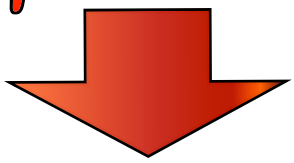
TOP-DOWN



SOURCE APPORTIONMENT

BOTTOM-UP

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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 of the authors.

What's covered in here?

SOURCE APPORTIONMENT

CITY REPRESENTATIVE

SIM-AIR MAN (FACILITATOR)

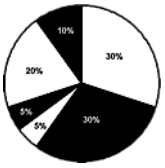
HOW DO WE REDUCE POLLUTION IN THE CITY?

FIRST WE NEED TO CONDUCT A SOURCE APPORTIONMENT STUDY WHICH WILL TELLS 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.

TOP-DOWN



BOTTOM-UP

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.

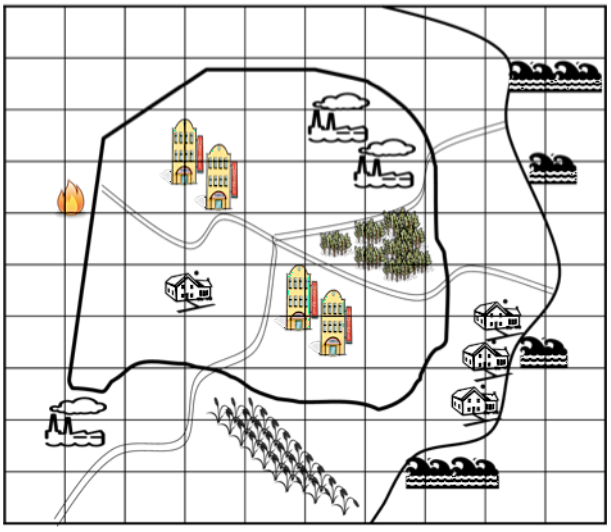
TOP-DOWN APPROACH

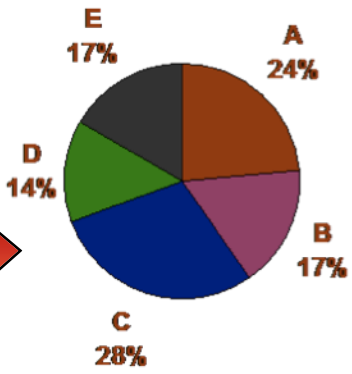
(1) DECISION TO CONDUCT SOURCE APPORTIONMENT

(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.

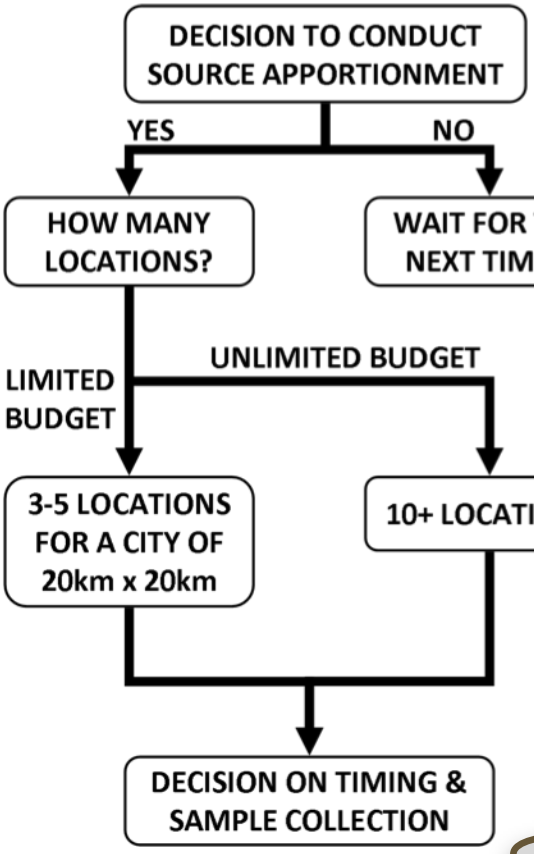
THE STEPS SEEM STRAIGHT FORWARD, BUT I AM SURE EACH ONE IS A PROJECT IN ITSELF...

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 PM2.5 (FINE PM)

Ambient Sampling



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

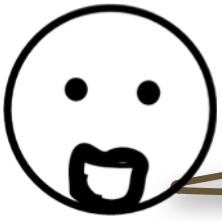
FOR EXAMPLE, DOMESTIC AND INDUSTRIAL HEATING REQUIREMENTS ARE DIFFERENT BETWEEN SUMMER AND WINTER.

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.

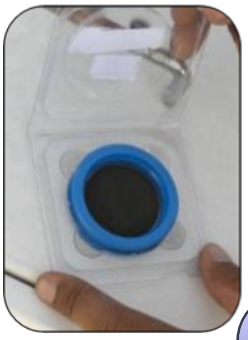
CAN YOU TELL US ABOUT A COMMONLY USED SAMPLER?



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)

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.

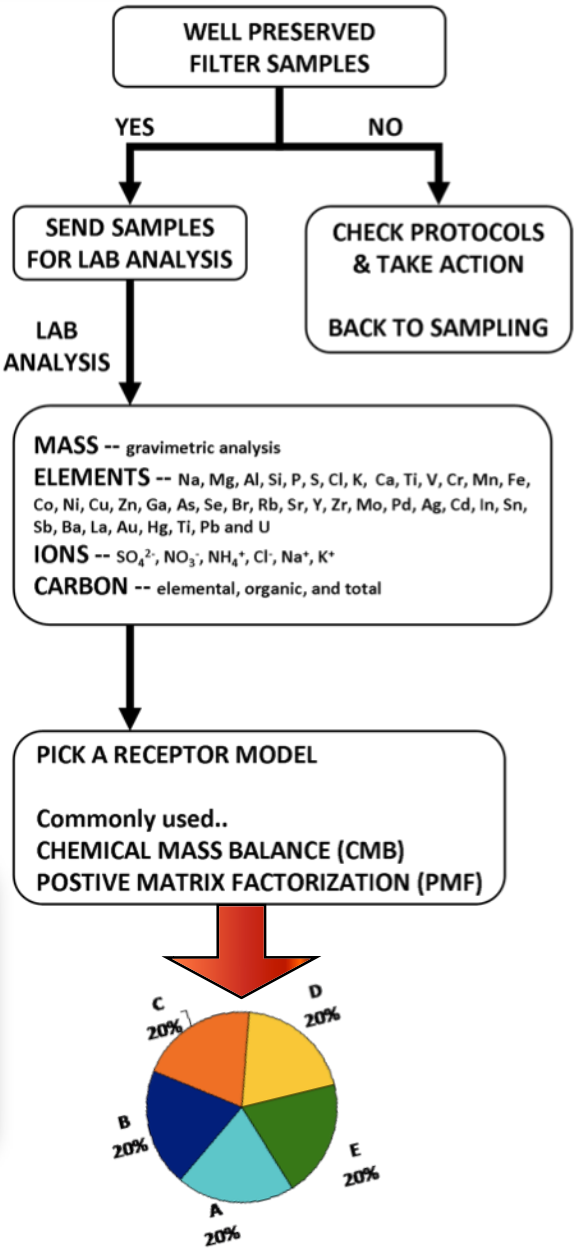
WHY DO WE NEED SO MUCH LAB WORK?

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.

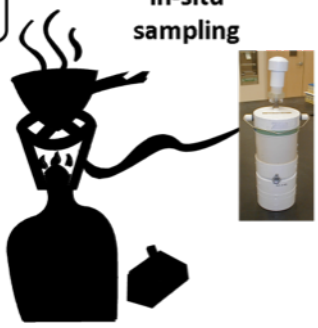
BESIDES THE LAB ANALYSIS, WE NEED SOURCE PROFILES.

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"

STOVES



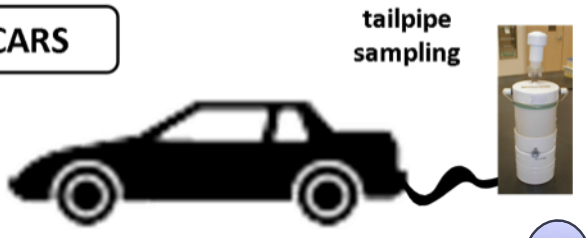
INDUSTRIES

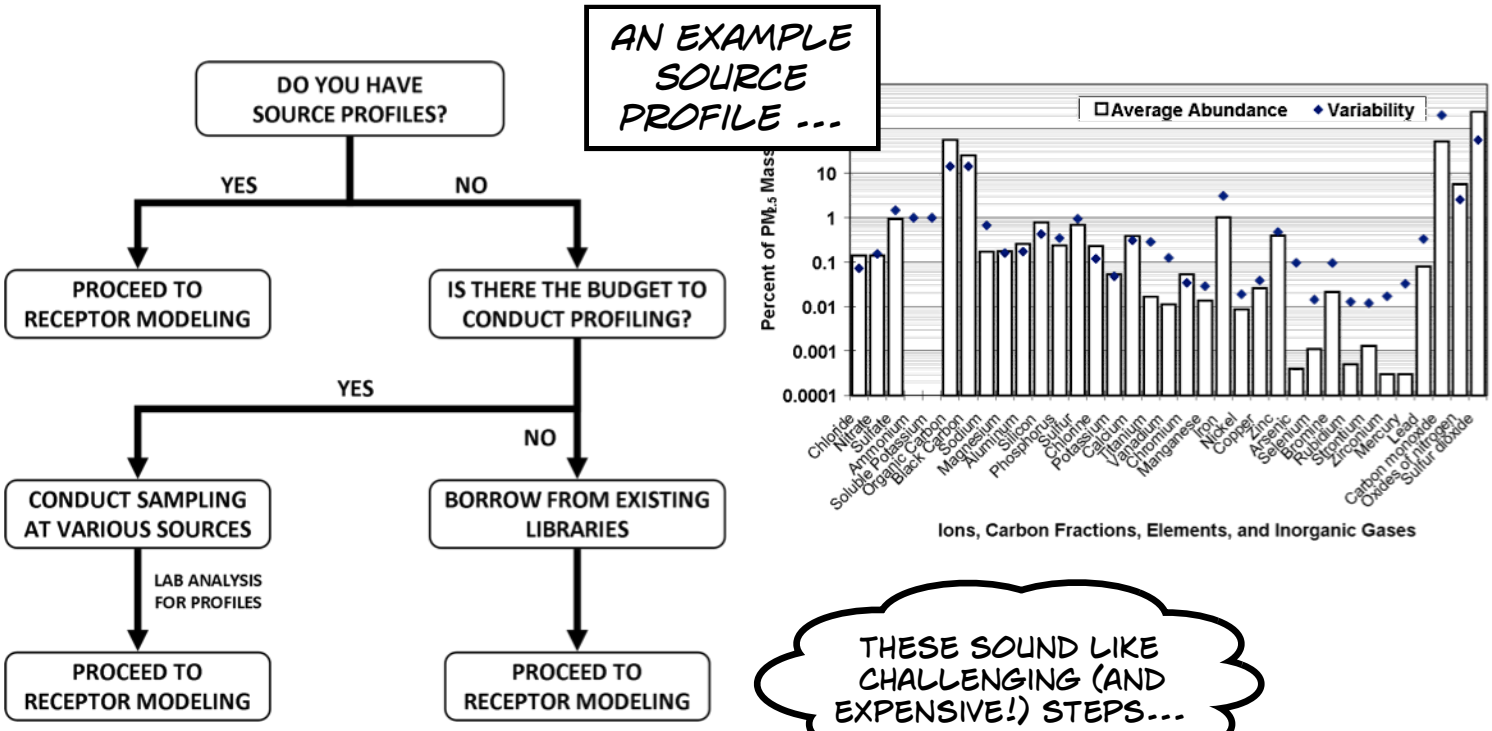
IDEALLY, ONE SHOULD HAVE SOURCE PROFILES FROM THE CITY WHERE THE STUDY IS BEING CONDUCTED. HOWEVER, IF BUDGETS ARE LIMITED, WE CAN BORROW SOURCE PROFILES FROM OTHER CITIES WITH SIMILAR POLLUTION SOURCES.

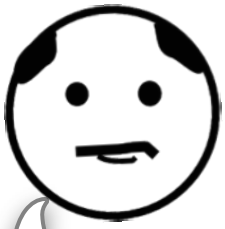
COMMON MARKERS INCLUDE

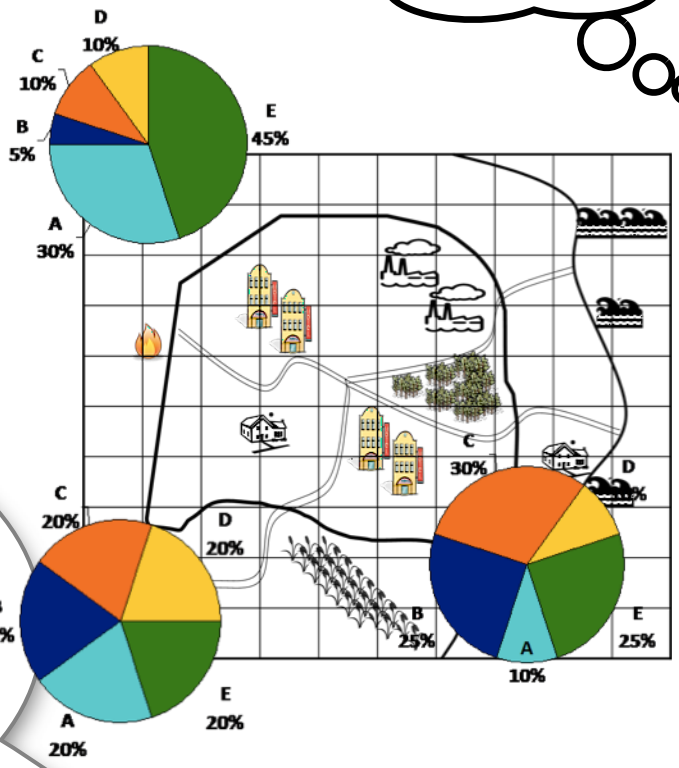
AL & SI FOR ROAD DUST
K FOR BIOMASS
NA FOR SEA-SALT
A MIX OF METALS FOR COAL
BC & OC RATIOS FOR VEHICLE EXHAUST

CARS





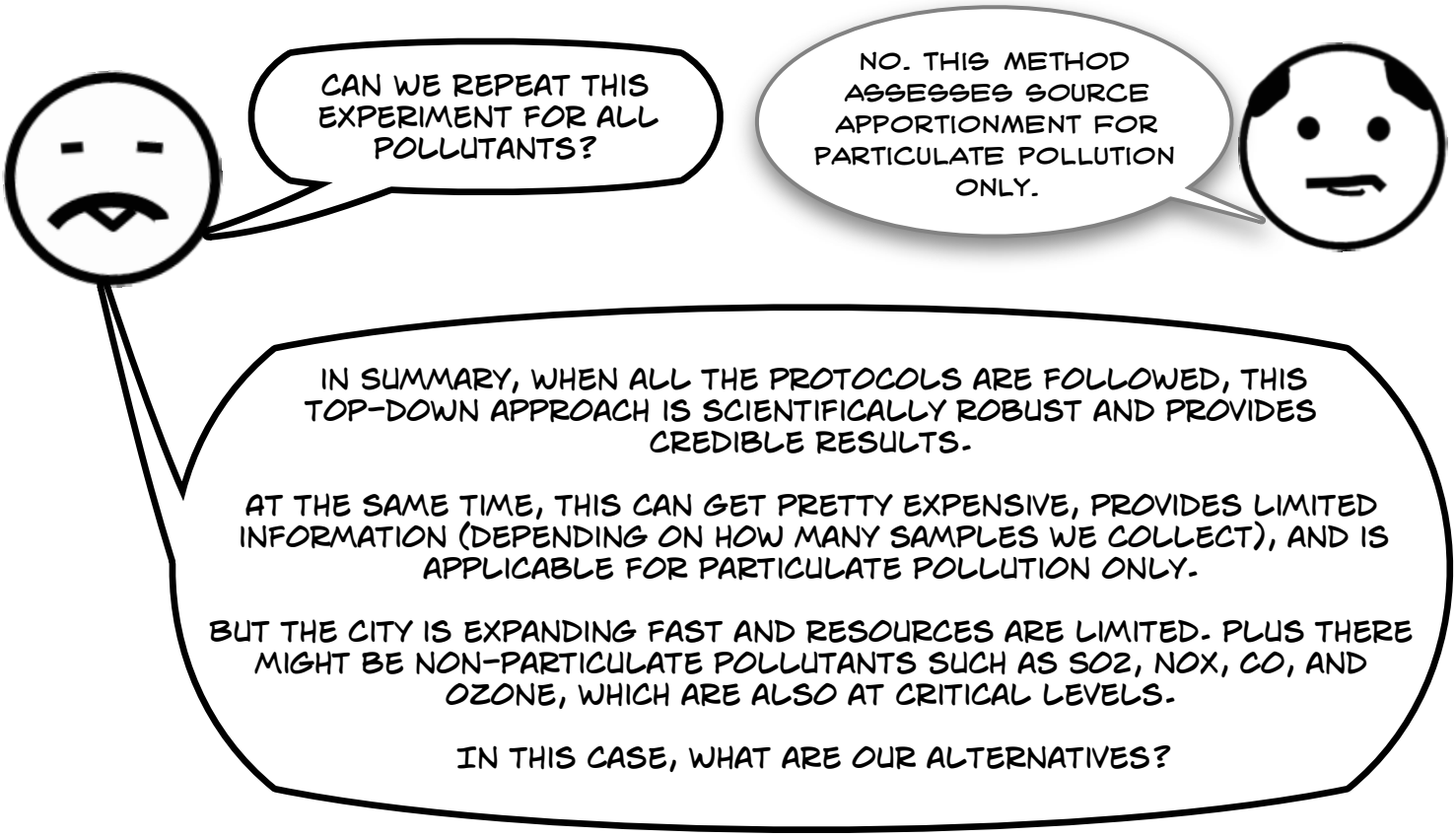


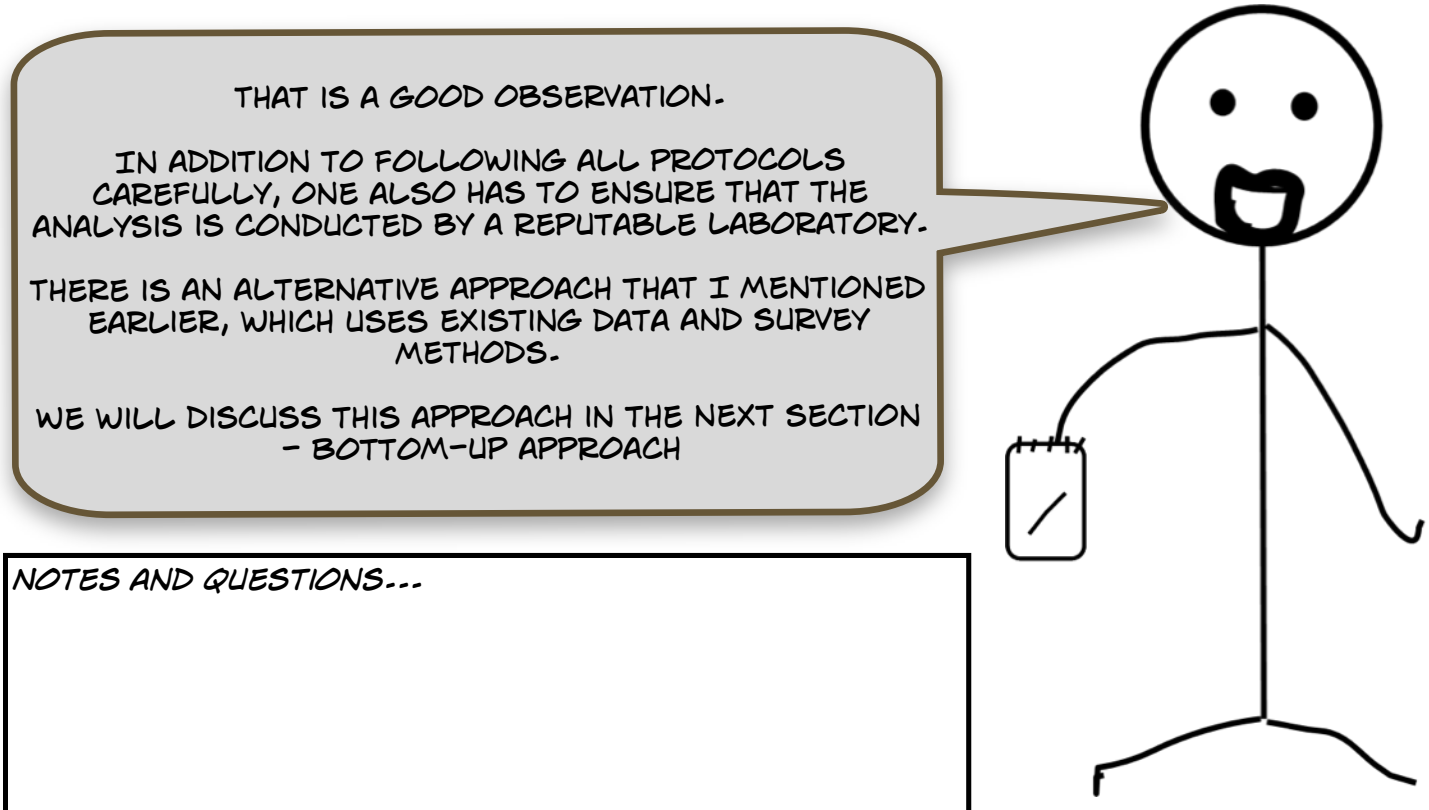


THIS APPROACH PROVIDES POLLUTION INFORMATION SPECIFIC TO THE SAMPLING LOCATION.

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.





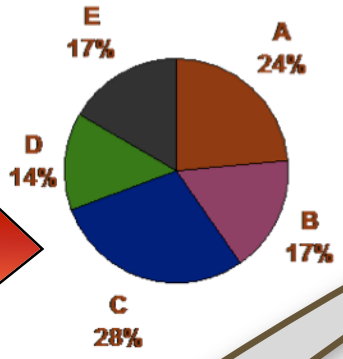
NOTES AND QUESTIONS...

BOTTOM-UP APPROACH

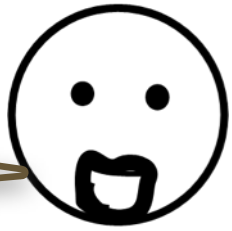
(1) DECISION TO CONDUCT MODELING

(2) EMISSIONS INVENTORY

(3) DISPERSION MODELING



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

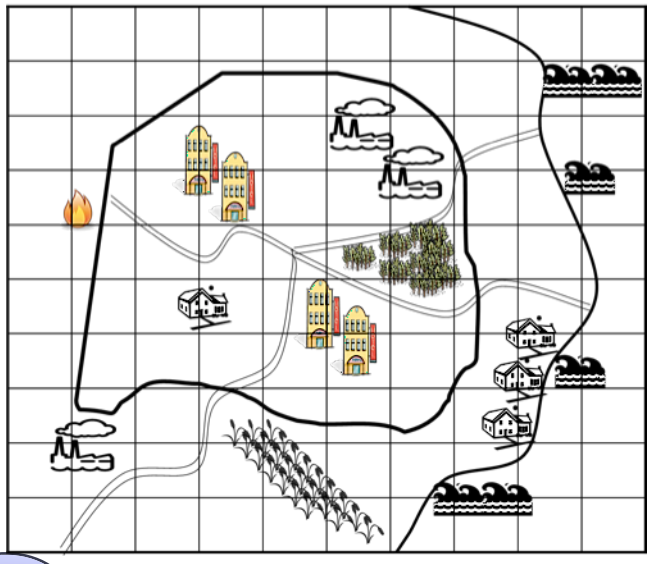


IT IS REALLY IMPORTANT THAT EVERY CITY ESTABLISHES AN EMISSIONS INVENTORY.

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

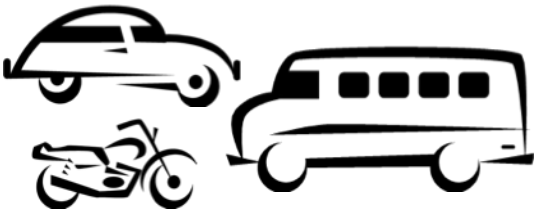
VEHICLE EXHAUST AND ROAD DUST

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---

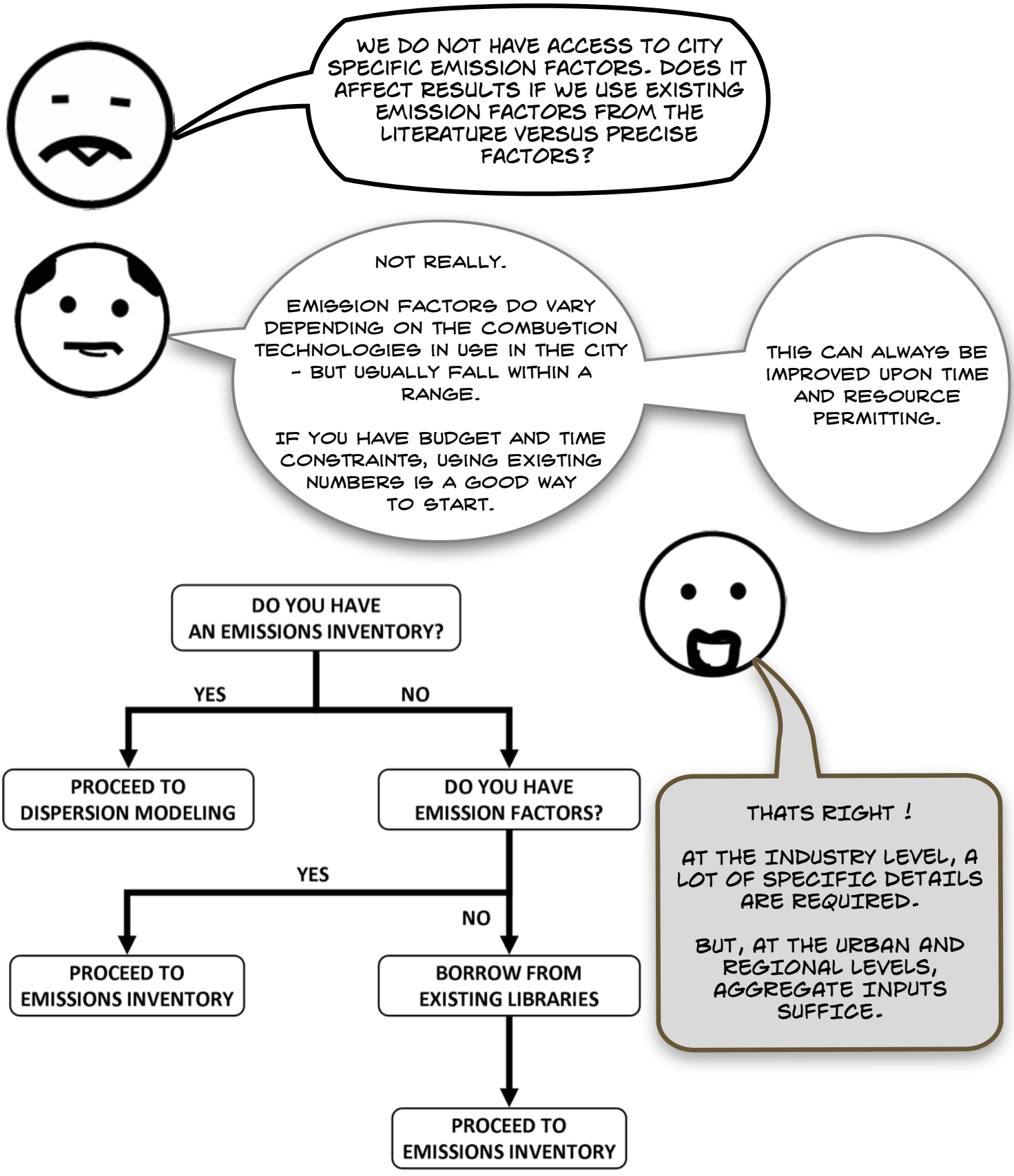
WE CAN THEN USE EXISTING EMISSION FACTORS TO CALCULATE EMISSIONS BY SECTOR

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--- **EMISSIONS = EMISSION FACTOR * ENERGY**

WHAT OTHER SOURCES SHOULD WE CONSIDER?

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



USUALLY INVENTORIES ARE ESTABLISHED FOR PARTICULATES (PM), SULFUR DIOXIDE (SO2), NITROGEN OXIDES (NOX), 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.

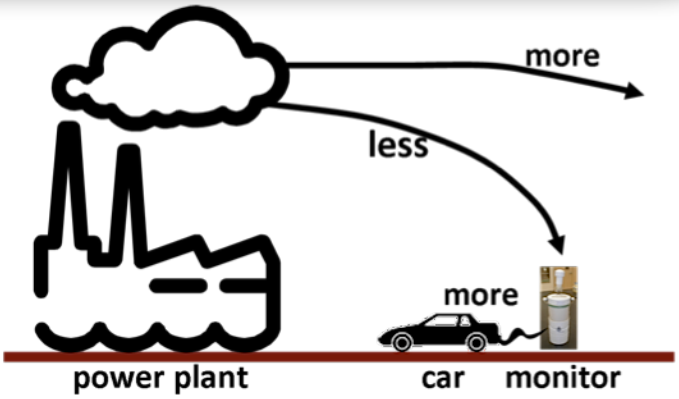
THESE RESULTS CAN THEN BE COMPARED TO THE RESULTS OF THE TOP-DOWN APPROACH.

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

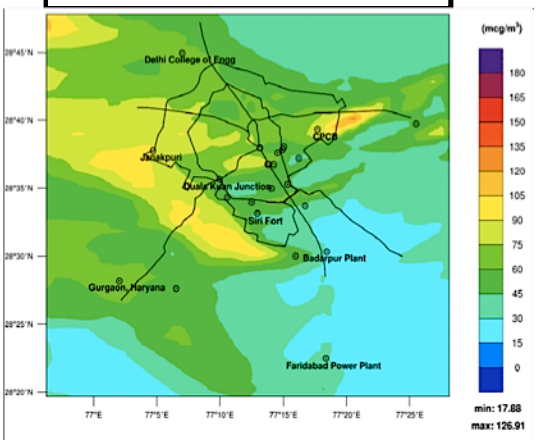
Dispersion Modeling

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

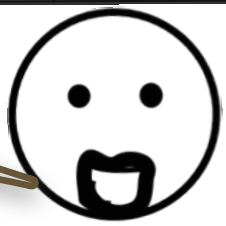
DISPERSION MODELING IS A TECHNICALLY CHALLENGING STEP, WHICH REQUIRES A CERTAIN LEVEL OF TRAINING AND PROFICIENCY. OFTEN THIS STEP BECOMES A BOTTLE-NECK FOR CITIES TRYING TO MAP POLLUTION.

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.

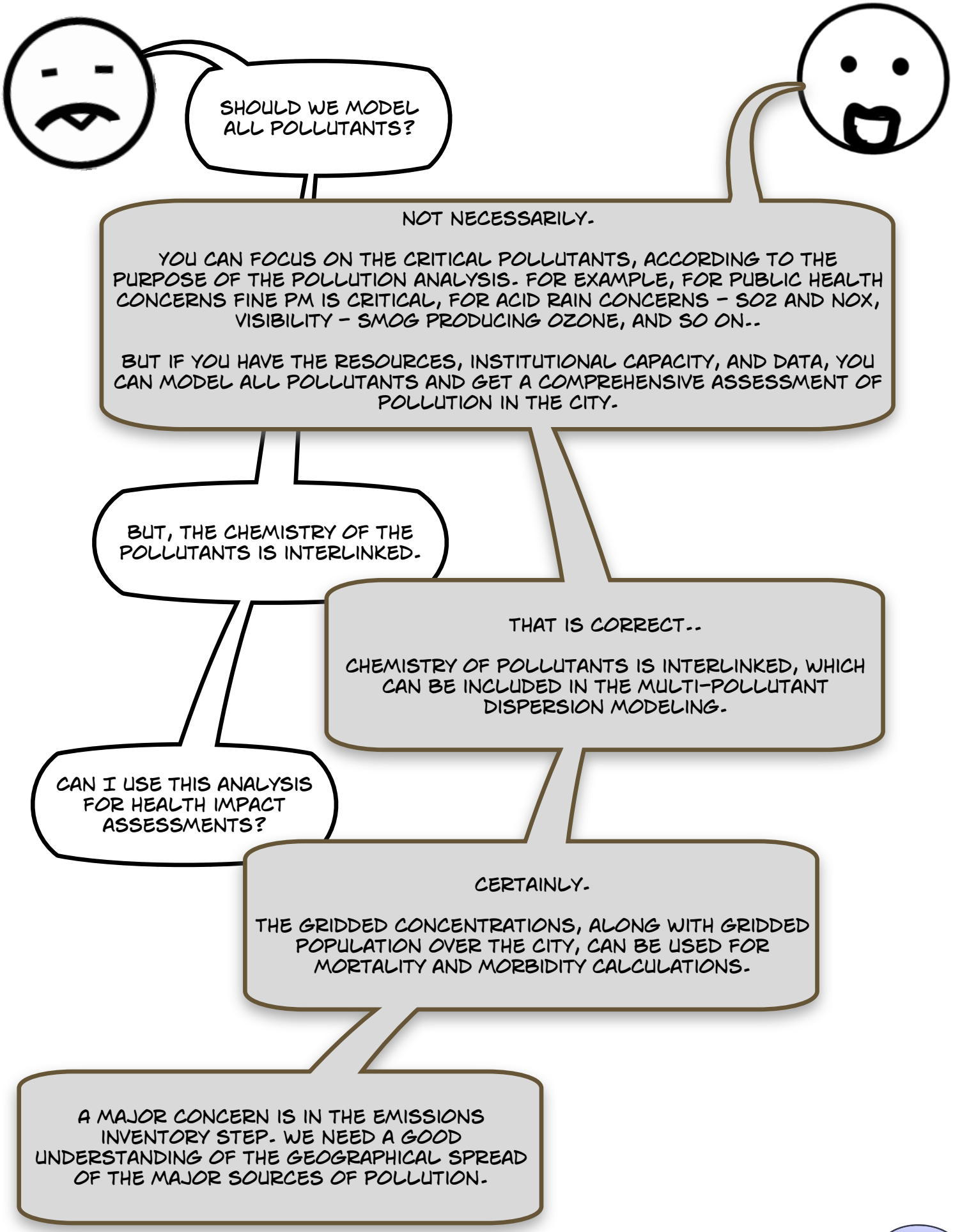
ARE THERE ANY SPECIFIC MODELS WHICH WE CAN FOLLOW?

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 NOX, 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

NOTE THAT EACH APPROACH CAN BE USED TO STRENGTHEN THE OTHER.

FOR EXAMPLE, WHILE BUILDING SOURCE PROFILES, MEASUREMENTS CONDUCTED CLOSE TO THE SOURCES CAN VALIDATE THE EMISSIONS FACTORS, WHICH CAN BE USED TO BUILD A ROBUST EMISSIONS INVENTORY

RESULTS BASED ON THE TOP-DOWN APPROACH CAN BE USED TO CORRECT THE MISSING SOURCES IN THE EMISSIONS INVENTORY.

TOP-DOWN

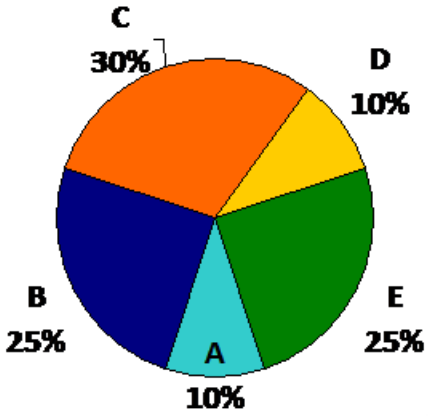
BOTTOM-UP

THE DISPERSION MODELING RESULTS CAN HELP IDENTIFY THE POLLUTION HOT SPOTS IN THE CITY, WHERE SAMPLING FOR THE TOP-DOWN APPROACH CAN BE PERFORMED.

MONITORING DATA CAN HELP VALIDATE THE RESULTS OF DISPERSION MODELING, WHICH CAN BE FURTHER EXPANDED FOR EVALUATING "WHAT-IF" EMISSION SCENARIOS.

TOGETHER, THESE METHODS PROVIDE A STRONG RESOURCE FOR DEVELOPING A POLLUTION CONTROL STRATEGY.

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

OR

SEND ME AN EMAIL
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