideal gas behaviour,

$$PV^\gamma = constant$$
$$\implies P^{1-\gamma}T^\gamma = const$$
$$\implies$$

So temp increases with increase in pressure and vice versa. Leading to unstable equilibrium.

Changing gradient in the atmosphere
This can change the nature of the equilibrium. Unstable dynamics to stable dynamics if the lapse rate changes tobe inside the adiabatic slope. Rate of temp drop is equal to adiabatic drop then its neutral. Volume of diluting air gets reduced by mixing vertically.

> **Exercise 3.0.1.** Two chimneys: (match the profile)

(d): Translate the adiabatic lapse rate to each height and compare the stable vs unstable regimes.

- Wind
- temperature lapse rates.

Question 3.0.2. Why are we doing all this

- If want to know what is the worst case scenario (if stable).
- quantification of lapse rates and wind becomes important.

§3.1 Gaussian Plume (dispersion) model

- Inputs to GPM

Example 3.1.1
Mumbai: Predominant wind direction dictates location of industries.

Example 3.1.2
Australia (forest fires), Singapore no more a destination place.

Exercise 3.1.3. Find the wind rose for-

- Mumbai
- Your city
- Does IMD have a met station near your city

Example 3.1.4 (Chandrapur Super Thermal power station)
Three stations having IMD data. It was the 4^{th} most poluted and after set up of controls and all to end up at 2^{nd}. MIRI and IITB were asked to address the issue. PhD student did his thesis based on this case. Water shortage caused shut down of industries and yet no difference in air quality.

1. Chandrapur is best during rains. Rain makes roads cleaner. Roads are major source.
2. Weather station put on a 30 ft high wwall, so Wind rose from CSTPS was not accurate compared to the other 3. Also compared Ambuja Cement and Lloyd metals. Decided to use MM5 data. Compared well.

Air is not within the profiles of air. Not looking at solid waste, chulhas burning or the roads.

§3.2 Nature of Pollutants

Gaseoues - Air pollution

- Concentration
  - Mass of pollution/volume air
  - no.of particles

  - opacity
- Duration- hours to days to years
- Criteria (US EPA) Pollutants
  - Primary
    * SO_x
    * NO_x
    * CO

NAAQS National ambient air quality standards. (insert table (later)).

These are the pollutants used to check the air quality.

4 Lecture Jan 20

§4.1 Experimental Set-up to measure Mass conentration of PM

Sample vs standard check difference. $\delta(m)$ and q to be measured. Anything larger than 10 μm will get stopped by the nose but smaller can go through to the lungs.

§4.2 Gaseous Pollutants

- smilar sized molecules
- Behaviour
  - Physics: same

§4.3 Paticulate pollutants

- Behaviour: not same.
- Physics: not same

§4.4 Scales

An estimate for the size of an ant is $2mm$. Ants vs elephants. Physics of ants different from that of elements.

§4.4.i Ants and elephants

- Well established physics of ants (Ideal gas) is not applicable to elephants.
- All magic of nano is the new world of elephants.
- Development of instrumentation for nano sizes
- Aerosol enginerring boom
  - Powder production- Materials Science
  - Nano-particles

Size of the particles decides whether they will attach to the lungs or not. Include Osmonics diagram (later). Light getting scattered by the particles reduces the visibility.

Example 4.4.1

Asian Paints has deluxe and normal paint: narrow pigment size scatters the light maximally. Lesser particles but more bright.

Respirable vs Stopped in Nose. Mucus gets black in color because of taking in air pollutants. Tobacco smoke is respirable.

Dispenser for asthama problems: problem because 80% gets stcuk in the lungs. In the villages, 'Chillam'. Physics is the same.

§4.5 Trimodal Size distribution

Another busy graph. Nuclei mode, accumulation mode, Coarse mode. Coarse are not harmful- benign. Combustion activities give rise to nuclei, smallest in size- most toxic. In the middle- neother small to diffuse or small enough sediment, so hangs around. Superimpose graph of no. of particles.

$$\text{Mass of } \quad 1\mu m \quad \text{particles} \quad \equiv \quad \text{Mass of } \quad 1000 \times 0.1\mu m \quad \text{particles}$$

Area under curve gives the number of particles.

$$\int_{d_1}^{d_2} m(dp) \cdot d(d_p) = \quad \text{total Mass of particles}$$

$$\int_{d_1}^{d_2} n(dp) \cdot d(d_p) = \quad \text{No. of particles}$$

Arteries vs veins: oxygenated vs deoxygenated blood. Medical size determined by what can go into the lungs.

Example 4.5.1 (Particle formation in coal combustion)

Vapour phase to solid phase by nucleation (supersaturation). Same as Darjeeling or any cold space has fog exhaling from our mouths. These particles are enriched by heavy metals.

Insert diagram (later) Collection/removal effieciency vs particle diameter.

PM_10 in Rajasthan vs PM_{10} in Mumbai is differetn. Benign in Rajasthan but harmful in India. $PM_{2.5} \subseteq PM_{10}$. $PM_{2.5}$ is more likely to be in Mumbai. Graph of measurements in Mumbai: slope is 2.8 times compared to UK. Shoots up during Diwali. As long as in the box, we meet the air quality standards in India.

- PM_{10} is the mass concentration of mass lesser than $10\mu m$.
- $PM_{2.5}$ is the mass concentration of mass lesser than 2.5 μm.

§4.6 Sizing of Particles

Different sizes will deposit in different parts of the lungs.

Example 4.6.1

Atta filtering out by sieving. Different sizes separate out.

Question 4.6.2. Measure or detect particles of size in order of nanometer range? (smaller particles don't have gravity

Answer Laser scatter from particles enables us to detect.

§4.6.i Instrumentation

Inertial impactor diagram(later). Introduce air from the nozzle, Impaction stage separates into smallest size, medium size and large size. Air takes a turn, ants, mice, horses take turn but elephant gets impacted on the surface. Particle sticks to the surface. Mice, ants, horses that escaped now go through a smaller nozzle with higher velocity, increasing the inertia. Repeat. Histogram of particles deposited on the impact stages (for 10 stages). Get a bimodal distribution.

Question 4.6.3. What is the dependence of size reduction to particle size deposited?

Use filter in the end for collecting particles lesser than 50nm.

5 Lecture Jan 21

Technical failure, laptop hanged. To be written shortly.

6 Lecture Jan 23

Unfortunately, we don't have the promised CO_2 measurement device to demo in the lecture, but we have a $PM_{2.5}$ sampler (high flow vs low flow). This is designed for 5 litres/minute. We usually do a 24hr sampling. Remove the cap from here and it sips in. Inertia removes particles greater than $10nm$. Once it comes in, it passes through the nozzle. It is callibrated to deposit greater than $10\mu m$. When on field, desiccate it first and then weigh it. The jeweller has a expensive weighing balance that is sensitive enough to be used. Difference between the weight before and after will give the PM_{10}. For $PM_{2.5}$, longer unit. For simultaneous measurement, keep both side-by-side. Special surface made from a very pure teflon thin film. For organic carbon, collect it on quartz. The organic vapours will evaporate and then oxidize. Depending on the analysis to be done, use a different substrate. This is just for interest and not for exam.

§6.1 To learn today

- Criteria Pollutant measurements
- Compare with national standards.
- Possible reasons
- If not in compliance, Dispersion Model
  - Are all sources accounted for?

There are 600+ monitoring stations that are going towards continuous monitoring. There's one near H15/16.

§6.2 Data Inference

Annual variation of pollutants data for last seven-eight years. Recently, started looking at the satellite data. A satellite has low resolution but great view point. Seasonal patterns of columnar NO_2 density over Maharashtra. Across UP and Madhya Pradesh also there's two powerplants across the state.

> **Question 6.2.1.** How to account for NO_2 via satellite

There are spectroscopy techniques that pin down the gas. We maybe able to extract the frequencies from the image that correspond to the spectroscopy signature of the gas.

§6.2.i Input Data for Air Quality Modeling

Created a Google doc. and sent to the indutry so that digital data can go into the model. RTO is not concerned about pollution but they will give us data of how many cars and trucks are registered. Survey to get density data in particular areas. Slums, cooking and other stuff have particular organizations. "All we want to know is that what is the

permission for."

- Meteorological data
- Terrain data
- Receptors

Reanalysis data, MM_5 data compared. Similar. Results:

- Yellow bars are actual measurements vs red bars are the estimated. $Yellow >>> Red$. Disaster.
- There's a huge gap so we do diagnostics. Look contribution of only point sources, line sources,etc. No significant contribution found. Recall, there was negligible effect on air quality even after shutting down industries.
- Likely Major source: Cooking stoves and road dust.
- Lets use episodic events

§6.2.ii Episodic Events

Rains

Two slides: one before monsoon and once after. Standard is 100 micrograms per cube, but measured was 1800 micrograms per cube. After monsoon, disappeared. Problem will be solved by managing dust on the roads and Combustion.

Example 6.2.2 (Poverty)
In Chandrapur, roads are trenched from the sides so that while transporting coal, trucks get tilted and the carbon falls out which can be then resold in the market.

Miner's Strike

$PM_{10}, PM_{2.5}$, Black Carbon. measurement.

§6.3 20 Questions Powerpoint

Can't make us air quality experts. Senior prof said that if you can answer the given 100 questions then the course is successful. We shall do with 20 questions.
Use these as pointers to prepare for exam for Air Quality module.

1. What are the classses of air pollutants? How are they managed.
   - Primary : NAAQS
   - Secondary: Ozone
2. Industrial
   - Emission factors: Industrial and vehicular emissions
   - Used to develop an inventory of all air pollutants from various category of sources. Give incentives/ credits for reduced emissions.

3. *Wind Rose: draw for two marks.*
4. Lapse rate: Stable and unstable
5. What are removal mechanisms for larger/smaller particles in the atmosphere?
6. 3 plots, *modes Nucleation, accumulation, Coarse.*
7. Aerosol particles smaller than 1 μm.
8. Electrical mobility measurement.
9. Cascade impactor
10. What is PM_{10} vs $PM_{2.5}$, *and* what could be difference between their levels at different places.*
11. 17. Reproduce Absorption: Individual gases
12. Elements of air quality management
13. Relative global warming potential
14. Albedo: Simple radiation balance: $E = S(1-\alpha) \cdot \pi R^2$,where
    - S = solar constant (1370 W/M^2)

Request to read on environmental issues for an hour everyday. End of teaching by Prof. Virendra Sethi. What a wonderful lecturer has he been! Among the very few who designed his teaching to capture the attention of an entire LA classroom. It was an honor to have the opportunity to be taught by him. Thank You.