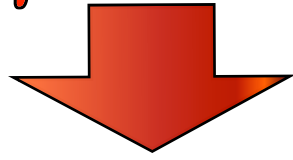
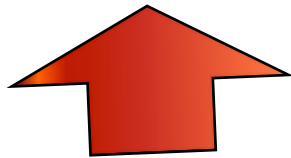


Top-down



SOURCE APPORTIONMENT



Bottom-up

Dr. Sarath Guttikunda
UrbanEmissions.info

A Primer on Source Apportionment (2011)

Author: Dr. Sarath Guttikunda

Designed by: Puja Jawahar

DISCLAIMER:

All characters are fictional.

**Errors & interpretations are the sole responsibility
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What's covered in here?

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SOURCE APPORTIONMENT

CITY REPRESENTATIVE

SIM-AIR MAN (FACILITATOR)

HOW DO WE REDUCE POLLUTION IN THE CITY?

FIRST WE NEED TO CONDUCT A SOURCE APPORTIONMENT STUDY WHICH WILL TELL US WHAT THE SOURCES OF POLLUTION ARE AND HOW MUCH EACH SOURCE CONTRIBUTES TO TOTAL POLLUTION.

I ALREADY HAVE AN IDEA OF THE SOURCES OF AIR POLLUTION HERE. WHY DO I NEED A STUDY?

BECAUSE A STUDY WILL SCIENTIFICALLY DETERMINE THESE CONTRIBUTIONS. THUS ELIMINATING THE TENDENCY TO OVEREMPHASIZE CERTAIN SOURCES OR UNDEREMPHASIZE OR IGNORE OTHERS.

THERE ARE 2 WAYS TO CONDUCT SOURCE APPORTIONMENT.

- 1) A TOP-DOWN APPROACH, WHICH INVOLVES COLLECTING SAMPLES AND ANALYZING THEM IN A LAB.
- AND/OR
- 2) A BOTTOM-UP APPROACH, WHICH USES EXISTING DATA AND SURVEY METHODS.

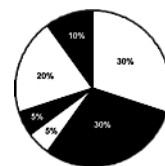
ARE THE RESULTS OF THE 2 METHODS SIMILAR?

IDEALLY YES.

USING THE TOP-DOWN APPROACH, WE GET ACCURATE RESULTS FOR SPECIFIC LOCATIONS (WHERE SAMPLES ARE COLLECTED), WHICH WE THEN AVERAGE TO GET A CITY-LEVEL PROFILE.

USING THE BOTTOM-UP APPROACH, DEPENDING ON THE EXISTING DATA, WE GET POLLUTION ESTIMATES FOR ANY PART OF THE CITY.

TOP-DOWN



BOTTOM-UP

TOP-DOWN APPROACH

(1)
DECISION TO
CONDUCT SOURCE
APPORTIONMENT



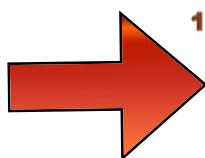
(2)
AMBIENT
SAMPLING



(3)
LABORATORY
ANALYSIS

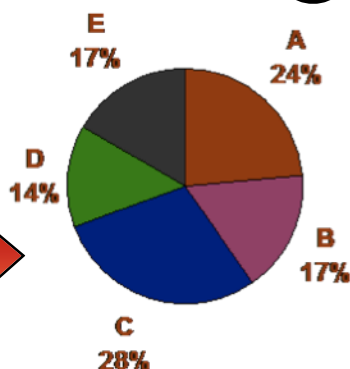


(4)
RECEPTOR
MODELING

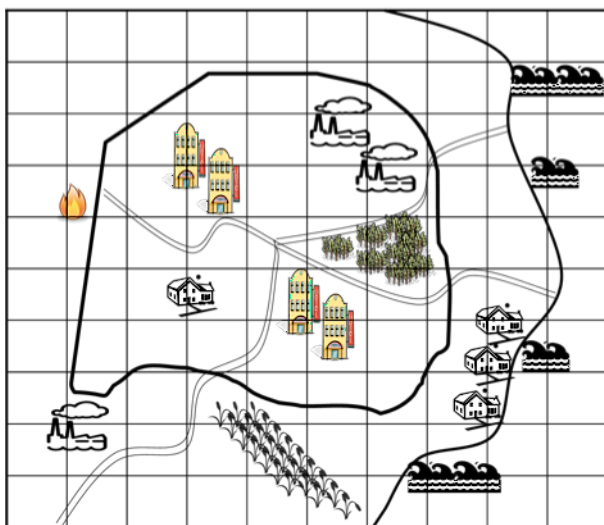


THIS APPROACH MEASURES POLLUTION
USING FILTERS. THESE ARE THEN
ANALYZED IN THE LAB FOR CHEMICAL
SIGNATURES TO ASSESS SOURCE
CONTRIBUTIONS.

THE
STEPS SEEM
STRAIGHT
FORWARD, BUT I AM
SURE EACH ONE IS
A PROJECT IN
ITSELF...



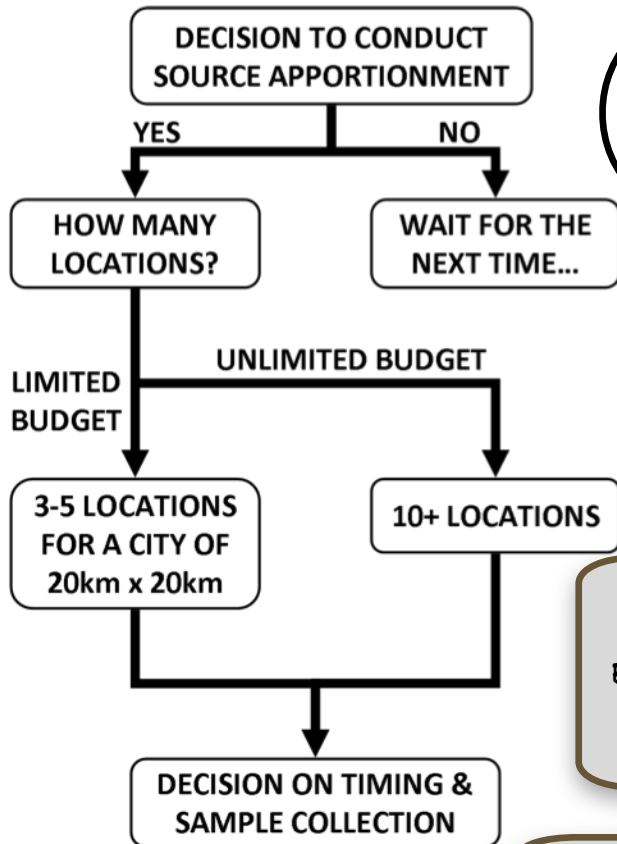
HOW MANY SAMPLES DO
WE COLLECT?



THE MORE THE MERRIER...
KEEPING BUDGET CONSTRAINTS
IN MIND, AN IDEAL STUDY WOULD
INCLUDE A MIX OF RESIDENTIAL,
INDUSTRIAL, ROADSIDE AND
BACKGROUND LOCATIONS AND
COLLECT AT LEAST 15 SAMPLES
FROM EACH LOCATION EVERY
SEASON.

THIS METHOD IS APPLIED FOR PARTICULATE POLLUTION ONLY. AMBIENT SAMPLING IS
CARRIED OUT FOR TWO SIZE FRACTIONS - PM₁₀ (COARSE PM) AND PM_{2.5} (FINE PM)

Ambient Sampling



WHY DO WE NEED TO CONDUCT SAMPLING FOR EVERY SEASON?

WHILE SOME OF THE SOURCES REMAIN THE SAME EVERY SEASON, FUEL CONSUMED AND RESULTING POLLUTION VARIES ...

METEOROLOGICAL CONDITIONS ALSO VARY BETWEEN SEASONS, WHICH AFFECTS THE AMBIENT POLLUTION.

A MULTI-SEASON STUDY THUS PROVIDES MORE ACCURATE RESULTS ON AVERAGE.

FOR A PARTICULAR SEASON, SAMPLING SHOULD BE CONDUCTED SIMULTANEOUSLY AT ALL LOCATIONS.

THIS WILL ALLOW FOR COMPARISON OF POLLUTION LEVELS AND SOURCES BETWEEN LOCATIONS.

CAN YOU TELL US ABOUT A COMMONLY USED SAMPLER?

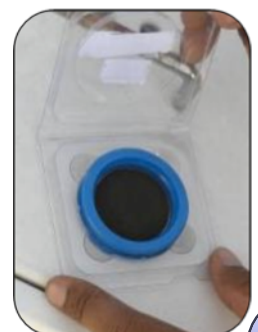
WE NEED FILTER BASED SAMPLERS
(SEE THE PICTURE FOR AN EXAMPLE OF A MINI-VOL SAMPLER - THESE ARE PORTABLE, EASY TO HANDLE AND ARE BATTERY OPERATED)



FOR EXAMPLE, DOMESTIC AND INDUSTRIAL HEATING REQUIREMENTS ARE DIFFERENT BETWEEN SUMMER AND WINTER.



AN EXAMPLE OF A SAMPLE FILTER FOR STORAGE



Laboratory Analysis



ONCE COLLECTED,
WHAT DO WE DO WITH THE
FILTER SAMPLES?



THE FILTERS ARE STORED IN A
CONTROLLED ENVIRONMENT (TO
PROTECT THE SAMPLES) AND SENT
TO THE LABORATORY FOR ANALYSIS.

WHY DO WE NEED SO
MUCH LAB WORK?



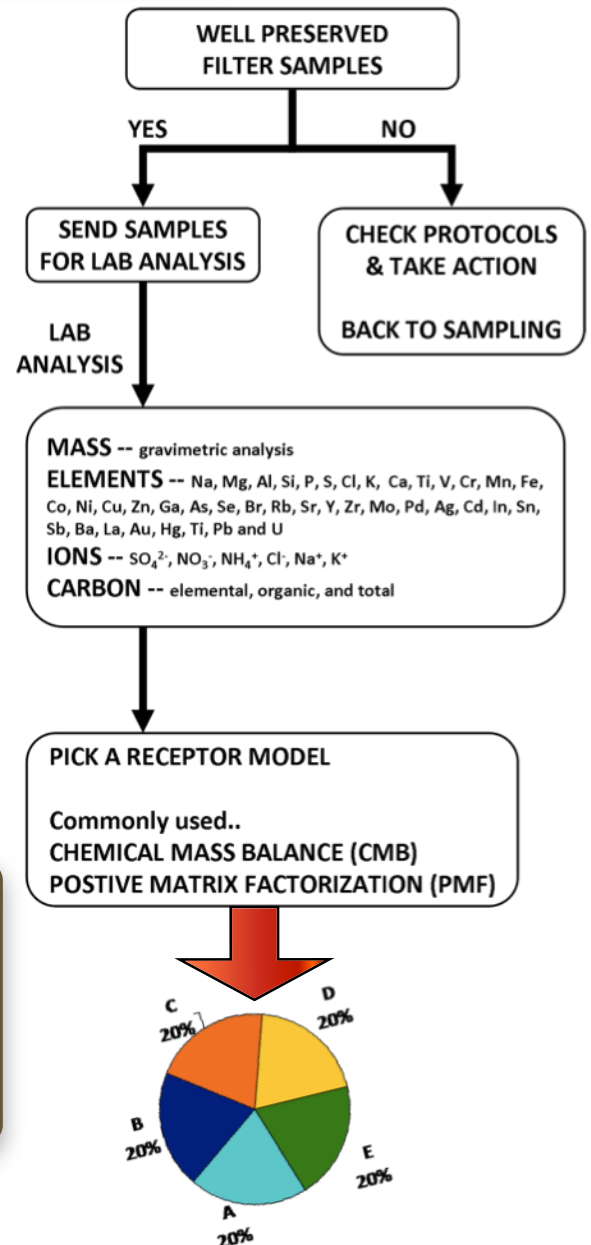
WE NEED INFORMATION ON METALS,
IONS, AND CARBON TO
SUCCESSFULLY DETERMINE THE
SOURCE CONTRIBUTIONS - THERE IS
NO SINGLE LABORATORY EQUIPMENT
TO ANALYZE THEM ALL.



HOW EXPENSIVE IS THIS
ANALYSIS?

THE LAB EQUIPMENT IS NOT CHEAP. HOWEVER,
ONCE THE SYSTEMS ARE IN PLACE AND WITH
PROPER TRAINING, ONE COULD REPLICATE
THESE STUDIES.

IF A CITY DOES NOT OPERATE ITS OWN LABS, THEY
CAN SEND THE SAMPLES TO A CERTIFIED LAB.



Receptor Modeling



EXPERT ON
MODELING

THE MOST COMMON
RECEPTOR MODEL USED FOR
THIS KIND OF ANALYSIS IS THE
CHEMICAL MASS BALANCE (CMB)
MODEL.

BESIDES THE LAB ANALYSIS, WE
NEED SOURCE PROFILES.



WHAT ARE SOURCE
PROFILES?

A SOURCE PROFILE
LOOKS SIMILAR TO THE
RESULTS OF AN AMBIENT
SAMPLE, BUT IS SPECIFIC TO
THE SOURCE TYPE



IT IS DEVELOPED
BY COLLECTING
SAMPLES VERY CLOSE
TO THE SOURCE, IN
ORDER TO CAPTURE
THE SOURCE'S
"SIGNATURE"

INDUSTRIES

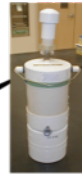


stack
sampling

STOVES



In-situ
sampling



IDEALLY, ONE SHOULD HAVE
SOURCE PROFILES FROM THE CITY
WHERE THE STUDY IS BEING CONDUCTED.
HOWEVER, IF BUDGETS ARE LIMITED, WE
CAN BORROW SOURCE PROFILES FROM
OTHER CITIES WITH SIMILAR POLLUTION
SOURCES.

COMMON MARKERS INCLUDE

AL & SI FOR ROAD DUST
K FOR BIOMASS
NA FOR SEA-SALT
A MIX OF METALS FOR COAL
BC & OC RATIOS FOR VEHICLE EXHAUST

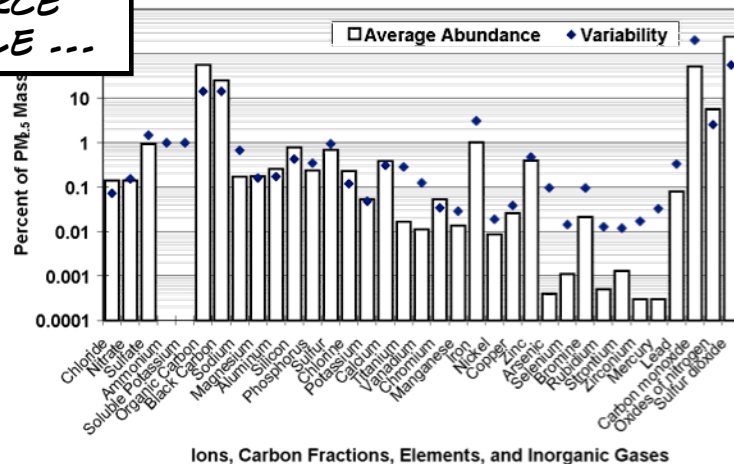
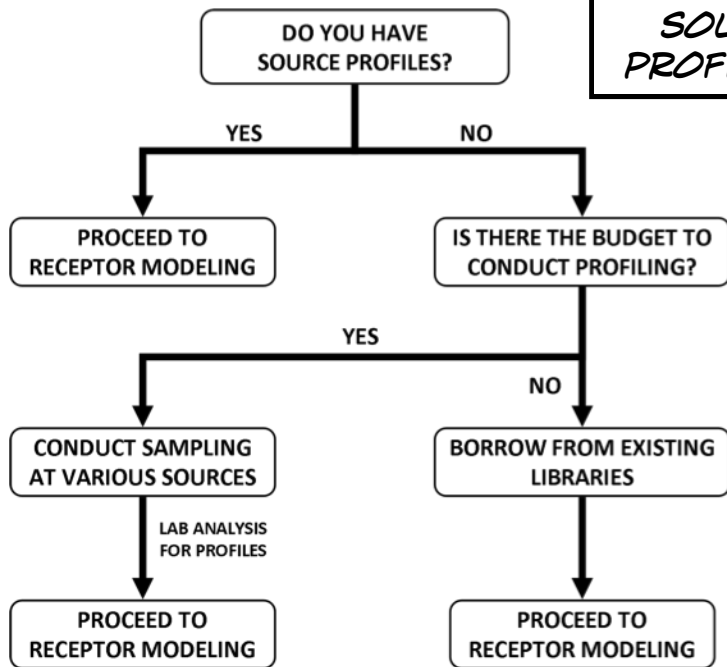
CARS



tailpipe
sampling



AN EXAMPLE SOURCE PROFILE ...

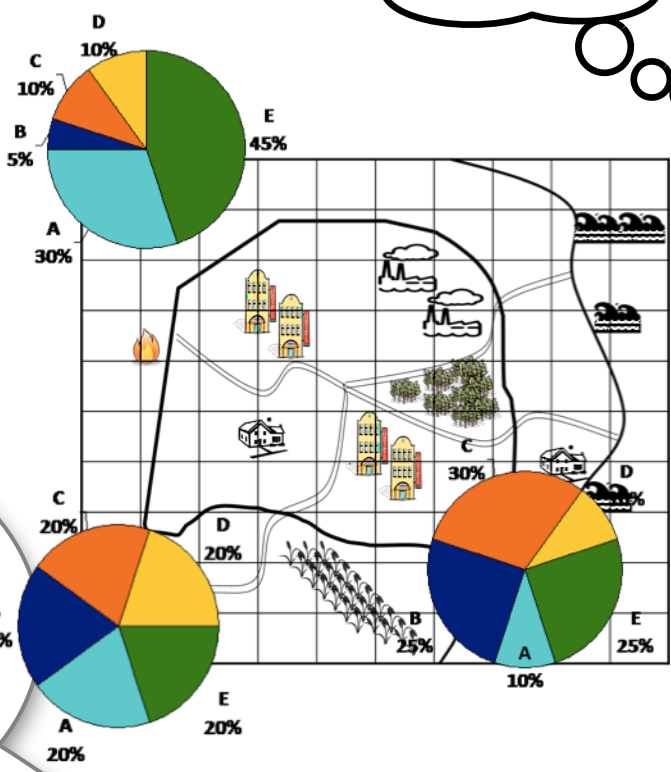


THESE SOUND LIKE CHALLENGING (AND EXPENSIVE!) STEPS...



THIS APPROACH PROVIDES POLLUTION INFORMATION SPECIFIC TO THE SAMPLING LOCATION.

FOR EXAMPLE, A SAMPLE COLLECTED NEAR A TRAFFIC JUNCTION WILL IDENTIFY TRANSPORTATION AS THE LARGEST SOURCE OF POLLUTION.



EACH FILTER SAMPLE ONLY REFLECTS THE SOURCES THAT ARE WITHIN A 2-3 KM RADIUS OF THE SAMPLING SITE. THEREFORE, BY AVERAGING THE RESULTS FROM SEVERAL LOCATIONS YOU GET AN APPROXIMATION OF CITY-LEVEL PROFILE.



CAN WE REPEAT THIS
EXPERIMENT FOR ALL
POLLUTANTS?

NO. THIS METHOD
ASSESSES SOURCE
APPORTIONMENT FOR
PARTICULATE POLLUTION
ONLY.



IN SUMMARY, WHEN ALL THE PROTOCOLS ARE FOLLOWED, THIS
TOP-DOWN APPROACH IS SCIENTIFICALLY ROBUST AND PROVIDES
CREDIBLE RESULTS.

AT THE SAME TIME, THIS CAN GET PRETTY EXPENSIVE, PROVIDES LIMITED
INFORMATION (DEPENDING ON HOW MANY SAMPLES WE COLLECT), AND IS
APPLICABLE FOR PARTICULATE POLLUTION ONLY.

BUT THE CITY IS EXPANDING FAST AND RESOURCES ARE LIMITED. PLUS THERE
MIGHT BE NON-PARTICULATE POLLUTANTS SUCH AS SO₂, NO_x, CO, AND
OZONE, WHICH ARE ALSO AT CRITICAL LEVELS.

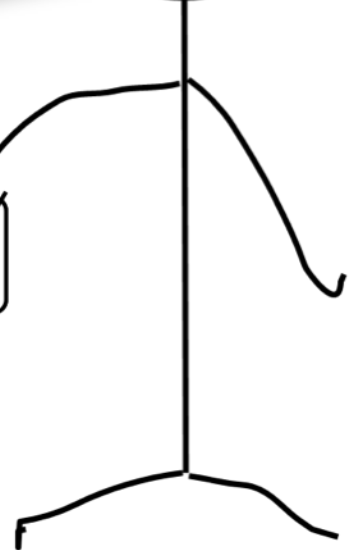
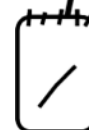
IN THIS CASE, WHAT ARE OUR ALTERNATIVES?

THAT IS A GOOD OBSERVATION.

IN ADDITION TO FOLLOWING ALL PROTOCOLS
CAREFULLY, ONE ALSO HAS TO ENSURE THAT THE
ANALYSIS IS CONDUCTED BY A REPUTABLE LABORATORY.

THERE IS AN ALTERNATIVE APPROACH THAT I MENTIONED
EARLIER, WHICH USES EXISTING DATA AND SURVEY
METHODS.

WE WILL DISCUSS THIS APPROACH IN THE NEXT SECTION
- BOTTOM-UP APPROACH



NOTES AND QUESTIONS...

BOTTOM-UP APPROACH

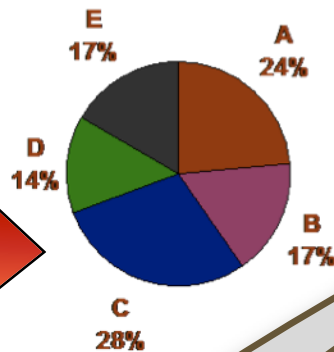
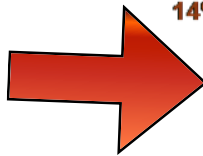
(1)
DECISION TO
CONDUCT
MODELING



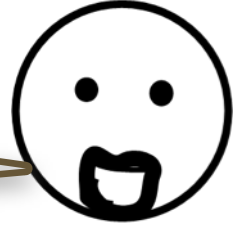
(2)
EMISSIONS
INVENTORY



(3)
DISPERSION
MODELING



A BOTTOM-UP APPROACH
ESTIMATES POLLUTION BASED ON
THE DISTRIBUTION OF POLLUTION
CAUSING ACTIVITIES IN A CITY



IT IS REALLY IMPORTANT THAT
EVERY CITY ESTABLISHES AN
EMISSIONS INVENTORY.

THIS SERVES AS A BASELINE FOR
MANY POLLUTION AND URBAN
POLICY RELATED ACTION PLANS.

A BASIC INVENTORY CAN BE
DEVELOPED USING
EXISTING INFORMATION AND
MINIMUM RESOURCES.

FIRST, YOU MAP VARIOUS
POLLUTION-CAUSING
ACTIVITIES*. THEN YOU ZERO IN
ON EACH OF THESE SOURCES TO
ESTIMATE ENERGY
CONSUMPTION AND EMISSIONS.



* COMMONLY ADDRESSED SOURCES ARE

INDUSTRY - CEMENT, BRICKS, POWER
PLANTS, ETC

RESIDENTIAL COOKING AND HEATING

GARBAGE BURNING

VEHICLE EXHAUST AND ROAD DUST

CONSTRUCTION AND

SMALL DIESEL POWER GENERATOR SETS

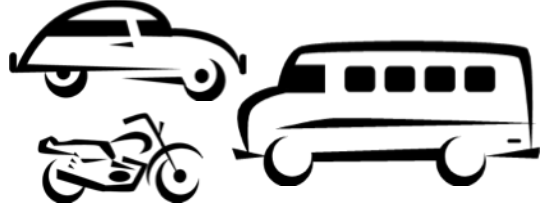
Emissions Inventory



WHAT KIND OF ACTIVITY DATA IS REQUIRED TO CREATE AN EMISSIONS INVENTORY?



COMPILE INDUSTRIAL ENERGY CONSUMPTION THROUGH AUDITS & ENERGY STATISTICS



.... ANALYZE VEHICLE STATISTICS FROM TRANSPORT CENSUS FOR VEHICLE MILES TRAVELED, NO OF VEHICLES, ETC....



.... SURVEY THE DOMESTIC SECTOR TO GET A SENSE OF ENERGY USE AT THE HOUSEHOLD LEVEL....

WE CAN THEN USE EXISTING EMISSION FACTORS TO CALCULATE EMISSIONS BY SECTOR

ONCE WE HAVE GATHERED THIS DATA ABOUT INPUTS/ENERGY USE BY SECTOR, WE CAN USE EXISTING EMISSION FACTORS**....

**** EMISSION FACTOR: UNIT OF POLLUTION RELEASED PER UNIT OF ENERGY CONSUMED. THUS... $\text{EMISSIONS} = \text{EMISSION FACTOR} * \text{ENERGY}$**



WHAT OTHER SOURCES SHOULD WE CONSIDER?

SEASONAL SOURCES SUCH AS DUST STORMS, FOREST FIRES, AND AGRICULTURAL BURNING ALSO CONTRIBUTE TO POLLUTION.





WE DO NOT HAVE ACCESS TO CITY SPECIFIC EMISSION FACTORS. DOES IT AFFECT RESULTS IF WE USE EXISTING EMISSION FACTORS FROM THE LITERATURE VERSUS PRECISE FACTORS?

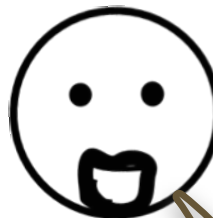


NOT REALLY.

EMISSION FACTORS DO VARY DEPENDING ON THE COMBUSTION TECHNOLOGIES IN USE IN THE CITY - BUT USUALLY FALL WITHIN A RANGE.

IF YOU HAVE BUDGET AND TIME CONSTRAINTS, USING EXISTING NUMBERS IS A GOOD WAY TO START.

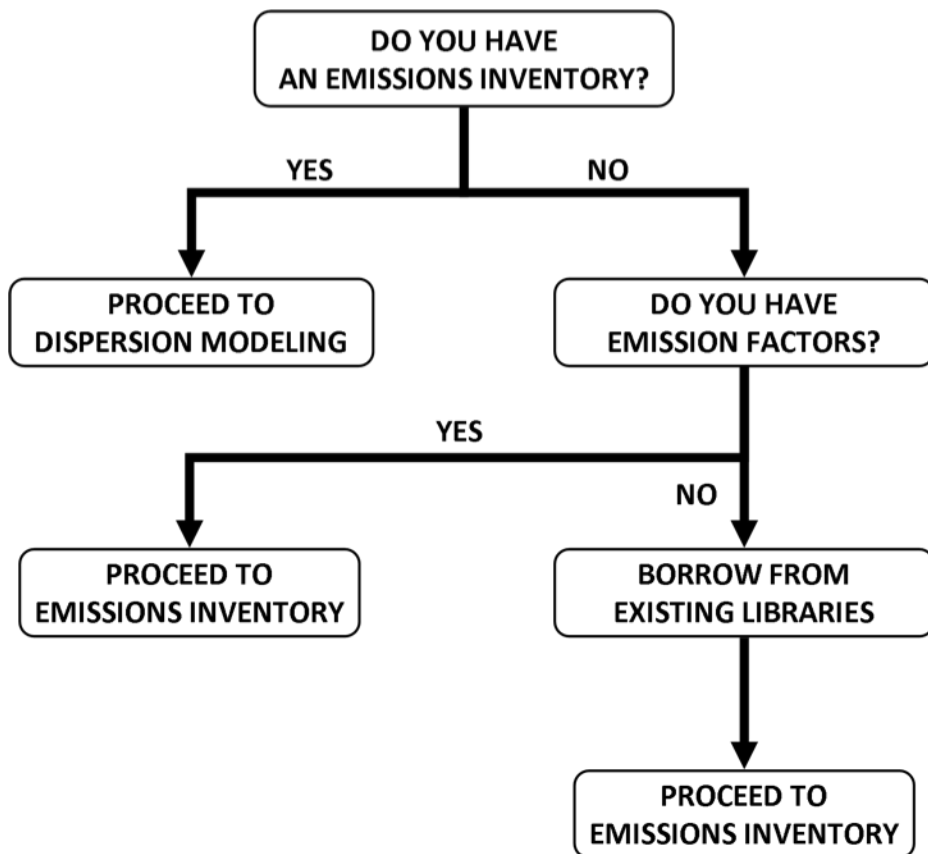
THIS CAN ALWAYS BE IMPROVED UPON TIME AND RESOURCE PERMITTING.



THATS RIGHT !

AT THE INDUSTRY LEVEL, A LOT OF SPECIFIC DETAILS ARE REQUIRED.

BUT, AT THE URBAN AND REGIONAL LEVELS, AGGREGATE INPUTS SUFFICE.



USUALLY INVENTORIES ARE ESTABLISHED FOR PARTICULATES (PM), SULFUR DIOXIDE (SO₂), NITROGEN OXIDES (NO_x), CARBON MONOXIDE (CO), HYDROCARBONS (VOC'S), BLACK CARBON (BC), AND ORGANIC CARBON (OC) - TONS/YEAR



OUR EMISSIONS INVENTORY FOR PARTICULATES GIVE US THE PERCENTAGE CONTRIBUTION OF VARIOUS SOURCES.. AND WE ALSO HAVE THE PERCENTAGE CONTRIBUTION FROM THE TOP-DOWN APPROACH.

WHAT IS THE DIFFERENCE BETWEEN THE TWO?



THAT'S A VERY IMPORTANT QUESTION.

THOSE TWO RESULTS ARE IN FACT VERY DIFFERENT.

RESULTS OF AN EMISSIONS INVENTORY GIVE THE WEIGHT OF POLLUTION FROM VARIOUS SOURCES (MASS/YEAR)

RESULTS OF A TOP-DOWN STUDY GIVE THE SOURCE CONTRIBUTIONS TO THE AMBIENT CONCENTRATIONS (MASS/VOLUME).

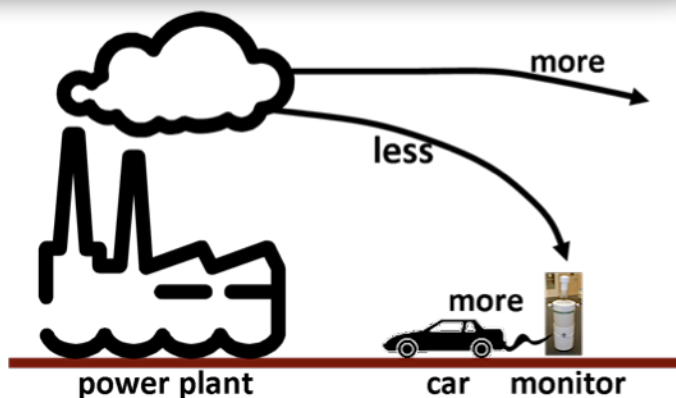
USING A DISPERSION MODEL (AND LOCAL METEOROLOGICAL CONDITIONS), WE CAN CONVERT THE EMISSIONS INTO AMBIENT CONCENTRATIONS.

THESE RESULTS CAN THEN BE COMPARED TO THE RESULTS OF THE TOP-DOWN APPROACH.

THE TYPE OF SOURCES INFLUENCE AMBIENT CONCENTRATIONS.

FOR EXAMPLE, GROUND LEVEL EMISSIONS FROM VEHICLE EXHAUST, THOUGH A SMALL % IN THE INVENTORY HAVE A DISPROPORTIONATELY LARGER SHARE IN THE LOCAL CONCENTRATIONS.

WHILE, A POWER PLANT EMITTING A LOT OF POLLUTION, CONTRIBUTES LESS TO THE IMMEDIATE VICINITY DUE TO LONG RANGE TRANSPORT.



THAT MAKES SENSE..



% EMISSIONS **DOES NOT EQUAL** % CONCENTRATIONS

Dispersion Modeling

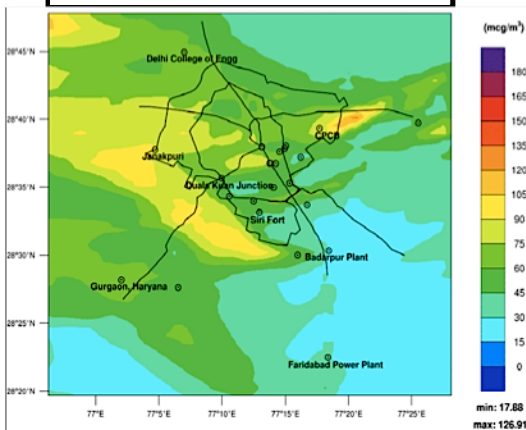


ONCE WE HAVE OUR EMISSIONS INVENTORY, DISPERSION MODELING ALLOWS US TO GET A SPATIAL PICTURE OF POLLUTANT "CONCENTRATIONS"

DISPERSION MODELING IS A TECHNICALLY CHALLENGING STEP, WHICH REQUIRES A CERTAIN LEVEL OF TRAINING AND PROFICIENCY. OFTEN THIS STEP BECOMES A BOTTLE-NECK FOR CITIES TRYING TO MAP POLLUTION.

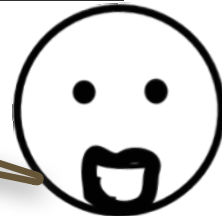
SEE THE COMPARISON OF MODELS BELOW.

AN ILLUSTRATION OF A DISPERSION MODELING OUTPUT ----



	Box	Plume	Eulerian
Complexity	★	★★	★★★★
Data requirement	★	★★	★★★★
Pollutant chemistry	★	★★	★★★★
Advection of pollutants		★★	★★★★
Ease of operations	★★★★	★★	★
Computational requirements	★	★★	★★★★
Results - level of detail	★	★★	★★★★

THE OUTPUT OF THIS STEP IS MOST VALUABLE, SINCE THE GRIDDED CONCENTRATIONS WILL PROVIDE US WITH A POLLUTION MAP, ALONG WITH HOT SPOT LOCATIONS, FOR THE ENTIRE CITY.



ARE THERE ANY SPECIFIC MODELS WHICH WE CAN FOLLOW?

FOR EXAMPLE, MODELS LIKE GAINS, HEAT, SEI TOOLKIT, AND USEPA'S AP-42, CAN HELP WITH EMISSIONS INVENTORY;

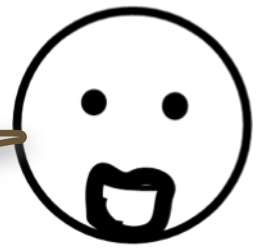
MODELS LIKE CMAQ, WRF, ATMOS, AND ISC3, CAN HELP WITH DISPERSION MODELING.

AFTER CAREFUL CONSIDERATION OF REQUIREMENTS AND RESOURCES, ONE SHOULD CHOOSE AN APPROPRIATE MODEL.





SHOULD WE MODEL
ALL POLLUTANTS?



NOT NECESSARILY.

YOU CAN FOCUS ON THE CRITICAL POLLUTANTS, ACCORDING TO THE PURPOSE OF THE POLLUTION ANALYSIS. FOR EXAMPLE, FOR PUBLIC HEALTH CONCERNS FINE PM IS CRITICAL, FOR ACID RAIN CONCERNS - SO₂ AND NO_x, VISIBILITY - SMOG PRODUCING OZONE, AND SO ON..

BUT IF YOU HAVE THE RESOURCES, INSTITUTIONAL CAPACITY, AND DATA, YOU CAN MODEL ALL POLLUTANTS AND GET A COMPREHENSIVE ASSESSMENT OF POLLUTION IN THE CITY.

BUT, THE CHEMISTRY OF THE
POLLUTANTS IS INTERLINKED.

THAT IS CORRECT..

CHEMISTRY OF POLLUTANTS IS INTERLINKED, WHICH
CAN BE INCLUDED IN THE MULTI-POLLUTANT
DISPERSION MODELING.

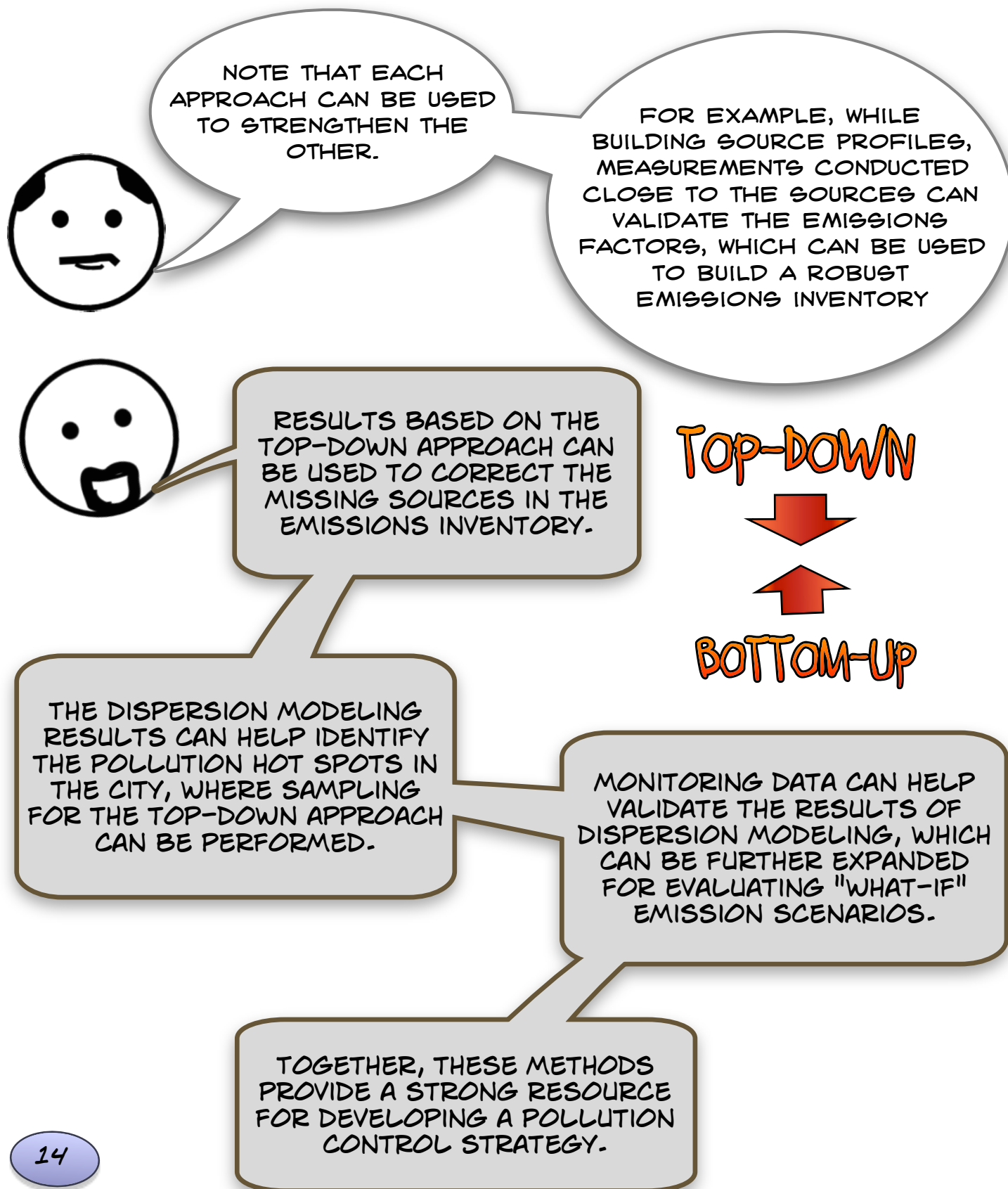
CAN I USE THIS ANALYSIS
FOR HEALTH IMPACT
ASSESSMENTS?

CERTAINLY.

THE GRIDDED CONCENTRATIONS, ALONG WITH GRIDDED
POPULATION OVER THE CITY, CAN BE USED FOR
MORTALITY AND MORBIDITY CALCULATIONS.

A MAJOR CONCERN IS IN THE EMISSIONS
INVENTORY STEP. WE NEED A GOOD
UNDERSTANDING OF THE GEOGRAPHICAL SPREAD
OF THE MAJOR SOURCES OF POLLUTION.

RECONCILING RESULTS



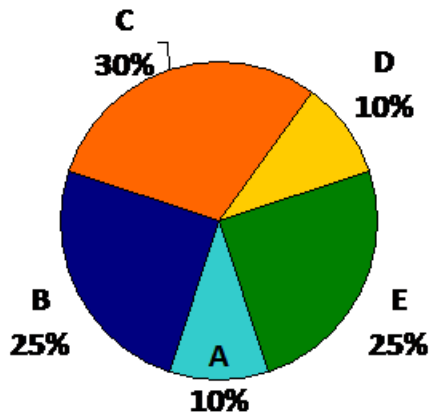
IN SUMMARY



EXCELLENT.

THESE ARE TWO DISTINCT APPROACHES TO COME TO THE SAME CONCLUSIONS.

DEPENDING ON OUR TECHNICAL AND FINANCIAL RESOURCES, WE CAN UTILIZE EITHER APPROACH (OR BOTH).



EXACTLY.

BOTH THE METHODS ARE ROBUST AND WELL TESTED IN CITIES ACROSS THE WORLD.

THE MOST IMPORTANT STEP IS TAKING THE DECISION TO CONDUCT A SOURCE APPORTIONMENT STUDY. THEN, BASED ON YOUR BUDGET AND THE INFORMATION THAT IS ALREADY AVAILABLE, WE CAN DECIDE WHICH APPROACH IS MOST APPROPRIATE

INDEED.. THANK YOU !!

FOR MORE DETAILS AND CASE STUDIES, YOU CAN VISIT US
@ [HTTP://WWW.URBANEMISSIONS.INFO](http://www.urbanemissions.info)

OR

SEND ME AN EMAIL
[SIMAIR@URBANEMISSIONS.INFO](mailto:simair@urbanemissions.info)

FURTHER REFERENCES

A handbook published by ESMAP (the World Bank, 2011) on the techniques of source apportionment, along with an array of applications from across the world is available
@ <http://www.esmap.org/esmap/node/1159>

An application of top-down and bottom-up approaches for the city of Hyderabad, India, was conducted under the US-EPA's IES program in 2007-08, is available
@ <http://www.epa.gov/ies/india/apportionment.htm>

An application of the bottom-up approach in Delhi, India, where an emissions inventory was built, as part of an air quality forecasting system is available
@ <http://www.aria.fr/delhi>

The "Chemical Mass Balance" (CMB) is the most common receptor model in use for a number of source apportionment studies across the world. An overview of the model, along with the merits and limitations are explained in detail
@ http://www.epa.gov/scram001/receptor_cmb.htm

To estimate emissions inventory, conduct dispersion modeling, and assess health impacts, access the the SIM-air family of tools
@ <http://www.urbanemissions.info>

www.urbanemissions.info