Impact of Deepwater Horizon Oil Spill on the Gulf Coast Air Quality: A Preliminary Assessment

Bhaskar Kura, PhD, PE
Director, Maritime Environmental Resources and Information Center (MERIC)
Professor of Civil & Environmental Engineering
bkura@uno.edu
http://coe.uno.edu/cee/kura/index.html
http://coe.uno.edu/meric/

Suruchi Verma
Graduate Student

University of New Orleans

October 27, 2010

Outline

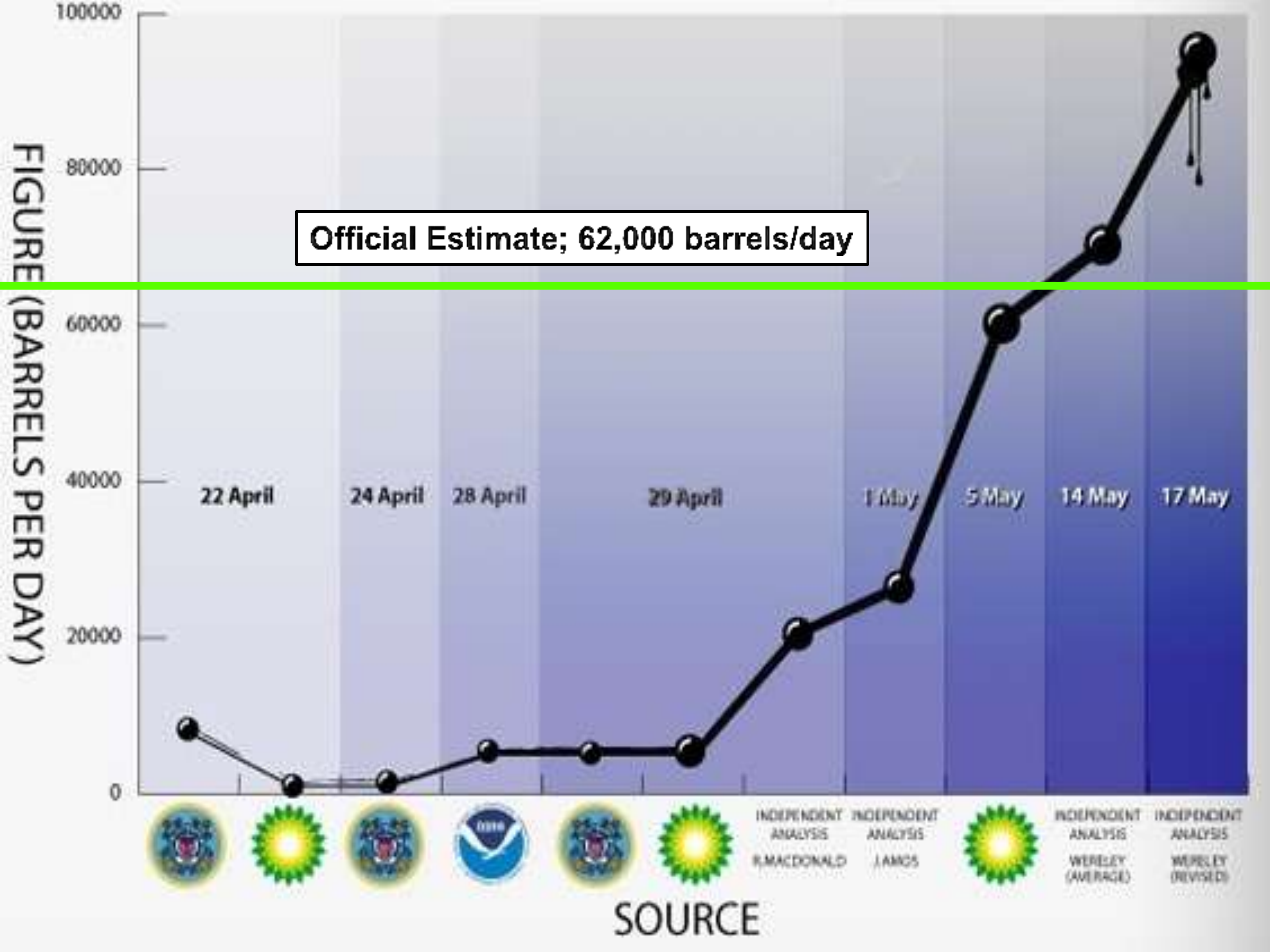
- Deepwater Oil Spill – Important Statistics
- Factors that Influence Air Emissions
- Crude and Natural Gas Characteristics
- Important Air Pollutants, Sources, and Health Effects
- Monitoring by Various Agencies
- Monitoring by UNO
- Results and Preliminary Assessment
- Additional Studies at UNO

Important Spill Statistics

- **Spill date**: 20 April, 2010 – 15 July, 2010
- **Well officially sealed**: 19 September, 2010
- **Depth of the spill:** 5000 feet **Area of spill**: 30,000sq miles
- **Loss of life**: The explosion (of about 36 hours) killed 11 platform workers and injured 17 others
- **Wellhead officially capped:** July 15, 2010
- **Crude released before capping:**
  - 4.28 million barrels or 180 million gallons
- **Initial rate of crude release**: 62,000 barrels per day
  - Decreased to 53,000 barrels per day just before being capped.
- **Well closure date**: 19 September, 2010; Well was declared officially dead.

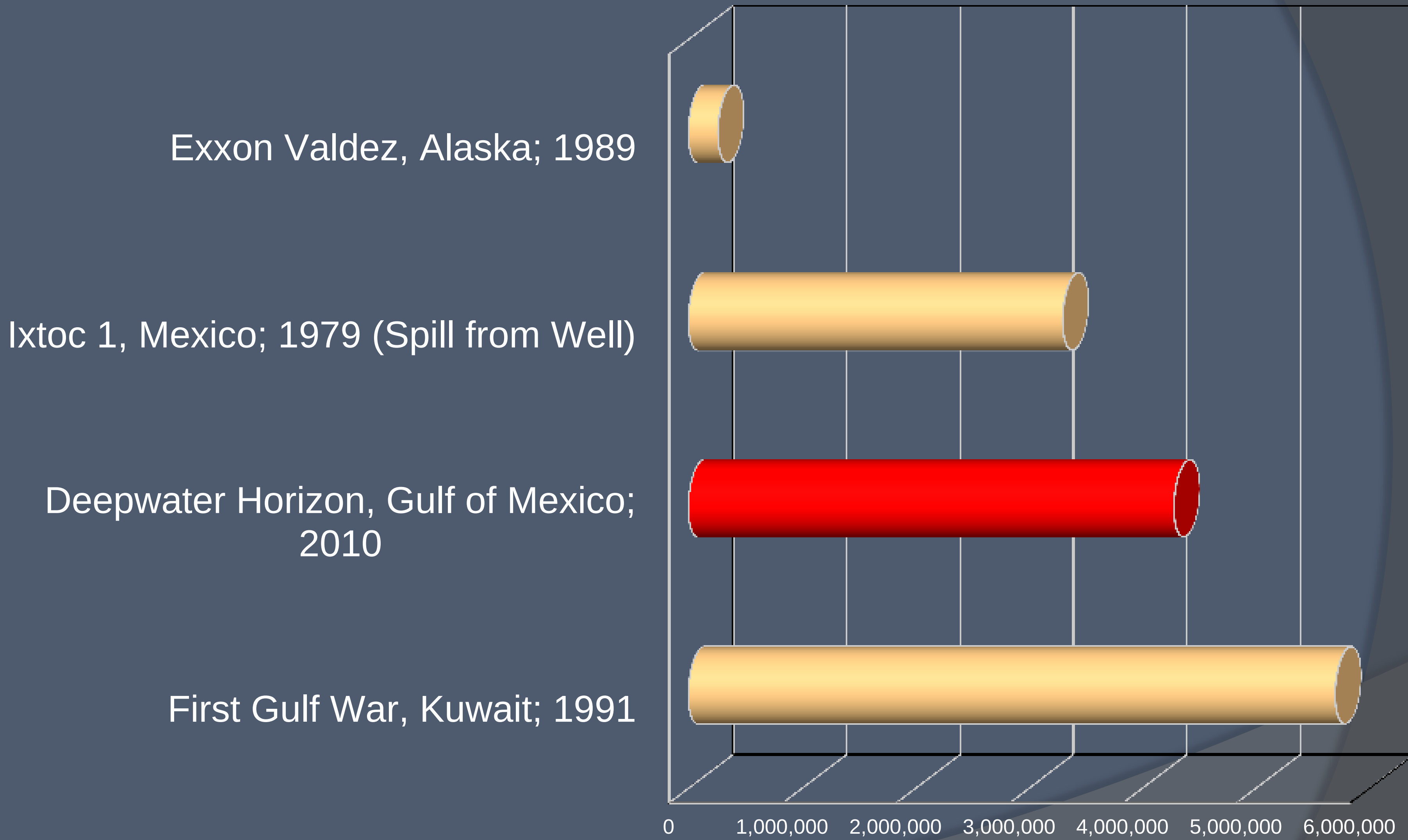
Spill – Predictions

Source	Date	Barrels per day	Gallons per day
BP estimate of hypothetical worst case scenario (assumes no blowout preventer)	Permit	162,000	6,800,000
United States Coast Guard	April 23 (after sinking)	0	0
BP and United States Coast Guard	24-Apr	1,000	42,000
Official estimates	29-Apr	1,000 to 5,000	42,000 to 210,000
Official estimates	27-May	12,000 to 19,000	500,000 to 800,000
Official estimates	10-Jun	25,000 to 30,000	1,100,000 to 1,300,000
Flow Rate Technical Group	19-Jun	35,000 to 60,000	1,500,000 to 2,500,000
Internal BP documents hypothetical worst case (assumes no blowout preventer)	20-Jun	up to 100,000	up to 4,200,000
Official estimates	2-Aug	62,000	2,604,000


Official Estimate; 62,000 barrels/day
FIGURE (BARRELS PER DAY)
100000
80000
60000
40000
20000
0
22 April
24 April
28 April
29 April
1 May
5 May
14 May
17 May
INDEPENDENT ANALYSIS R.MACDONALD
INDEPENDENT ANALYSIS J.AMOS
INDEPENDENT ANALYSIS WERELEY (AVERAGE)
INDEPENDENT ANALYSIS WERELEY (REVISED)
SOURCE

Comparison of Spills (Barrels)

(Note: Some variability exists in the quantity reported among sources)



	First Gulf War, Kuwait; 1991	Deepwater Horizon, Gulf of Mexico; 2010	Ixtoc 1, Mexico; 1979 (Spill from Well)	Exxon Valdez, Alaska; 1989
■	5,700,000	4,280,000	3,300,000	260,000

Factors that Influence Air Emissions from Spills

- Magnitude of spill
- Composition of crude and natural gas
- Characteristics of spill
- Hydrological conditions
- Meteorological conditions

Typical Crude Composition

Carbon	84 – 87%
Hydrogen	11 – 14%
Sulfur	0.06 – 2%
Nitrogen	0.1 – 2%
Oxygen	0.1 – 2%

Benzene	0-2%
Toluene	0-20%
Xylene	0-20%
Ethylbenzene	0-4%
Trimethyl Benzene	0-2%
Hydrogen Sulphide	0-1%
PAHs	1-10%

Typical Natural Gas Composition

Carbon	65 – 80%
Hydrogen	1 – 25%
Sulfur	0.0 – 0.2%
Nitrogen	1 – 15%

Methane	70-98%
Ethane	1-10%
Propane	< 5%
Butane	< 2%

Spill and Spill Related Sources of Air Emissions

- Direct release - Natural Gas (Methane and others)
- Evaporation (VOCs/HAPs; light and heavy organics)
- Burning (CO; CO_2; SO_2; NO_x; Others)
- Spill response equipment and vehicles (VOCs; NO_x; PM; CO; Heavy metals)
- Short term and long term remediation (by products of remediation)

Selective HAPs from Spill and Health Impacts

Chemical Name	Health Effects
Benzene	Causes cancer, adverse effects on Skin, causes fatigue and irritability, reduces blood flow, decreases fertility, birth defects.
Benzo a pyrene (PAH)	Lung and other cancer; adequate evidence among animals and inadequate evidence in humans.
Naphthalene	Cataracts and damage to the retina. EPA has classified naphthalene as a Group C, possible human carcinogen.
Toluene	Child birth defects, cause adverse effects on the liver, alters immune system, kidney failure. Effects central nervous system and respiratory system
Xylene	Variety of cardiovascular diseases, child birth and growth defects, kidney failure, skin disease. Affects nervous system, immune system, respiratory system and reproductive system.
Ethylbenzene	Cancer causing (lab rats), kidney and liver failure, skin diseases. Effects endocrine system, reproductive and respiratory system; EPA has classified ethylbenzene as a Group D, not classifiable as to human carcinogenicity
Nickel	Cancer causing, cardiovascular diseases, effects child birth and growth, kidney failure, skin diseases. Effects nervous system, immune system, reproductive system and respiratory system.

Air Monitoring Locations
(PM_{10}; H_2S; VOCs; PAHs)

UNO Air Monitoring Efforts

- **Locations:** Grand Bayou; Southpass 55; Olga
- **H_2S; PM_{10}; $PM_{2.5}$:** Real-time Monitoring
- **VOCs/HAPs:** Sampling by summa canisters; Analysis using TO-15


UNO
THE UNIVERSITY of
NEW ORLEANS

ASU Team Working with UNO

El Paso Team Supporting UNO


NO STEP

Preliminary Assessment (April 28th to June 5, 2010)

Chemical Name	Lowest Concentration Recorded after Spill	Highest Concentration Recorded after Spill	Ambient Air Quality Standards	OSHA Limits
Benzene	0	16.2 µg/m³ [125 times]	0.13 µg/m³© , 30 µg/m³ (nc)	32 mg/m³ (10ppm)
Toluene	0	169 µg/m³	300 µg/m³ (nc)	750mg/m³ (200ppm)
Xylene	0.663 µg/m³	68.6 µg/m³	100 µg/m³ (nc)	435mg/m³ (100ppm)
Ethylbenzene	0	12.3 µg/m³	1000 µg/m³(nc)	435mg/m³ (100ppm)
Nickel	Not available	Not available	0.004 µg/m³ ©, 0.05 µg/m³(nc)	1mg/m³
Naphthalene	0.0052 µg/m³	16 µg/m³ [120 times]	0.05 µg/m³(nc)	50mg/m³ (10ppm)

Preliminary Assessment (April 28th to June 5, 2010)

Chemical Name	**Lowest Concentration Recorded after Spill**	**Highest Concentration Recorded after Spill**	**Ambient Air Quality Standards**	**OSHA Limits**
Benzo (a) anthracene	-	-	0.009 © µg/m³	-
Benzo (a) pyrene	0	0.001568 µg/m³ [2 times]	0.0009© µg/m³	0.2mg/m³
Benzo (b) fluoranthene	0	0.001245 µg/m³	0.009 © µg/m³	-
Chrysene	0.00003 µg/m³	0.00136 µg/m³	0.09 © µg/m³	0.2mg/m³
Diesel Products	-	-	-	-

Preliminary Assessment
(April 28th to June 5, 2010)

Chemical Name	Lowest Concentration Recorded after Spill	Highest Concentration Recorded after Spill	Ambient Air Quality Standards	OSHA Limits
Sulphur Dioxide	-	-	365 µg/m^3(24 hr avg), 80 µg/m^3 (annual avg)	13mg/m^3 (5ppm)
Carbon dioxide	-	-	-	9000mg/m^3 (5000ppm)
Carbon monoxide	-	-	10mg/m^3 (8 hr avg), 40mg/m^3 (1hr avg)	55mg/m^3 (50ppm)
Hydrogen Sulphide	139 µg/m^3 (0.1 ppm)	2085 µg/m^3 (1.5 ppm) [7.5 to 15 times]	278 µg/m^3 (1 hr avg), 139 µg/m^3 (24 hr avg)	15 mg/m^3 (10ppm)
Methane	-	-	160 µg/m^3(3 hr avg)	Simply Asphyxiant

Preliminary Assessment (April 28th to August 20, 2010)

Chemical Name	Lowest Concentration Recorded after Spill	Highest Concentration Recorded after Spill	Ambient Air Quality Standards	OSHA Limits
PM_{10} (DataRAM, MIE; or EBAM, Met One, Inc.)	0	944.2 µg/m^3 [6 times]	150 µg/m^3 (Not to exceed once/yr over 3-yr period)	
Total VOCs (Area RAEs)	0	71.9 ppm		
Hydrogen Sulphide (Area RAEs)	0 µg/m^3 (0 ppm)	2085 µg/m^3 (1.5 ppm) [7.5 to 15 times]	278 µg/m^3 (1 hr avg), 139 µg/m^3 (24 hr avg)	15 mg/m^3 (10ppm)

Additional Studies Under Progress at UNO

Questions Being Addressed

- What specific air pollutants were emitted from the spill?
- What were the quantities emitted?
- How did they change from April 20^{th} to July 15^{th}, 2010 and beyond?
- Why is this information important?
- How can we evaluate cancer and non-cancer health risks to public and response workers?

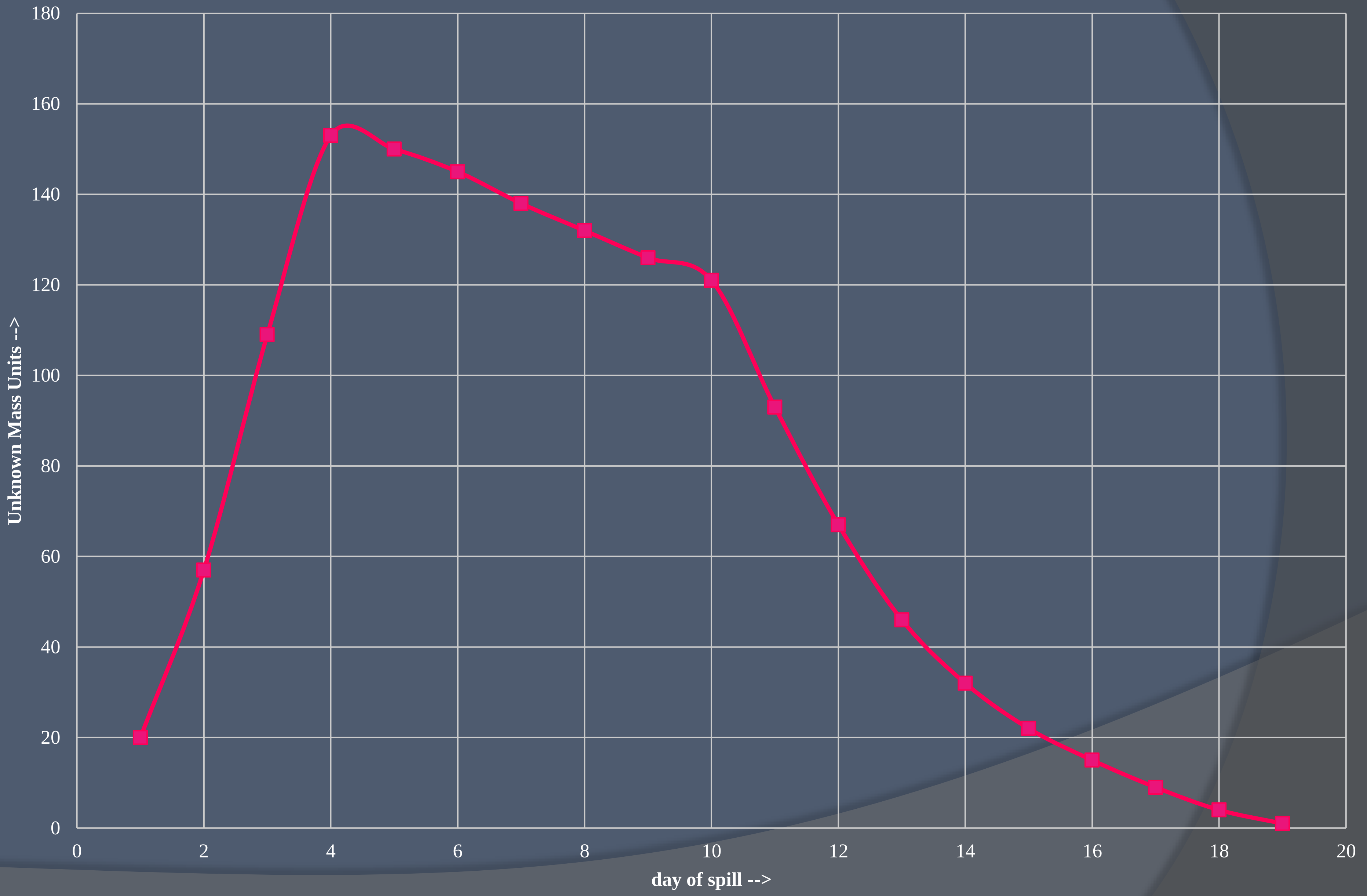
Methods to Estimate Emissions

- Laboratory Simulation
  - To trace **evaporation** rate
  - Build **emission spectrum**
- Inverse Dispersion Modeling
  - To trace **emission** rate
  - Build **emission spectrum**

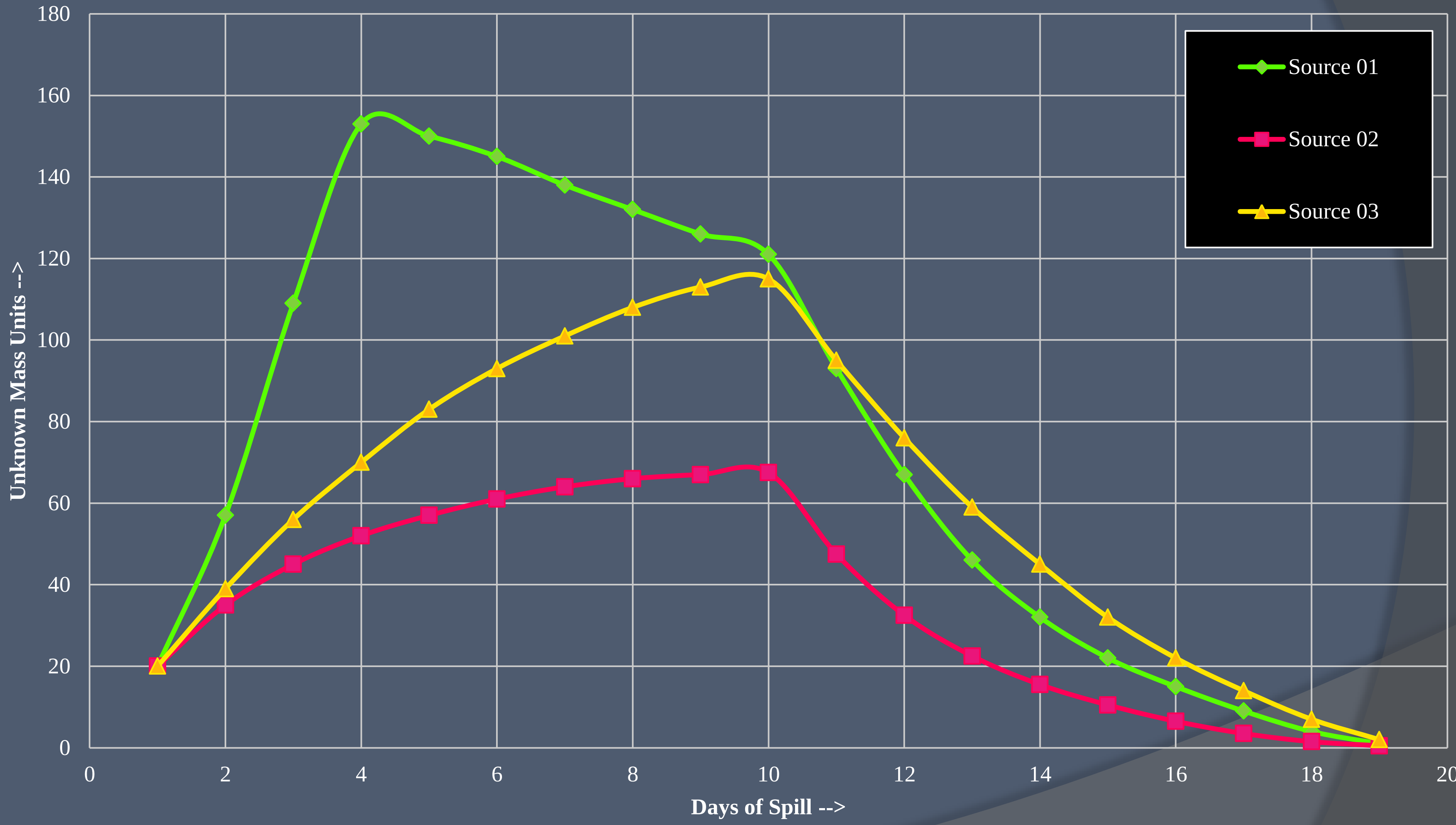
Emission Spectrum for 10-Day Hypothetical Spill (Unknown Mass Units)

Day	1	2	3	4	5	6	7	8	9	10	Total
1	20	-	-	-	-	-	-	-	-	-	20
2	17	40	-	-	-	-	-	-	-	-	57
3	15	34	60	-	-	-	-	-	-	-	109
4	12	30	51	60	-	-	-	-	-	-	153
5	10	24	45	51	20	-	-	-	-	-	150
6	7	20	36	45	17	20	-	-	-	-	145
7	6	14	30	36	15	17	20	-	-	-	138
8	5	12	21	30	12	15	17	20	-	-	132
9	3	10	18	21	10	12	15	17	20	-	126
10	1	6	15	18	7	10	12	15	17	20	121
11	-	2	9	15	6	7	10	12	15	17	93
12	-	-	3	9	5	6	7	10	12	15	67
13	-	-	-	3	3	5	6	7	10	12	46
14	-	-	-	-	1	3	5	6	7	10	32
15	-	-	-	-	-	1	3	5	6	7	22
16	-	-	-	-	-	-	1	3	5	6	15
17	-	-	-	-	-	-	-	1	3	5	9
18	-	-	-	-	-	-	-	-	1	3	4
19	-	-	-	-	-	-	-	-	-	1	1

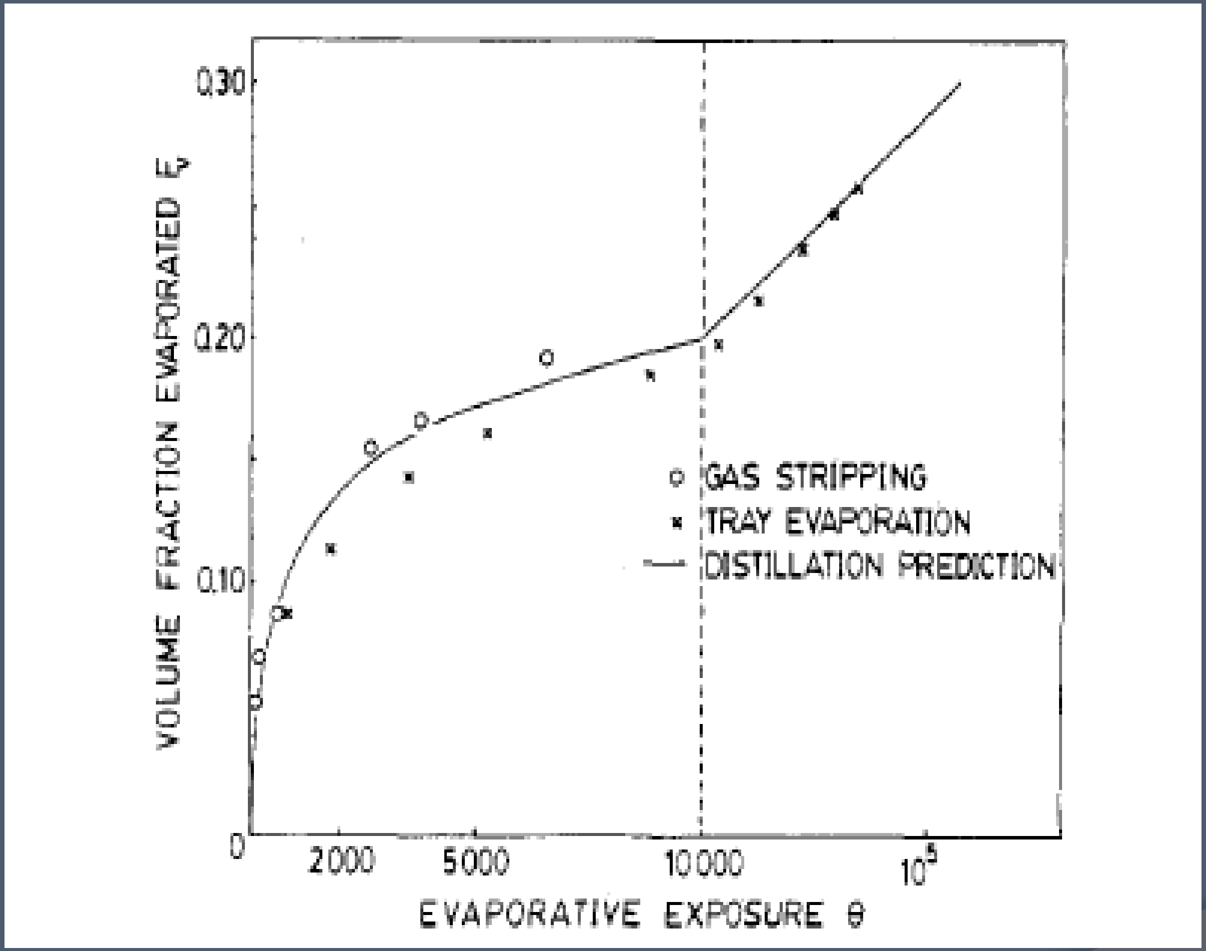
Emission Spectrum for Unknown HAP



Emission Spectrum of Multiple Sources for an Unknown HAP



F_v versus Θ



Plot of Volume Fraction Evaporated vs. Evaporative Exposure for Kuwait Crude at 22C (Stiver and Mackay, 1984)

Evaporative Exposure

$$\Theta = kat/V_o$$
$$= kt/d_o$$

Θ	= evaporative exposure (dimensionless)
k	= mass transfer coefficient (m/s)
a	= area of the oil surface (m2)
t	= elapsed time since the spill (s)
V_o	= volume of the spill (m^3)
d_o	= depth of the spill (m)

Lab-scale Wind Tunnel Study (Johnson, 2010)

Lab-scale Wind Tunnel Study (Johnson, 2010)

Lab-scale Wind Tunnel Study (Johnson, 2010)

Lab-scale Wind Tunnel Study (Johnson, 2010)

Inverse Gaussian Dispersion Modeling

$$C = \frac{Q}{2\pi\sigma_y\sigma_z}\exp\left(-\frac{1}{2}\frac{y^2}{\sigma_y^2}\right)\left\{exp\left(-\frac{(z-H_e)^2}{2\sigma_z^2}\right)+exp\left(-\frac{(z+H_e)^2}{2\sigma_z^2}\right)\right\}$$

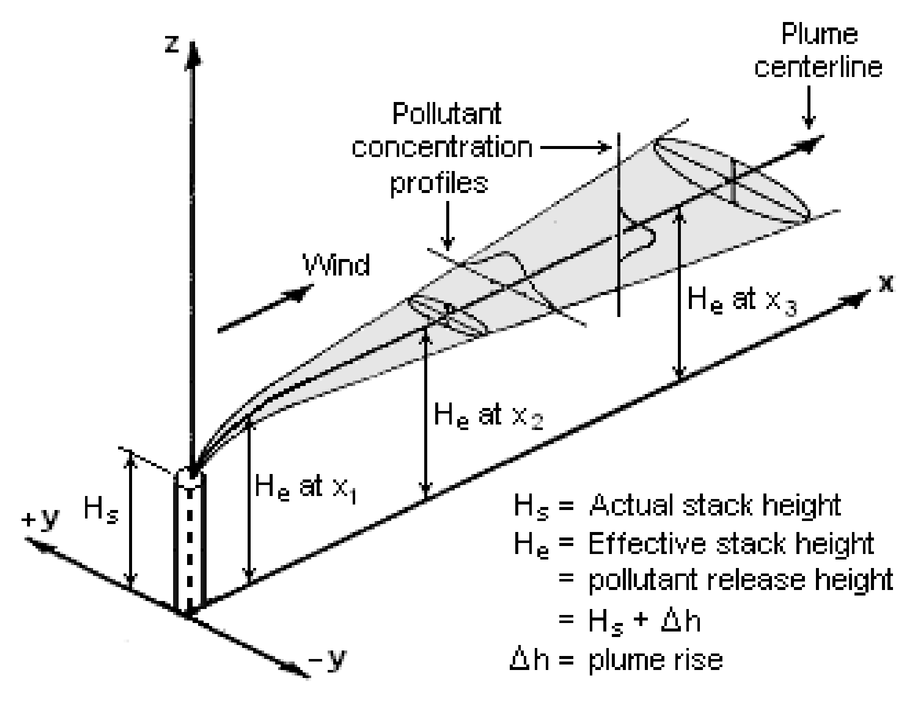
$$C = \frac{Q}{\pi u \sigma_y \sigma_z}\exp\left(-\frac{1}{2}\frac{y^2}{\sigma_y^2}\right)$$

$Z=H_e=0$

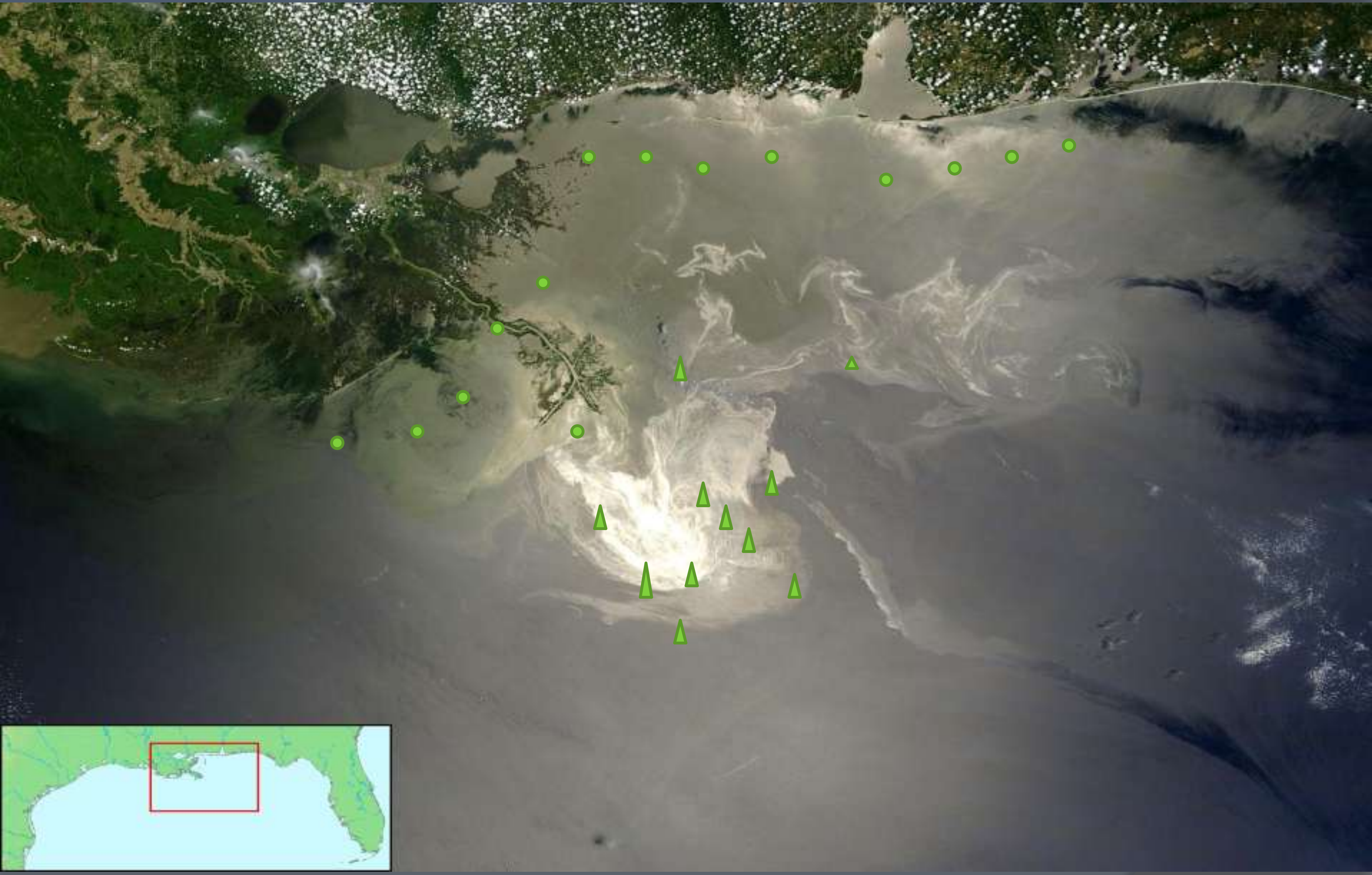
$$f = \frac{1}{\pi u \sigma_y \sigma_z}\exp\left(-\frac{1}{2}\frac{y^2}{\sigma_y^2}\right)$$

$$C_{i,j} = f(x,y)_{i,j} * Q_j$$

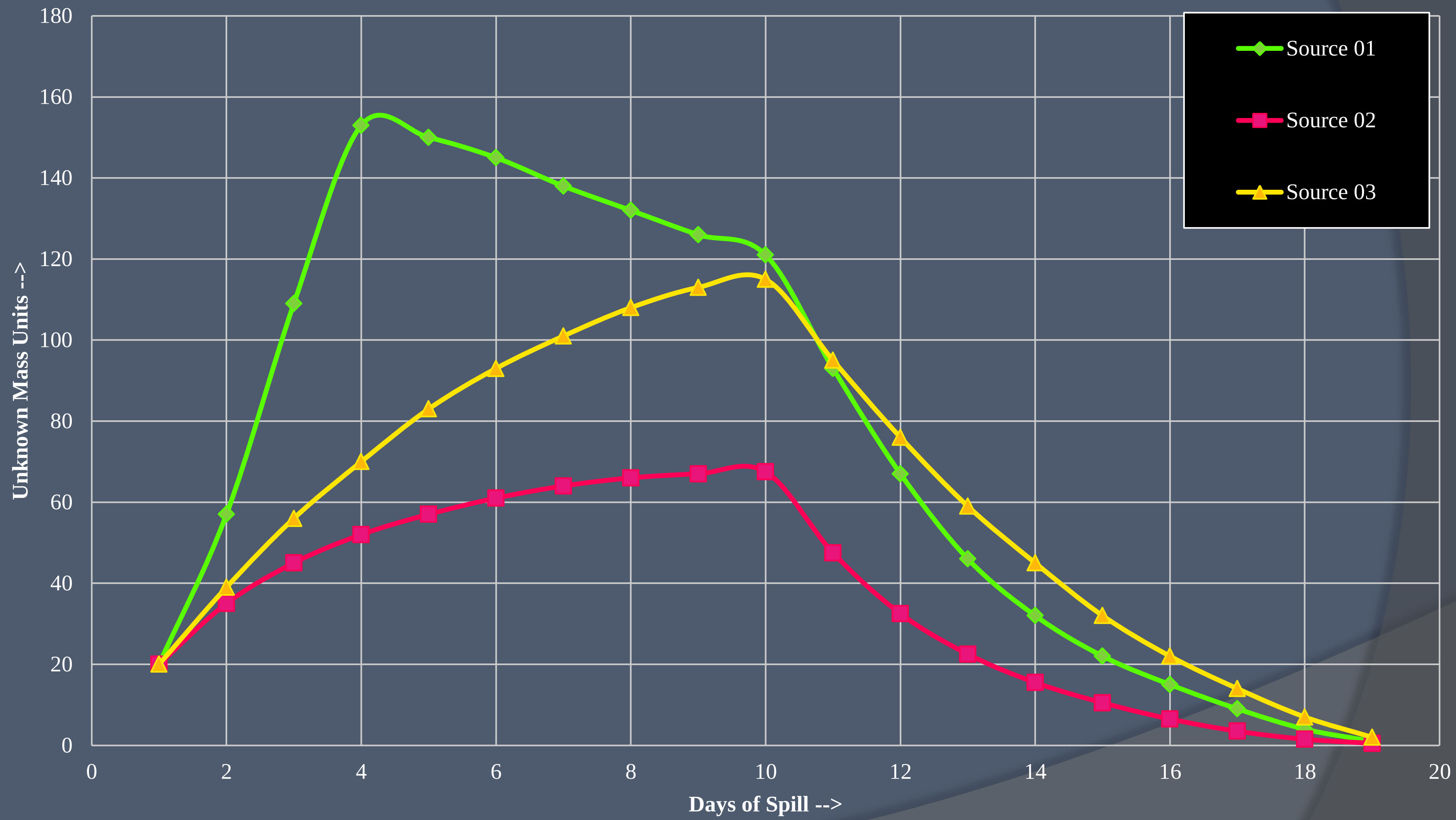
$$q = \mathbf{F}^{-1} c_{\text{measured}}$$



Inverse Gaussian Dispersion Modeling



Emission Spectrum of Multiple Sources for an Unknown HAP



Advantages of Inverse Dispersion Modeling

- No need to know actual oil leak quantities
- Quantities estimated are based on actual ambient concentrations recorded
- Allows identification of the emission locations (equally important in evaluating health risks)
- Ability to quantify a variety of VOCs or HAPs
- Ability to quantify emissions from spill response related activities such as burning, remediation etc. (e.g., PM, CO, CO_2, SO_2, NO_x)

Conclusions

- Large scale efforts are needed to clearly understand air quality impacts
- Emission spectra for various air pollutants, development of software applications/models are needed
- UNO efforts will be valuable in assessing public health risks
- UNO collaborating with many agencies and corporations to accomplish its goals and welcomes your participation

Thank you for your attention!

QUESTIONS?