Ambient Air Sampling Project Development

Presented by

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WHY DO WE SAMPLE AMBIENT AIR

1. **USEPA has National Ambient Air Quality Standards (NAAQS) for Conventional Air Pollutants**
2. **USEPA has established Risk-based Screening Levels (SLs) for most chemical pollutants**
3. **Air exposure represents an adsorption and ingestion pathway for volatile constituents**
4. **Air exposure represents an ingestion pathway for most chemical compounds**
5. **The air pathway directly contributes to soil and surface water contamination and indirectly to groundwater contamination**
6. **The source of many constituents found in soils come from anthropogenic sources, such as PAHs in soils and sediments are primarily from automobile emissions, as well as, mercury found in our rivers**

RISK-BASED ANALYSES

1. **USEPA and States have established Risk-Based Screening Levels (SLs) that are based on the Precautionary Principle**
2. **Courts rule on Causation which are at levels much higher than precautionary SLs that have "nonproven" safety factors applied to known impacts to rodents**
3. **SLs are established for a $1*10^{-6}$ to $1*10^{-4}$ increase in cancer**
4. **USEPA uses $1*10^{-4}$ SLs to determine if remediation is necessary**
5. **Normal Incidence of cancer in U.S. is 0.5 for men or 1 out every 2 men will have a cancer in their lifetime and 0.33 for women or 1 out of every 3 women will have a cancer in their lifetime**

USEPA REGIONAL SLs

master_sl_table_run_12SEP2008

Key: I = IRIS; P = PPRTV; A = ATSDR; C = Cal EPA; H = HEAST; W = WHO; S = see user guide Section 5; L = see user guide on lead; M = mutagen; V = volatile; c = cancer; * = where: n SL < 100X c SL; ** = where n SL < 10X c SL; n = noncancer; m = Concentration may exceed ceiling limit (See User's Guide); s = Concentration may exceed Csat (See User's Guide); SSL values are based on DAF=1

Contaminant		Toxicity and Chemical-specific Information														Screening Levels																Protection of Groundwater	
		SFO	k e y	IUR	k e y	RfDo	k e y	RfCi	k e y	v o c	muta-gen	RAGS Part E GIABS	RAGS Part E ABS	Csat		Residential Soil	key	Industrial Soil	key	Residential Air	key	Industrial Air	key	Tapwater	key	MCL		Risk-based SSL	MCL-based SSL				
Analyte	CAS No.	(mg/kg-day)$^{-1}$		(ug/m^3)$^{-1}$		(mg/kg-day)		(mg/m^3)						mg/kg		mg/kg		ug/m^3		ug/m^3		ug/L		ug/L		mg/kg	mg/kg				
Nitrosomethylethylamine, N-	10595-95-6	2.2E+01	I									1	0.1			2.2E-02	c	7.8E-02	c					3.1E-03	c			1.1E-06					
Nitrosopyrrolidine, N-	930-55-2	2.1E+00	I	6.1E-04	I							1	0.1			2.3E-01	c	8.2E-01	c	4.0E-03	c	2.0E-02	c	3.2E-02	c			1.7E-05					
Nitrotoluene, m-	99-08-1					2.0E-02	P					1	0.1			1.2E+03	n	1.2E+04	n					7.3E+02	n			8.0E-01					
Nitrotoluene, o-	88-72-2	2.2E-01	P			9.0E-04	P			V		1		1.3E+03		2.9E+00	c*	1.3E+01	c*					3.1E-01	c			2.5E-04					
Nitrotoluene, p-	99-99-0	1.6E-02	P			4.0E-03	P					1	0.1			3.0E+01	c**	1.1E+02	c*					4.2E+00	c*			3.4E-03					
Norflurazon	27314-13-2					4.0E-02	I					1	0.1			2.4E+03	n	2.5E+04	n					1.5E+03	n			1.7E+01					
Nustar	85509-19-9					7.0E-04	I					1	0.1			4.3E+01	n	4.3E+02	n					2.6E+01	n			9.0E+01					
Octabromodiphenyl Ether	32536-52-0					3.0E-03	I					1	0.1			1.8E+02	n	1.8E+03	n					1.1E+02	n			3.1E+01					
Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetra (HMX)	2691-41-0					5.0E-02	I					1	0.006			3.8E+03	n	4.9E+04	n					1.8E+03	n			7.1E+00					
Octamethylpyrophosphoramide	152-16-9					2.0E-03	H					1	0.1			1.2E+02	n	1.2E+03	n					7.3E+01	n			1.3E-01					
Oryzalin	19044-88-3					5.0E-02	I					1	0.1			3.1E+03	n	3.1E+04	n					1.8E+03	n			4.8E+00					
Oxadiazon	19666-30-9					5.0E-03	I					1	0.1			3.1E+02	n	3.1E+03	n					1.8E+02	n			1.3E+00					
Oxamyl	23135-22-0					2.5E-02	I					1	0.1			1.5E+03	n	1.5E+04	n					9.1E+02	n	2.0E+02		2.0E-01	4.4E-02				
Paclobutrazol	76738-62-0					1.3E-02	I					1	0.1			7.9E+02	n	8.0E+03	n					4.7E+02	n			1.2E+01					
Paraquat Dichloride	1910-42-5					4.5E-03	I					1	0.1			2.7E+02	n	2.8E+03	n					1.6E+02	n			4.9E-01					
Parathion	56-38-2					6.0E-03	H					1	0.1			3.7E+02	n	3.7E+03	n					2.2E+02	n			8.2E-01					
Pebulate	1114-71-2					5.0E-02	H					1	0.1			3.1E+03	n	3.1E+04	n					1.8E+03	n			2.1E+00					
Pendimethalin	40487-42-1					4.0E-02	I					1	0.1			2.4E+03	n	2.5E+04	n					1.5E+03	n			7.9E+00					
Pentabromodiphenyl Ether	32534-81-9					2.0E-03	I					1	0.1			1.2E+02	n	1.2E+03	n					7.3E+01	n			4.5E+00					
Pentabromodiphenyl ether, 2,2',4,4',5- (BDE-99)	60348-60-9					1.0E-04	I									7.8E+00	n	1.0E+02	n					3.7E+00	n								
Pentachlorobenzene	608-93-5					8.0E-04	I					1	0.1			4.9E+01	n	4.9E+02	n					2.9E+01	n			1.2E-01					
Pentachloroethane	76-01-7	9.0E-02	P									1	0.1			5.4E+00	c	1.9E+01	c					7.5E-01	c			3.9E-04					
Pentachloronitrobenzene	82-68-8	2.6E-01	H			3.0E-03	I					1	0.1			1.9E+00	c*	8.6E+00	c					2.6E-01	c			1.3E-03					
Pentachlorophenol	87-86-5	1.2E-01	I			3.0E-02	I					1	0.25			3.0E+00	c	9.0E+00	c					5.6E-01	c	1.0E+00		3.9E-03	7.0E-03				
Perchlorate and Perchlorate Salts	14797-73-0					7.0E-04	I					1				5.5E+01	n	7.2E+02	n					2.6E+01	n								
Permethrin	52645-53-1					5.0E-02	I					1	0.1			3.1E+03	n	3.1E+04	n					1.8E+03	n			6.5E+02					
Phenmedipham	13684-63-4					2.5E-01	I					1	0.1			1.5E+04	n	1.5E+05	nn					9.1E+03	n			6.8E+00					
Phenol	108-95-2					3.0E-01	I	2.0E-01	C			1	0.1			1.8E+04	n	1.8E+05	nn	2.1E+02	n	8.8E+02	n	1.1E+04	n			8.1E+00					
Phenylenediamine, m-	108-45-2					6.0E-03	I					1	0.1			3.7E+02	n	3.7E+03	n					2.2E+02	n			7.8E-02					
Phenylenediamine, o-	95-54-5	4.7E-02	H									1	0.1			1.0E+01	c	3.7E+01	c					1.4E+00	c			5.0E-04					
Phenylenediamine, p-	106-50-3					1.9E-01	H					1	0.1			1.2E+04	n	1.2E+05	nn					8.9E+03	n			2.4E+00					
Phenylphenol, 2-	90-43-7	1.9E-03	H									1	0.1			2.5E+02	c	8.9E+02	c					3.5E+01	c			7.2E-01					
Phorate	298-02-2					2.0E-04	H					1	0.1			1.2E+01	n	1.2E+02	n					7.3E+00	n			7.9E-03					
Phosgene	75-44-5							3.0E-04	I	V		1		8.7E+04		4.0E-01	n	1.7E+00	n	3.1E-01	n	1.3E+00	n										
Phosmet	732-11-6					2.0E-02	I					1	0.1			1.2E+03	n	1.2E+04	n					7.3E+02	n			2.1E-01					
Phosphine	7803-51-2					3.0E-04	I	3.0E-04	I			1				2.3E+01	n	3.1E+02	n	3.1E-01	n	1.3E+00	n	1.1E+01	n								
Phosphoric Acid	7664-38-2							1.0E-02	I			1				1.4E+07	nn	8.0E+07	nn	1.0E+01	n	4.4E+01	n										
Phosphorus, White	7723-14-0					2.0E-05	I					1				1.6E+00	n	2.0E+01	n					7.3E-01	n			2.7E-03					
Phthalic Acid, P-	100-21-0					1.0E+00	H					1	0.1			6.1E+04	n	8.2E+05	nn					3.7E+04	n			1.3E+01					
Phthalic Anhydride	85-44-9					2.0E+00	I	2.0E-02	C			1	0.1			1.2E+05	nn	1.2E+06	nn	2.1E+01	n	8.8E+01	n	7.3E+04	n			1.8E+01					
Picloram	1918-02-1					7.0E-02	I					1	0.1			4.3E+03	n	4.3E+04	n					2.6E+03	n	5.0E+02		8.0E-01	1.2E-01				
Picramic Acid (2-Amino-4,6-dinitrophenol)	96-91-3					2.0E-03	P					1	0.1			1.2E+02	n	1.2E+03	n					7.3E+01	n			2.9E-02					
Pirimiphos, Methyl	29232-93-7					1.0E-02	I					1	0.1			6.1E+02	n	8.2E+03	n					3.7E+02	n			1.7E-01					
Polybrominated Biphenyls	59536-65-1	3.0E+01	C	8.6E-03	C	7.0E-06	H					1	0.1			1.8E-02	c*	5.7E-02	c*	2.8E-04	c	1.4E-03	c	2.2E-03	c								
Polymeric Methylene Diphenyl Diisocyanate (PMDI)	9016-87-9							6.0E-04	I			1	0.1			8.5E+05	nn	3.6E+06	nn	6.3E-01	n	2.6E+00	n										
Potassium Perchlorate	7778-74-7					7.0E-04	I					1				5.5E+01	n	7.2E+02	n					2.6E+01	n								
Prochloraz	67747-09-5	1.5E-01	I			9.0E-03	I					1	0.1			3.2E+00	c	1.1E+01	c					4.5E-01	c			2.5E-03					
Profluralin	26399-36-0					5.0E-03	H					1	0.1			3.7E+02	n	3.7E+03	n					2.2E+02	n			8.0E+00					
Prometon	1610-18-0					1.5E-02	I					1	0.1			9.2E+02	n	9.2E+03	n					5.5E+02	n			2.8E-01					
Prometryn	7287-19-6					4.0E-03	I					1	0.1			2.4E+02	n	2.5E+03	n					1.5E+02	n			2.3E-01					
Propachlor	1918-16-7					1.3E-02	I					1	0.1			7.9E+02	n	8.0E+03	n					4.7E+02	n			3.7E-01					
Propanil	709-98-8					5.0E-03	I					1	0.1			3.1E+02	n	3.1E+03	n					1.8E+02	n			1.1E-01					
Propargite	2312-35-8					2.0E-02	I					1	0.1			1.2E+03	n	1.2E+04	n					7.3E+02	n			2.0E+02					
Propargyl Alcohol	107-19-7					2.0E-03	I					1	0.1			1.2E+02	n	1.2E+03	n					7.3E+01	n			1.5E-02					
Propazine	139-40-2					2.0E-02	I					1	0.1			1.2E+03	n	1.2E+04	n					7.3E+02	n			8.7E-01					
Propham	122-42-9					2.0E-02	I					1	0.1			1.2E+03	n	1.2E+04	n					7.3E+02	n			3.3E-01					
Propiconazole	60207-90-1					1.3E-02	I					1	0.1			7.9E+02	n	8.0E+03	n					4.7E+02	n			6.4E+00					
Propylene Glycol	57-55-6					2.0E+01	P					1	0.1			1.2E+05	nn	1.2E+07	nn					7.3E+05	n			1.5E+02					
Propylene Glycol Dinitrate	6423-43-4							A 2.7E-04	A	V		1		1.4E+05		6.0E+01	n	2.5E+02	n	2.8E-01	n	1.2E+00	n	5.7E-01	n			1.9E-04					
Propylene Glycol Monoethyl Ether	1569-02-4					7.0E-01	H					1	0.1			4.3E+04	n	4.3E+05	nn					2.6E+04	n			5.2E+00					
Propylene Glycol Monomethyl Ether	107-98-2					7.0E-01	H	2.0E+00	I			1	0.1			4.3E+04	n	4.3E+05	nn	2.1E+03	n	8.8E+03	n	2.6E+04	n			5.2E+00					
Propylene Oxide	75-56-9	2.4E-01	I	3.7E-06	I			3.0E-02	I	V		1		8.8E+04		1.9E+00	c	8.7E+00	c	8.6E-01	c*	3.3E+00	c*	2.3E-01	c			4.7E-05					
Pursuit	81335-77-5					2.5E-01	I					1	0.1			1.5E+04	n	1.5E+05	nn					9.1E+03	n			2.7E+01					

Establishing the Scope of Work

- **Problem Identification and Goals**
- **Site Reconnaissance / Background**
- **Determine Applicable Regulations and Guidance**
- **Constituents of Concern in this Case:**
  - PAHs
  - VOCs
  - Pentachlorophenol
  - Dioxins and Furans

USEPA SCREENING LEVELS (SLs) EVALUATIONS

- **Step 1**
  - Compare to SL tables
- **Step 2**
  - Compare with background
- **Step 3**
  - Conduct risk assessment OR
  - Compare with ATSDR or USEPA specified remedial goal levels

SLs Evaluation

- **Step 1 is to compare the highest concentration of each constituent to the SLs**
- **SLs are given for a $1 * 10^{-6}$ risk level.**
- **Sites with concentrations at or below the unrestricted SLs do not require further evaluation or action.**
- **Sites with chemical concentrations in air or soils that are greater than the SLs are then analyzed further.**

If Higher than the SLs

- **The background chemical concentration is used as the next decision point if it is higher than the $1*10^{-6}$ SLs.**
- **Background concentrations typically fall within $1*10^{-4}$ to $1*10^{-6}$ risk levels, but can be higher or lower.**

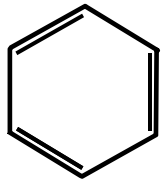
Final Evaluation

- **A site-specific risk assessment where site-specific Remediation Goals are developed and approved by the regulatory agency can be performed.**
- **The cumulative (total) site carcinogenic risk is typically set at a not to exceed $1*10^{-4}$ for carcinogenic constituents (such as, Mississippi, Texas).**
- **USEPA and others have set specific concentration levels where some action should be considered.**

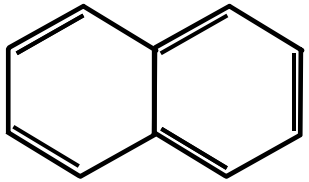
Consider Common Sources of Constituents

- **Polycyclic Aromatic Hydrocarbons (PAHs)**
  - Petroleum products
  - Coal
  - Creosote
  - Cigarette Tar
  - Burning of combustible products
- **Pentachlorophenol**
  - Wood preservative
  - Herbicides
- **Volatile Organics (Benzene)**
  - Gasoline
  - Wood
  - Plastics
  - Perfumes, dyes and paints
  - Burning of any combustible product
- **Phenols and Cresols**
  - General disinfectant
  - Phenolic and epoxy resins
  - Germicidal paints
  - Pharmaceuticals
  - Laboratory reagents, dyes
  - Degradation product of PAHs
- **Dioxins and Furans**
  - Byproduct in some herbicides
  - Burning of combustible product
  - Byproduct in pentachlorophenol

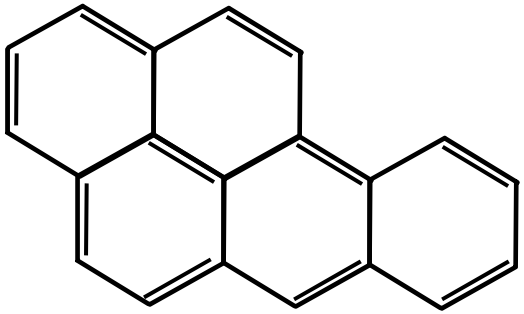
PHYSICAL STRUCTURE



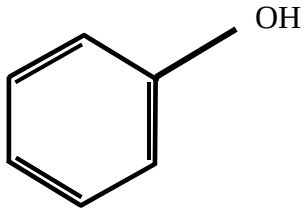
BENZENE
C_6H_6



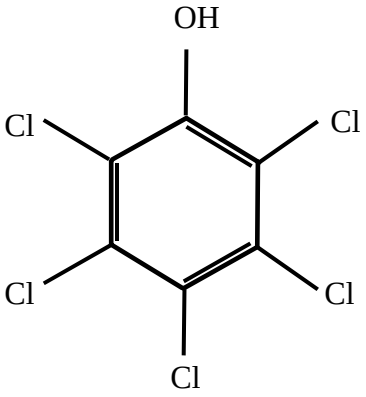
NAPHTHALENE
$C_{10}H_8$



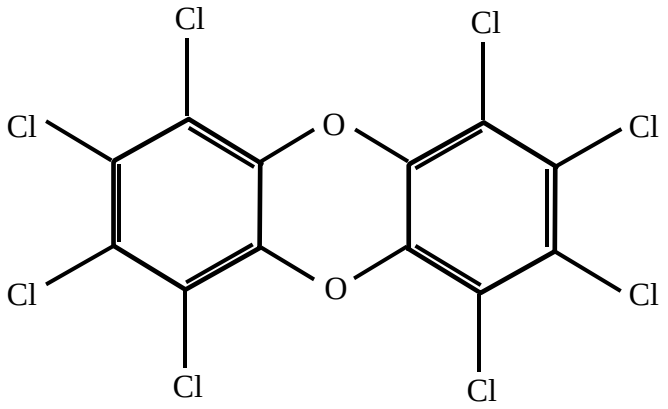
BENZO(a)PYRENE
$C_{20}H_{12}$



PHENOL
C_6H_5OH



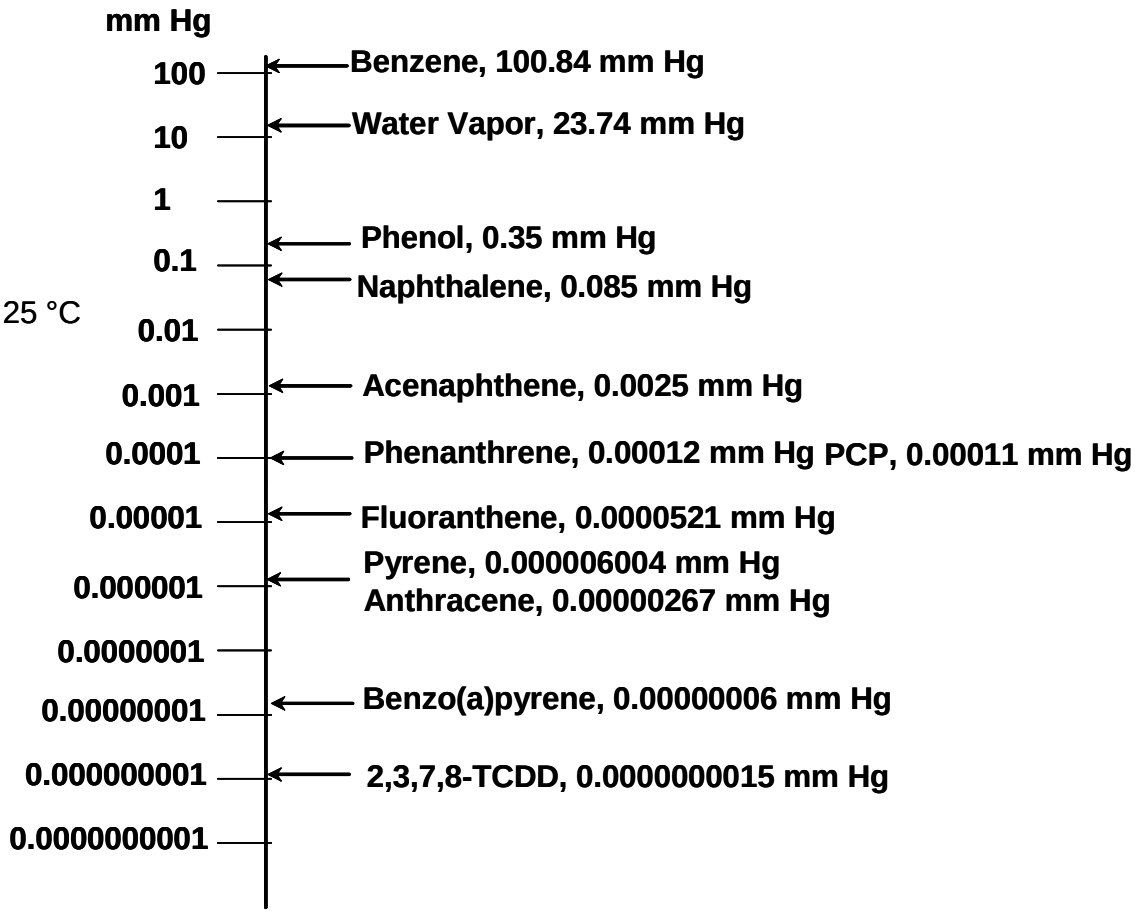
PENTACHLOROPHENOL
C_6HCl_5O



1,2,3,4,6,7,8,9-OCTACHLORODIBENZO-p-DIOXIN
$C_{12}Cl_8O_2$

Volatile (Evaporation) Index

All vapor pressures at 25 °C



Benzene (gasoline)

Water Vapor

Moth Balls
(naphthalene)

Benzo(a)pyrene
(Asphalt)

FIELD METHODS

- **Applicable Methods**
  - Dioxin/Furan EPA Method TO-9A
  - PAHs EPA Method TO-13A
  - VOCs EPA Method TO-14A
  - Phenolics OSHA Method 32

COMPARISON OF UNITS

1 kilogram	=	200	teaspoons
1 gram	=	0.2	teaspoon
1 milligram	=	0.0002	teaspoon
1 microgram	=	0.0000002	teaspoon
1 nanogram	=	0.0000000002	teaspoon
1 picogram	=	0.0000000000002	teaspoon
1 femtogram	=	0.0000000000000002	teaspoon

1 kilogram	=	1,000,000	parts per million (ppm)
1 gram	=	1,000	parts per million (ppm)
1 milligram	=	1	parts per million (ppm)
1 microgram	=	0.001	parts per million (ppm)
1 nanogram	=	0.000001	parts per million (ppm)
1 picogram	=	0.000000001	parts per million (ppm)
1 femtogram	=	0.000000000001	parts per million (ppm)

Per Kilogram for soil

Per Liter for water

Per cubic meter for air

Laboratory Details

- **Detection Limits**
  - MDL – Lowest Theoretical Limit
  - PQL – Detection Quantifiable
  - RL – Value Statistically Valid
  - Qualifiers
- **Preservatives / Hold Times / Shipping**
- **Results Turnaround**
  - Data Package – Lab Documentation
  - Data Validation – Third Party QAQC
- **Laboratory Qualifications**

Standard Operating Procedures (SOPs)

- **USEPA, ASTM, OSHA, State-Agency, Standard Methods, NRC, etc.**
- **Use SOPs to Develop Field Specific Procedures that can be Field Adjusted**
  - Physical Boundaries
  - Logistical Constraints
  - Budget Considerations
  - Example: Calibrate flow devices every 24 hours for a three day test. Calibration takes an entire workday. Resolution, Calibrate at the beginning and end.

Work Plan Development

- **Based on all of information gathered above, the Work Plan is the vehicle that documents:**
  - What
    - Tasks to be completed
  - When
    - Timing/logistics
  - How
    - SOPs / Training / Safety&Health
  - Who
    - Roles - Team Leader / Sampling Team

Team

- **Leader – Responsible for Overseeing the sampling effort**
- **Samplers – Operating instrumentation and collecting samples**
- **Record Keeper – Documentation**
  - Written data logs, calibration
  - Photo log
  - GPS Location
- **Decontamination - Keep it Clean!!**

Laboratory Requirements

- Sample Handling/Labeling
- Sample Preparation (Ice and packaging)
- Chain of Custody
- Holding Times

Field Preparation

- Design Data Collection Format
- Brief Sampling Team Members
- Perform Dry Run with Equipment and Procedures
- Sampling Logistics
- Human Elements
- Adjust Work Plan as Necessary

Ambient Air Monitoring Study

SAMPLING LOCATIONS

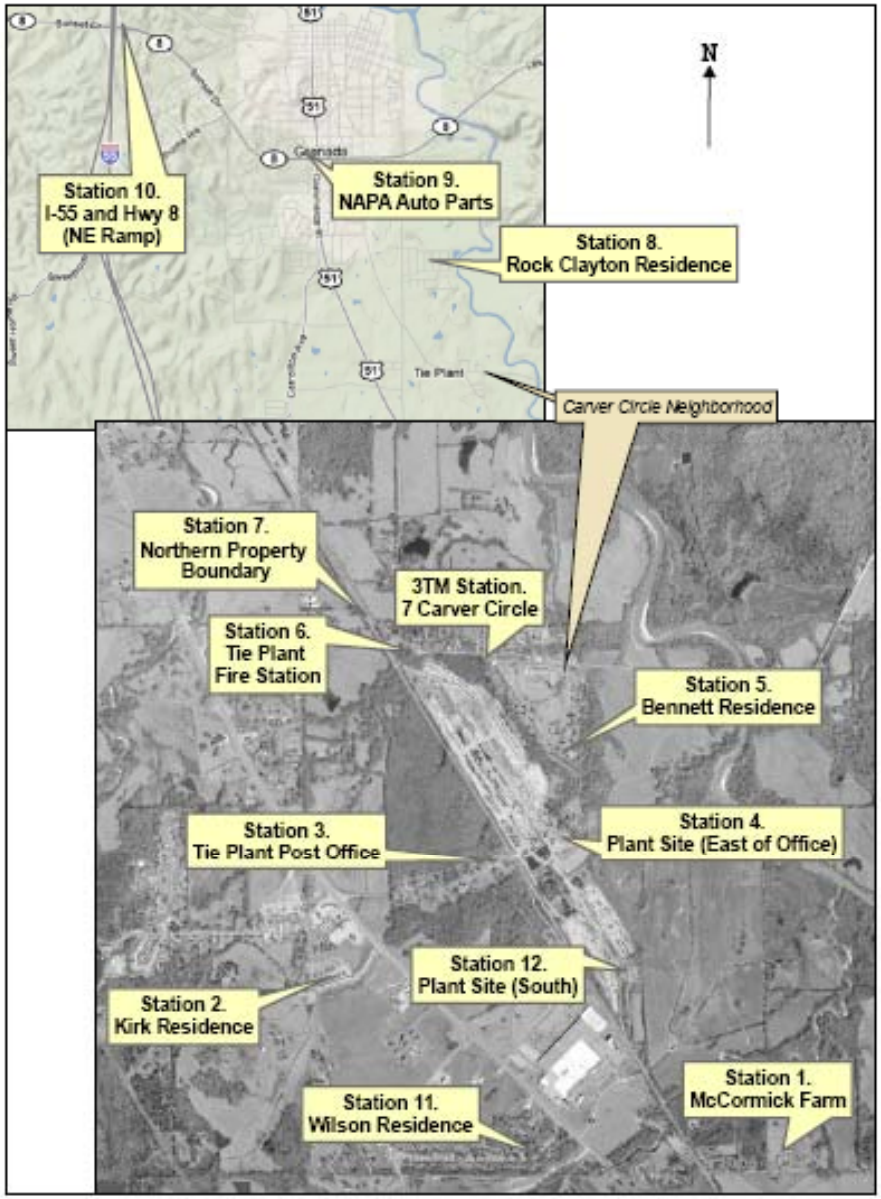
- 2 On-site Stations
- 8 Stations around the Plant
- 2 Local Reference Stations

CONSTITUENTS

- Polycyclic Aromatic Hydrocarbons (PAHs)
- Volatile Organics (Benzene)
- Phenols and Cresols
- Pentachlorophenol
- Dioxins and Furans

- Meteorological

Air Monitoring Stations Map



Air Monitoring Equipment

Sample Measurements

- **Ambient Air Monitoring**
  - Micrograms per cubic meter (ug/m^3)
    - Numerator – Mass
      - Condense, capture or adsorb onto or into a media (for example: PUF)
      - Extract Sample from Media
      - Analyze Extract (GC/Mass Spectrometer)
    - Denominator – Volume
      - Known Volume of Air
        - Volume = Flowrate * Time
        - Calibrated Flow Device
        - Time of Media Exposure

Weather Station

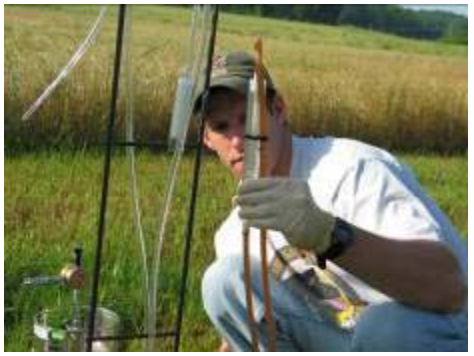
- Temperature
- Wind Speed and Direction
- Barometer Pressure
- Relative Humidity

Air Sampling Equipment

- **Hi Volume Samplers**
  - PAHs/TO-13A
  - Dioxons/Furans/TO-9A

- **Summa Canisters**
  - Volatile Organics/TO-14A

- **Low Volume Samplers**
  - Pentachlorophenol/TO-10A
  - Phenols-Cresols/OSHA 32



Hi-Volume Air Samplers

Initial Calibration

Inside Front Compartment

Top View with Sample Canister

Hi-Volume Air Canister

Calibration of Low Volume Samplers

Set-Up

Plant Site

Post Office

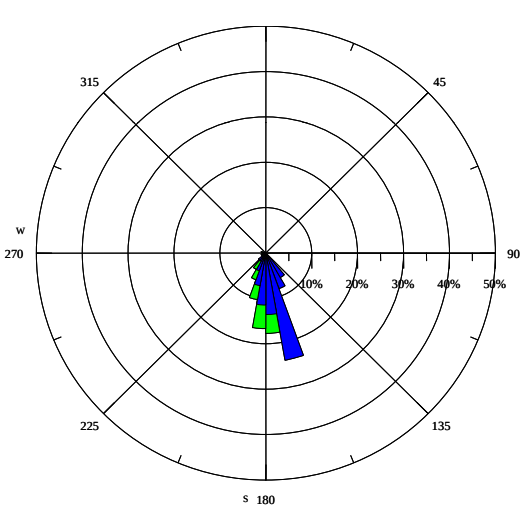
Reference Station

Sampling for 3 Consecutive 24-Hour Periods

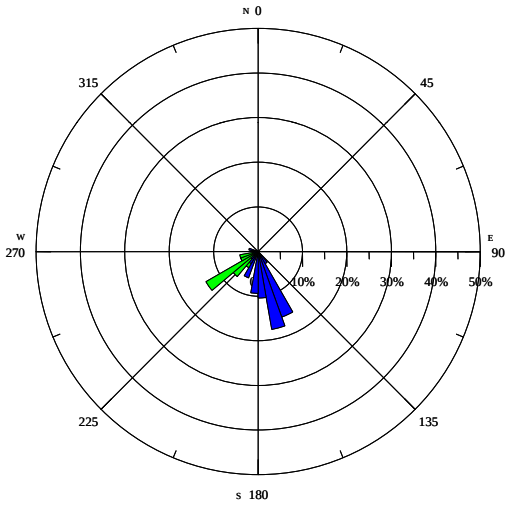
Sample Preparation for Shipment

Windrose Data
May 13-15, 2003

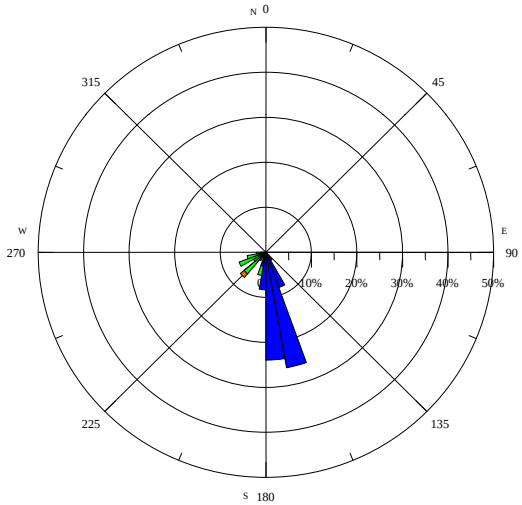
May 13, 2003

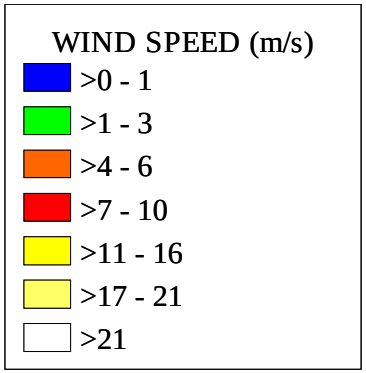


May 14, 2003

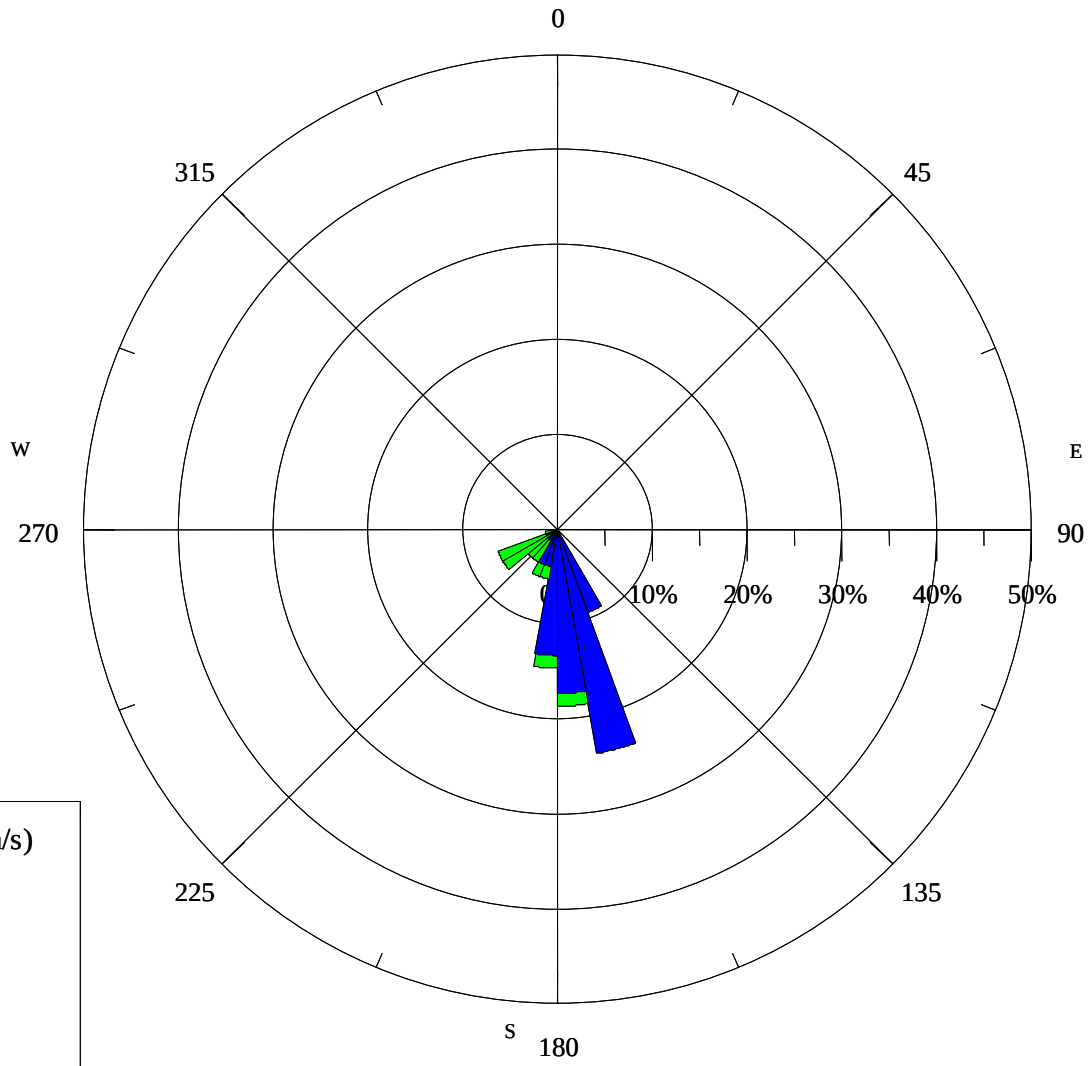


May 15, 2003





Composite Windrose May 13-15, 2003



Sampling Results for PCP and PAHs

METHOD	ANALYSES	MEDIA	REPORTING LIMIT (ug)	13-May		
				RESULT (ug)	FLOW (m^3)	RESULT (ug/m^3)
TO-10A	Pentachlorophenol	PUF	0.014 Dilution Factor*	3.19 40	7.1047	0.44900
TO-13A	1-Methylnaphthalene	PUF	5	6.3	328.46	0.02
	2-Methylnaphthalene		5	15.1	328.46	0.05
	Acenaphthene		5	32.5	328.46	0.10
	Acenaphthylene		5	< 5	328.46	< 0.02
	Anthracene		5	12.2	328.46	0.04
	Benzo(a)anthracene		5	< 5	328.46	< 0.02
	Benzo(a)pyrene		5	< 5	328.46	< 0.02
	Benzo(b)fluoranthene		5	< 5	328.46	< 0.02
	Benzo(e)pyrene		5	< 5	328.46	< 0.02
	Benzo(g,h,i)perylene		5	< 5	328.46	< 0.02
	Benzo(k)fluoranthene		5	< 5	328.46	< 0.02
	Biphenyl		5	< 5	328.46	< 0.02
	Carbazole		5	< 5	328.46	< 0.02
	Chrysene		5	< 5	328.46	< 0.02
	Dibenz(a,h)anthracene		5	< 5	328.46	< 0.02
	Dibenzofuran		5	33.2	328.46	0.10
	Fluoranthene		5	16.2	328.46	0.05
	Fluorene		5	41.5	328.46	0.13
	Indene		5	< 5	328.46	< 0.02
	Indeno(1,2,3-cd)pyrene		5	< 5	328.46	< 0.02
	Naphthalene		5	30.6	328.46	0.09
	Phenanthrene		5	115	328.46	0.35
	Pyrene		5	9.3	328.46	0.03
	Quinoline		5	< 5	328.46	< 0.02

Sampling Results for Phenolics and Volatiles

METHOD	ANALYSES	MEDIA	REPORTING LIMIT (ug)	13-May			
				RESULT (ug)	FLOW (m^3)	RESULT (ug/m^3)	
OSHA 32	2,4-Dimethylphenol	XAD-7	0.84	< 0.84	0.14241	<	5.90
	2-Methylphenol		1.5	< 1.5	0.14241	<	10.53
	3&4-Methyl phenol		2.4	< 2.4	0.14241	<	16.85
	3,5-Dimethylphenol		1.6	< 1.6	0.14241	<	11.24
	Phenol		1	< 1	0.14241	<	7.02

			REPORTING LIMIT (ppbv)	RESULT (ppbv)	CONVERT (mw/24.45)	RESULT (ug/m^3)
TO-14A	Benzene	SUMMA	0.058	0.256	3.19	0.82
	Toluene		0.05	2.4	3.77	9.04
	Ethylbenzene		0.074	0.144	4.34	0.63
	1,3- and 1,4-Dimethylbenzenes (m,p-Xylene)		0.1	0.237	13.03	3.09
	1,2-Dimethylbenzene (o-Xylene)		0.05	0.089	13.03	1.16
	Naphthalene		0.2	0.471	5.24	2.47
	1-Methylnaphthalene		0.32	< 0.32	5.82	< 1.86
	2-Methylnaphthalene		0.41	< 0.41	5.82	< 2.38
	Furan		0.13	< 0.13	2.78	< 0.36

Example Problem