Environmental Studies (ES 200, IITB) by Prof. Virendra Sethi Prof. Munish Kumar Chandel Prof. Swatantra Pratap Singh

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 20

§1.1 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.

§1.2 Gaseous Pollutants

- smilar sized molecules
- Behaviour
  - Physics: same

§1.3 Paticulate pollutants

- Behaviour: not same.
- Physics: not same

§1.4 Scales

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

§1.4.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 1.4.1

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.

§1.5 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 de-oxygenated blood. Medical size determined by what can go into the lungs.

Example 1.5.1 (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.

$PM_1 0$ 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.

§1.6 Sizing of Particles

Different sizes will deposit in different parts of the lungs.

Example 1.6.1
Atta filtering out by sieving. Different sizes separate out.

> **Question 1.6.2.** 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.

§1.6.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 1.6.3.** What is the dependence of size reduction to particle size deposited?

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

2 Lecture Jan 21

Technical failure, laptop hanged. To be written shortly.

3 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.

§3.1 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.

§3.2 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 3.2.1.** 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.

§3.2.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

§3.2.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 3.2.2 (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.

§3.3 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.

4 Lecture Jan 27

§4.1 Solid Waste Management

§4.2 Course Logistics

33 Marks. 10 mark for Assignments (will have 3 weeks from now), 23 for Midsem.

§4.3 Solid Waste

> **Question 4.3.1.** What is Solid Waste?

Waste that is solid.

> **Question 4.3.2.** But how to define waste?

Example 4.3.3 (Shirt)
A shirt that is not liked is of no use to one person but maybe useful for someone else

Definition 4.3.4 (Waste)**.** (later)

§4.4 Municipal Solid Waste

Urban Waste (MSW) as opposed to agricultural waste.

§4.5 Rule

Electronic are to be treated separately from biomedical waste. Biomedical waste is related to urban waste, in fact, in US, they are both handled together.

5 Transformation of Solid Waste

Treatment of solid waste. Focus on solid waste management.

> **Question 5.0.1.** Why do we need to treat our physical wastes and what methods can be used?

- Physical
- Pyrolysis
- Composting

§5.1 Shear shredders

Make uniform size depending on further treatment. What kind of shredder? Depends on material, applications etc.

Example 5.1.1 (Segregation Problems)
There's spoons in waste coming from hostel mess. This breaks the shredders. Can there be a sensor put for detecting and segregation of the waste. Next time there could be some stone. Hence this is not efficient.

§5.2 Trommel Screen

Drums with pores. Coarser material remains and rest goes through. Want to use the final compost and sell it in the market.

> **Question 5.2.1.** Screen clogging. How to prevent that? Again segregation system needed.

§5.3 Air Classifiers

Shred the material up to a fine size and then pass through flowing air. Light fraction gets carried away. If we go to any facility, we wil find all kinds of classification machines. Efficiency is still low 10-15%.

§5.4 Magnetic Separation

Separate ferrous materials in the waste depending on magnetic properties. Non-ferrous is not attracted to magnet and it passes pn the coveyer belt. Multiple stage leads to cleaner waste separation.

§5.5 Biological Process

Robot has a fixed number of instructions. In foreign places, laser technology, other technology can be used. Not in India. We have only couple of them - Goa uses conveyer belts, air classifiers and shredders. These are at MRF facility.

§5.5.i Aerobic Stabilization: Composting

IIT Bombay campus has 6 composting sites. There's green shads small buildings. Air flow needed. Aerobic bacteria grows and they eat the waste. Food waste naturally doesn't degrade altogether. It may have lignin components that can stay till 20 years. There's some materials which are simple to degrade, which the bacteria will consume first. Aerobically degraded the food : simpler sugars, fats etc. will degrade. Phosphorus generated may not be sufficient, use artificial, but not too much. The kind of material that you can compost is limited

Advantages

Closed cycle.

§5.5.ii Composting Process

The temperature increase up to 60-65 degrees celsius due to reaction is key to disinfect or kill the microbes and pathogens. This process will be slow if temperature is not allowed to rise. Although aerobic process, need to control, hence not in air. Fungus will start breaking the molecules further. At least in a month's time a good compost will be formed. Stabilization achieved. Residence time of 1 month needs that kind of storage place. Storing 15kg of waste in home itself is challenging. Compost can be produced and used in home.

§5.5.iii Windrow Composting

Big platform. Covering for taking care of Rain etc. Piles for each day. It remains for 4-5 days, temperature increases but air circulation is not off. No pores to move air. Need to use different piles on different days. Moving from one pile to another, gets surface exposed to air. After four weeks time and separate via sieves and then sell in the market. In case there's no air from below, they have aeration system from below. Some design aspects: Moisture needed for bacteria, height of the pile depends on aeration.

Example 5.5.1

Plastics, glass, lead and other stuff may also be in the composting ground. Need to shred first to make fine compost powder. What about pieces that are still remaining as small particles in the powder. If put in agriculture to make hummus, it becomes hard and new plants can't grow out. The heavy metals are included in the food chain.

Whole problem is about mixing of waste. Need bigger market : in farms, maintaining quality by segregating waste at the first stage itself.

§5.6 Drum Composting

Same process as before in a rotating drum to save odour and attraction of rodents, keep aeration. Can suck up the gasses generated.

§5.7 Vermicomposting

Composting we have seen so far is done by bacteria. Here we use worms (especially in rainy season). They eat the food waste and their excreta is a good compost. Better market than before. **Eudrilus Eugeniae** and **Eisenia fetida**- African worms that are strong: 1kg worms eat 1kg residue every day. On campus they can be grown but rats like them.

§5.7.i Types

We have covered:

- Conventional
- Drum Composting
- Vermicomposting : worms to compost

§5.8 Anaerobic Digestion of Solid Waste

Anaerobic bacteria consume food and produce Biogas: 60% Methane (CH_4) and other is CO_2. They can't Digest all so we get : biogas and undigested. Go to Hostel 14 for seeing biogas use in the mess. Putting in back to biogas plant is not that effective.

§5.8.i BARC Mumbai's Biogas Plant

Using solar heat to make the plant work. One behind Tansa and Hostel 4.

§5.8.ii Status India

If economically viable, they would have already become a business. We produce some products which may not payoff for the entire setup.

- 32 MeV from Mumbai MSW with 4000 tonne/day.
- How much electricity can be produced from anaerobic digestion in your city?

Assignment uploaded. Next class we will do waste to energy.

6 Lecture Feb 3

§6.1 Grate Incinerator for MSW burning

Scale issues: Apartment building or personal level application is better.

§6.2 Incinerartion

$S \rightarrow SO_2$, $C \rightarrow CO_2$. Gives calorific value. Plastic, wood, leaves =, food waste (depending on moisture) can be burnt. However, the dust, stones, etc. can be burnt. It is ok to burn but if the calorific value is higher then we can generate heat, electricity, etc.

§6.2.i Grate Incinerator

Bottom ash: inert materials remain. If we have mostly paper etc. then low ash. In India, we have largely low calorific value, hence Incinerator may not be of much use. If the gases going out are harmful, then pollution can be more than generation of energy. Hence, pass through gas filters. These need to be controlled as per standards. It looks simple but modern incinerator have a series of control deivces to control NO_x, Hg, etc. There is extremely efficient incinerator. For instance, Denmark has live screens displaying the values. Almost 60% of the cost of the plant goes into air control. They have a lot of light waste. Our waste has a lot of wet waste. Because the calorific value is lower, we have low incineration .

> **Question 6.2.1.** Calorific value of Coal?

In developed countries its a decent fuel. In India its low (around 6.58?) so we dont burn. Europeana. American and Japanese also go for Incinerators.

§6.2.ii Emissionds

There are emissions:

- Organic : Dioxins, Furans, Polychlorinated biphenyls (PCBs), Volatile.
- Heavy Metals

We have many organic suctances and chlorine.

§6.2.iii Dioxines and Furans

Structure is

- Polychlorinated dibenzo-p-dioxins (PCDDs)
- Dibenzo

Question 6.2.2. Can we control dioxins and furans?

Yes. For instance, there are activated carbon beds, others that can absorb these.
Also residence time can be lowered to control process. This does not allow formation of furans.
Don't put chlorine in wastes. Howver difficult to prevent in foods. Salt has cholrides. Controlling chlorine decreases formation of dioxines and furans.

Question 6.2.3. What to do with the solid ash generated?

The ash is not completely burned. Good residue to be used in cement industry. Some kind of waste may not be good ash to be used in industry. Most probably disposed by landfill.

§6.3 Gasification

Carbon monoxide and Hydrogen are both useful gases. Synthetic gases. How to deal with the gases? Produce gases which may be polluting in nature but use it later. Not going directly to the atmosphere. The problem is that so many materials causes lower efficiency of gasification process. This is still technology in development. Higher temperature.

§6.4 Pyrolysis

Plastic waste can be gasified or pyrolysis. Simply increase the temperature to thermally destroy the waste. Thats the option to deal with plasic waste, Producing synthetic oils close to diesel. Fuel has specific standards with calorific value and compounds. To process, it costs a lot of money. Without processing, it cannot be sold in the market. Challenge remains, research being done. If the plastic is clean, slightly better. Hence Incineration is favored.

§6.5 Disposal

Nothing works then we have to use

- Open dumping: Emissions due to degradation are going into air. Rains will cause leeching to take the waste into rivers and oceans.
- Barging in to sea: Not acceptable now due to rise in plastic in oceans
- Land filling: Disposal in soils of Earth. Problems are with accumulation of gases. Scientific landfilling. Put a liner system on the bottom. Cap system so that gases are captured and treated. Waste generated is also treated.

§6.6 Sanitary Landfill

Components:

- Liner System
- Cap system

- Gas management system
- Leachate management system
- Air and water managemenet system

§6.6.i Landfill operation

Compacted soil (source wikipedia commons) and put liner. On the top of liner, leachate generated. Collecting from many pipes into a common. Design of components: perforation, vacuum generation, slopes, holes clogging etc. need to be managed.

§6.6.ii Landfill Cell

Compacted waste cell. Need to buy soil. Put six inches of soil everyday. Another challenge. Compost generated is of low value. Another big problem in rainy season. Rains in Mumbai for three months. No perfect solution, need to move to a temporary place.

Vertical Piping Section

> **Question 6.6.1.** What will be the composition of the gas?

Anaerobic conditions due to large numebr of layers. Methane and CO_2 largely comprising the gas. Can use as fuels. Many times the gases are flared.

> **Question 6.6.2.** Why cant we directly let the gases go to atmosphere? Why flare it when we are not producing any energy out of it?

§6.6.iii Postclosure Care

MSW rules 2016 recommends at least fifteen years of monitoring. Also monitor water both upstream and downstream. Ensure that no pollution is being caused by the site. Maybe used for construction later or restore landfill to create recreational parks or grounds.

> **Example 6.6.3** (Estimating Landfill Requirements)
> Calculate the area required (later)

§6.7 MBT : Mechanical Biological Treatment

Mixed waste is coming: want to deal with waste separately. Segregate biologically, mechanically. Conveyer belt on which there is manual sorting.

§6.8 Environmental Hierarchy of MSW Management

Open dumping is not counted as a technology.

7 Lecture Feb 4

§7.1 Biomedical Waste Managament

Types of Hospital Wates: Infeectious vs Non-infectious.

§7.2 Infectious Waste

In rains, there is increase in infections due to spread of such waste by rains, viruses can easily spread. Need to isolate this waste.

§7.3 Non-infectious waste

Non-infectious Hospital waste may come from:

- Kitchen Waste and office wastes $\sim$ to household waste.
- Non-infectious wastes constitute $\sim$ 80-85 %.

§7.4 Status in India

There are cler guidelines to be very cautious with biomedical waste.

Example 7.4.1 (Study in 2011)
52,000($\sim$ 53%), helath care establishments are in operation without having the permissions from SPCBs, PCCs which means that the waste generated from such facilities goes unaccounted and is dumped without any adequate treatment illegally.

Example 7.4.2
288.2 tons($\sim$ 57%), treated properly.

Biomedical Waste generation average is 1.60kg/bed/day.

§7.4.i Rules 2016

Management and handling rules 2016:

- Every occupier to take all necessary steps to ensure bio-medical waste is handled wothout any adverse effect to health.

Question 7.4.3. What happens to the waste from IITB hospitals?

Go there and ask.

§7.5 Elements of Biomedical Waste Management

As per rules

Biomedical Waste
↓
Biomedical waste minimization/separation
↓
Biomedical waste identification
↓
Biomedical Waste treatment

To make a proper register to maintain records and government can cross-verify.

§7.6 Categories, Segmentation, treatment

§7.6.i Yellow

Production of dioxins and furans is much higher if the plastic bags are chlorinated. Hence use yellow bags which are non-chlorinated. Skipping this part because nothing much to say.
In exams, ask a lot of quantities. Its very difficult as engineers to not quantify stuff. Be careful to specify quantities precisely.

§7.7 Treatment

Needle Cutter and Syringe Destroyer. Disinfection of needles. Boiled water may also spread diseases, so now use "use and throw" ones.

§7.8 Incinerator

Incineration is prefered in biomedical wastes. Out of 8000 tonnes generated, only 50 tonnes it is easier to get rid of quickly. Want to destroy most of the waste especially when it may be infectious. Hence burning will give disinfection and destroy the waste.

§7.8.i Operating Standards

Combustion efficiency (CE) shall be at least 99.00%. Excess oxygen (air) is used to ensure full combustion happens. Residence time is finite hence, extra oxygen is needed to drive the kinetics. The combustion efficiency is

$$\text{efficiency} = \frac{\%CO_2}{\%CO_2 + \%CO \times 100\%}$$

§7.8.ii Emission Standards

All standards are in nanograms because hazardous. Stack Height: Minimum height shall be 30m above the ground. However in cities with 50m buildings this is infeasible.

§7.9 Microwaving

Microbial inactivation occurs as a result of thermal effect of electromagnetic radiation spectrum lying between the frequencies 300 to 30000Hz. This is a disinfection technology.

§7.10 Autoclave

Generate high pressure steam and use to kill the bacteria.

> **Question 7.10.1.** How to check if the job is done or not

Non-tempered panel recording the stats.

§7.11 Irradiation

Gamma radiation is used for killing the germs.

§7.12 Plasma Pyrolysis or Gasification

Plasma torch can generate 20000^0C. To heat, we can use furnace etc. but not efficient to be used inside hospitals, hence better to use plasma torch. For instance at Goa Medical College.

§7.13 Common Bio-Medical Waste Treatment Facility (CBWTF)

Installation of individual treatment facilities allowed by the government. This will have all: incinerator, autoclaving, pyrolysis etc. Agreement by paying fees to the common facility. Better than asking individual hospitals.

§7.14 Deeo Burial

In rural areas which are farther away from cities, difficult to transport the waste. Hence, allowed to do deep burial. Deep inside the soil, build a burial.

> **Question 7.14.1.** What about water, flooding? What if animals uncover it?

Only allow in places where these possibilities are negligible.

> **Question 7.14.2.** What to do with ash generated after incineration?

Secure Landfill. Here the big difference is a double liner system. Extra cautious. We can do something if the first lining fails.