Assessment of Anthropogenic Background PAH Concentrations in East Anglia Soils

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What is Background?

Background concentrations are generally considered to be the level or amount of a chemical found in common areas not associated with a particular contaminant release.

Parks, roadways, residential areas, non-industrialized properties are typical background areas.

The definition from Tiered Approach to Corrective Action Objectives (TACO (Illinois) is:

"Area Background" means concentrations of regulated substances that are consistently present in the environment in the vicinity of a site that are the result of natural conditions or human activities, and not the result solely of releases at the site.

Information summarized from Urban Area Polycyclic Aromatic Hydrocarbons Study Tiered Approach to Corrective Action Objectives, Illinois EPA

Motivating Factors for the Study

ALARA Principle – Remediation to target levels < background is not practicable, cost efficient, or beneficial from a health protection standpoint;

Delineating limits of contamination from point sources;

Screening out sites from Preliminary Investigations relative to more detailed studies;

Understanding local conditions – will be highly variable

Because we can – large amounts of data are available, and can be retrospectively analysed, as long as amenable to electronic data reading and manipulation (AGS data format proved to be the key)

Study Objectives

Assess anthropogenic background levels of PAH levels detected in East Anglia Soils.

- Rural (no identified current or historic source)
- Urban (no identified current or historic source)
- Industrial
- Farms
- Automotive works

Design

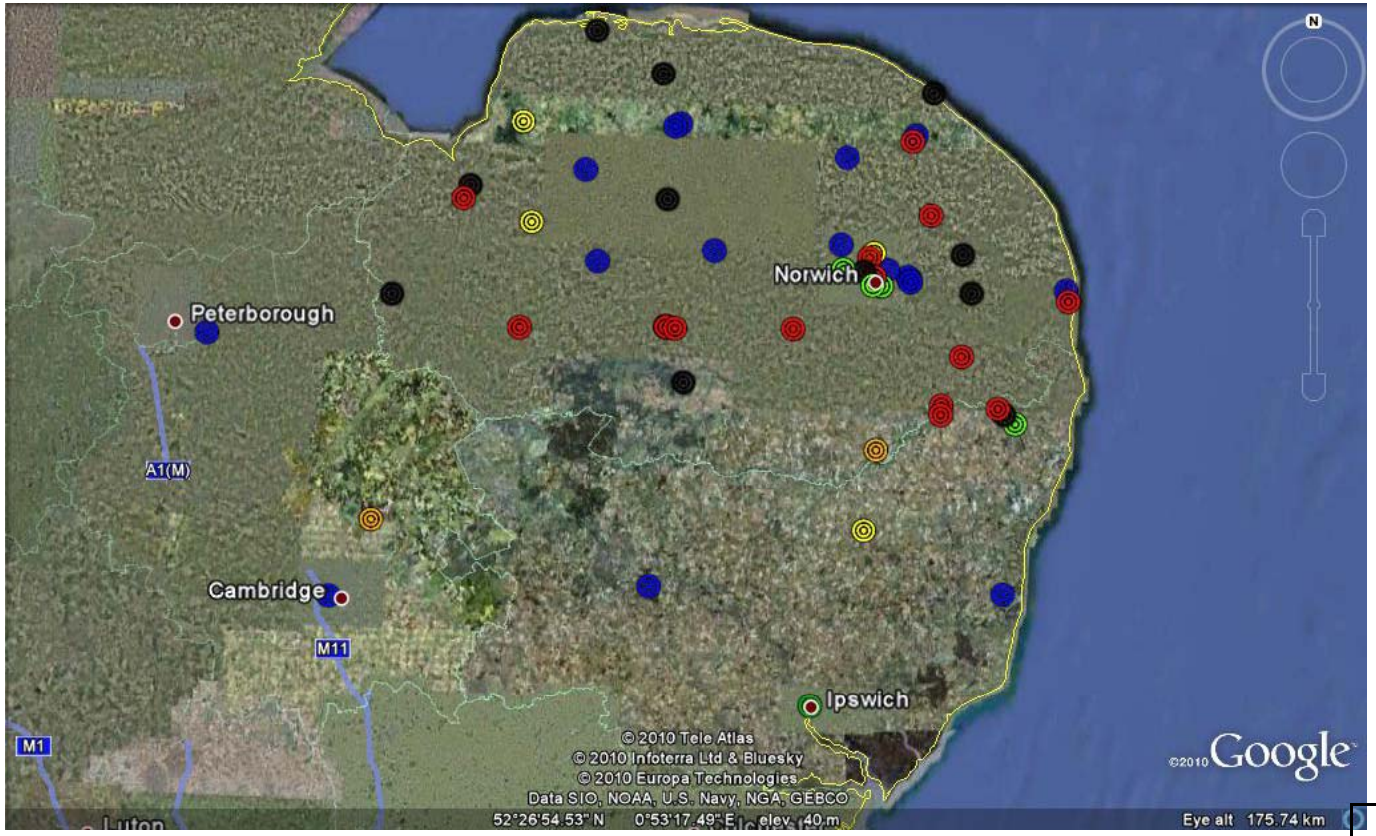
Retrospective examination of SI data between 2004 and 2010

- Non-structured selection of sites – SIs conducted by Harrison Group with archived AGS electronic data

- Classification of sites as per land uses based on Desk Study information

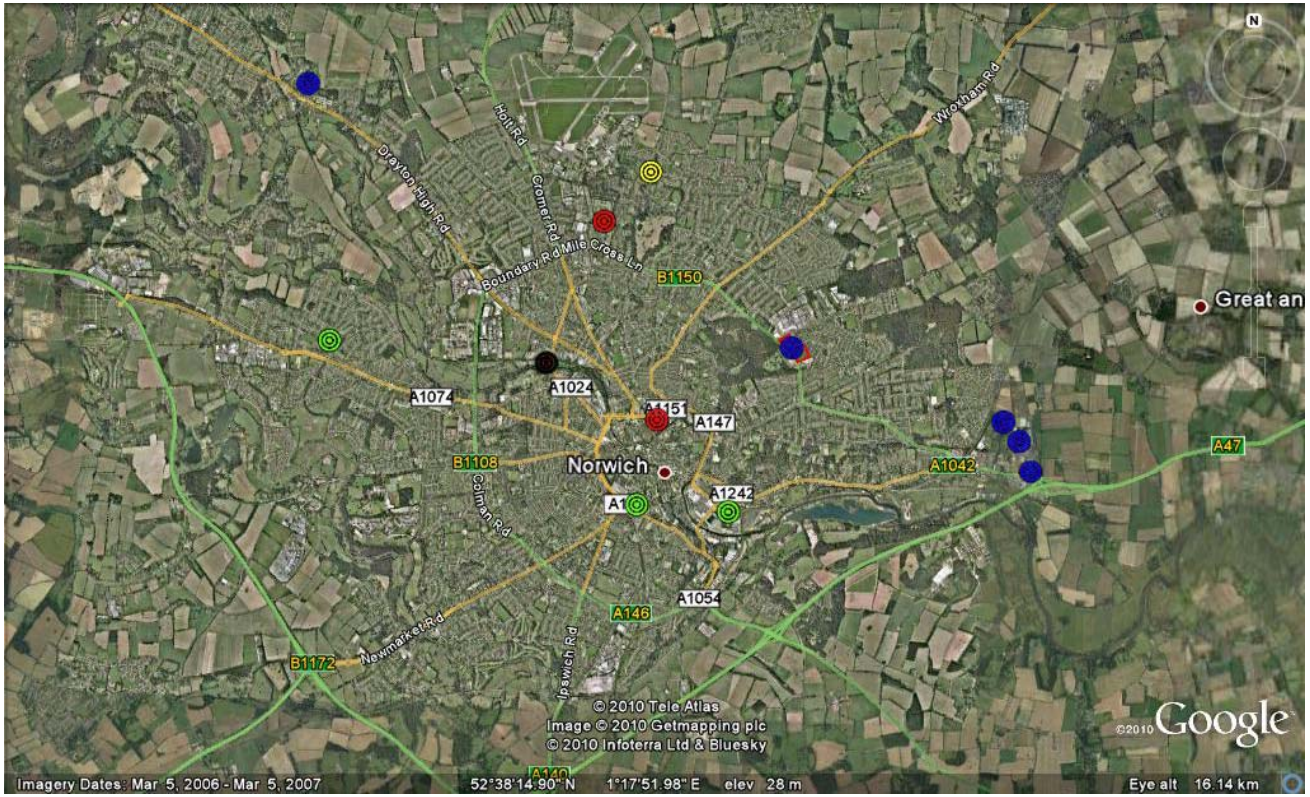
- Statistical review of PAH data
  - Distributional characteristics
  - Outlier identification
  - Development of baseline data set
  - Derivation of statistical parameters
  - Comparison with published values

Design



Group	Sites	Samples	
Farm	2	13	
Industrial	15	104	
Urban	7	28	
General	16	69	
Automotive	10	45	
Total	50	259	

Sites in Urban Areas



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Statistical analysis :

- Normal probability plots
- Tests for normality (Shapiro Wilkes)
- Test for outliers (Grubbs Test)
- Upper Confidence Limits (Normal, Log-Normal, Non-Parametric)
- 95% Upper Tolerance Limits
- Multi-Variate Analysis (Fingerprinting)

Spatial Analysis

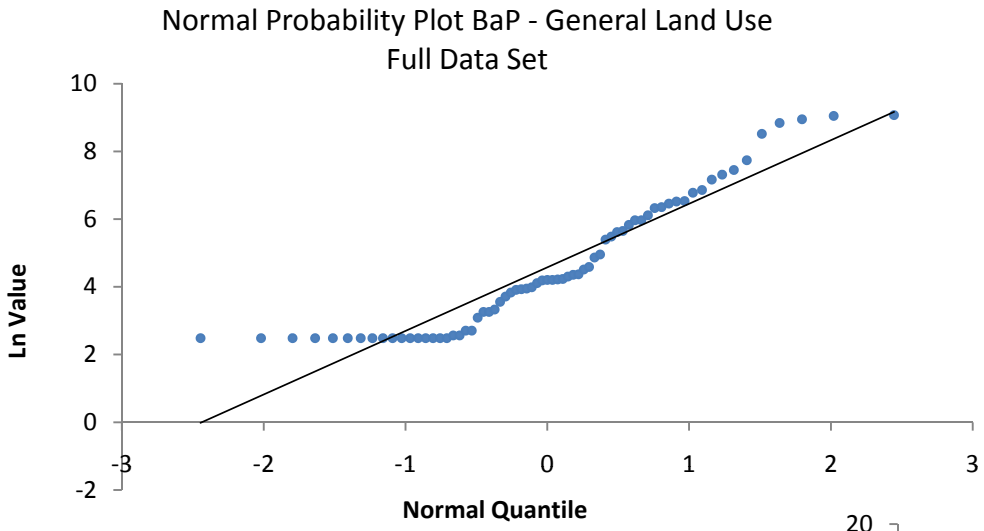
- Lateral and Vertical extent
- Hot-spots
- Concentration Gradients

Summary Statistics - General (no identified current or historic source)

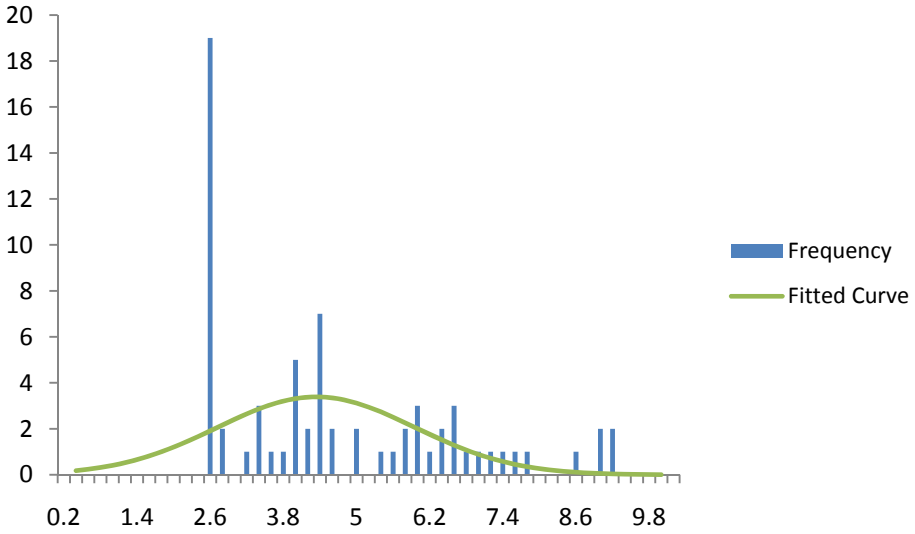
Summary Statistics General Data

					Log-Normal		
Constituent	**Min**	**Max**	**Mean**	**Geometric Mean**	**95% UCL**	**95th Percentile**	**95% Upper Tolerance Limit**
Acenaphthene	14	760	53	28	56	132	197
Acenaphthylene	5	890	84	20	114	258	492
Anthracene	9	1700	169	35	222	484	948
Benzo (a) anthracene	12	8100	686	117	1141	2200	4656
Benzo (a) pyrene	12	8700	768	97	1564	2518	5781
Benzo (b) fluoranthene	16	11000	930	128	1794	3049	6846
Benzo (ghi) perylene	10	6700	603	87	1164	2073	4662
Benzo (k) fluoranthene	25	7400	534	97	652	1403	2776
Chrysene	10	7000	716	107	1532	2581	5818
Dibenzo (ah) anthracene	8	1500	129	26	150	336	643
Fluoranthene	25	21000	1529	198	2859	4803	10839
Fluorene	12	1300	79	31	87	213	348
Indeno (1.2.3 - cd) pyrene	11	5900	467	63	746	1350	2947
Naphthalene	10	5100	253	75	362	839	1554
Phenanthrene	21	8500	722	140	1147	2337	4795
Pyrene	22	17000	1240	172	2248	3918	8702

Statistical Distribution - General (no identified current or historic source)



- High end outliers
- Left censored (detection limits)
- Bi-modal



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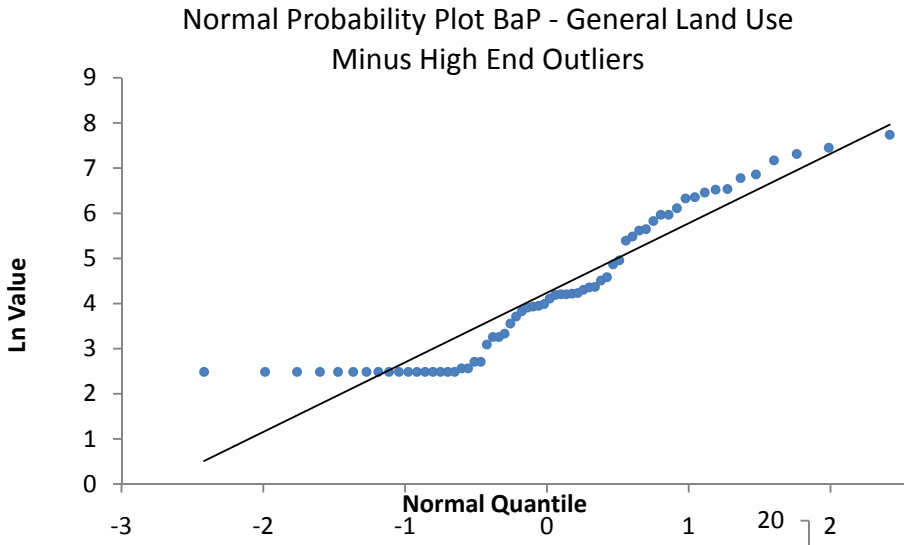
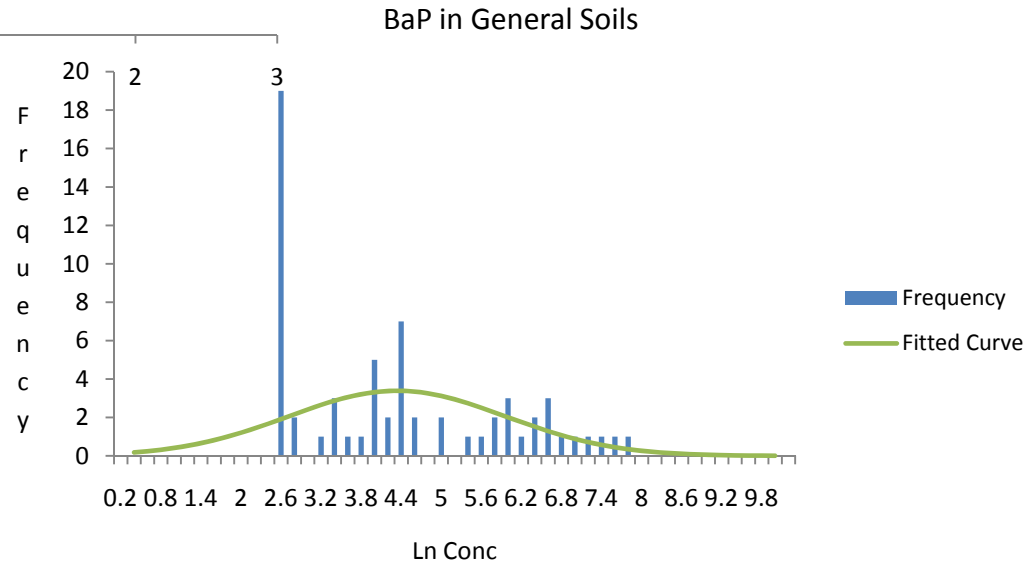




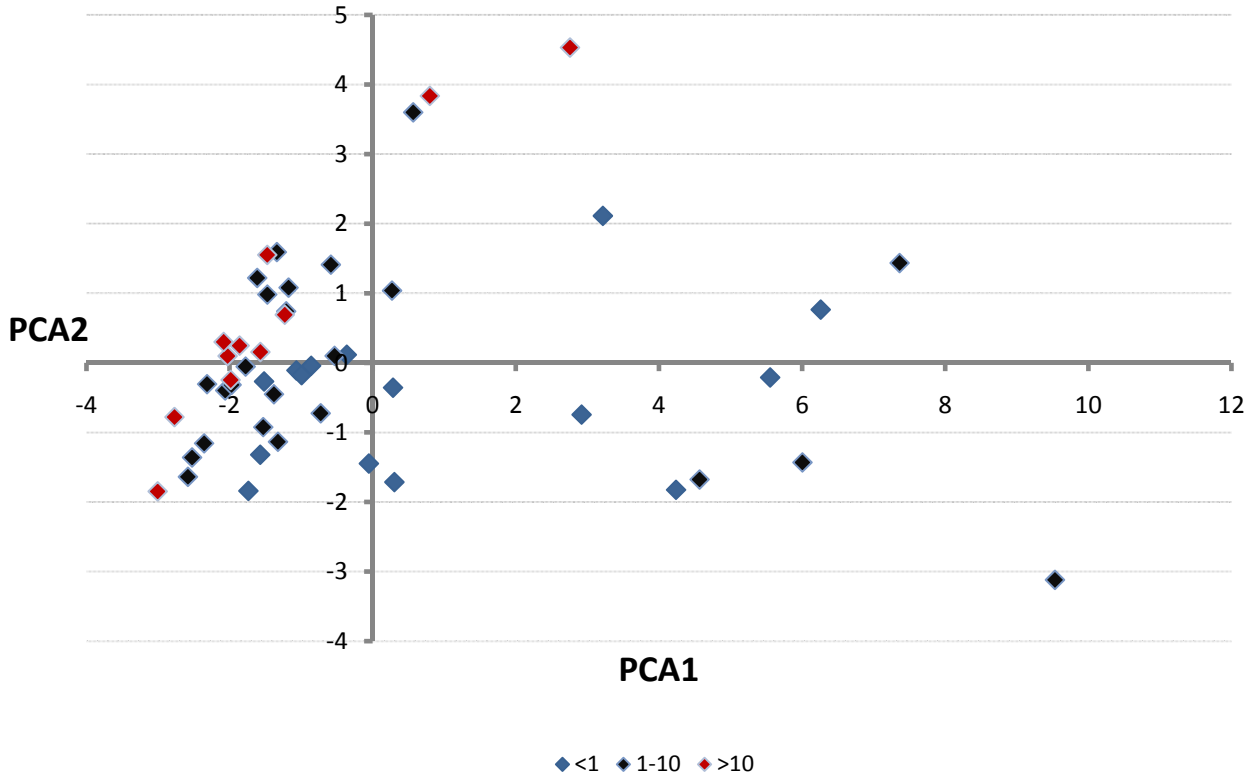
- Closer conformity with Log-normal Distribution
- Left censored (detection limits)

Dealing with Non-Detects

- Detection Limit (approach used)
  - Detection Frequency 75%
- ½ Detection Limit
- Maximum Likelihood Estimation for Left Censored Data - replacement of non-detect values with fitted values
  - To be assessed

Pattern Assessment – Variation in Isomer ratios (assessment of discrete sources)

- Principal Components Analysis of Isomer Ratios
- Data divided by concentration – assess if outliers are from unique sources

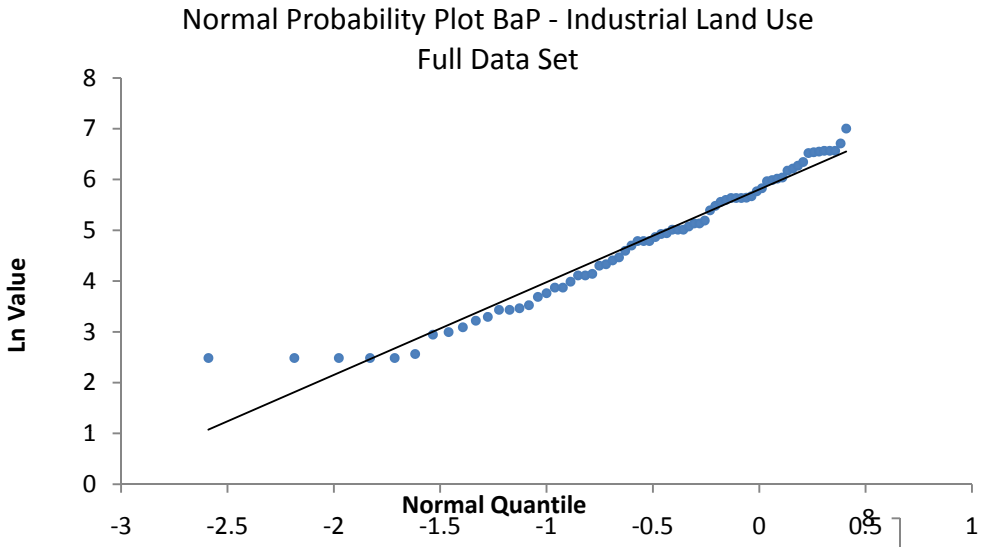


No clear difference by Concentration level.

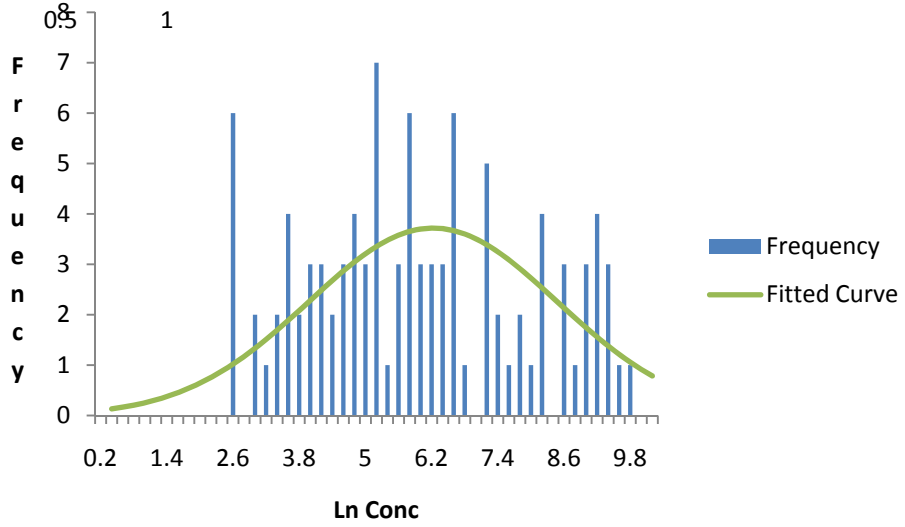
Most samples showed very similar profiles

Suggestive of common source

Statistical Distribution - Industrial



- Good fit with Log-normal Distribution
- Left censored (detection limits)



Data Comparison Across Groups

					Log-Normal		
Constituent	**Min**	**Max**	**Mean**	**Geometric Mean**	**95% UCL**	**95th Percentile**	**95% Upper Tolerance Limit**
Urban	12	4700	498	129	1447	1933	5214
General	12	8700	768	97	1564	2518	5781
Industrial	12	220000	6049	508	13414	19717	50176
Automotive	12	16840	1276	222	2913	4414	9950
Farm	26	14000	2008	561	33072	11559	76123

Comparison with Published Literature

Background Levels of Polycyclic Aromatic Hydrocarbons (PAH) and Selected Metals in New England Urban Soils
L. J. N. Bradley B. H. Magee and S. L. Allen Journal of Soil Contamination, 3(4): (1994)

•Samples of surficial soils from urban locations in three New England cities. Sixty samples – twenty from each city

Concentrations of Polynuclear Aromatic Hydrocarbons and Inorganic Constituents in Ambient Surface Soils – Chicago Illinois, 2001-2002
Kay et al, 2003, USGS Report 03-1045

•57 Sites in Chicago Metropolitan Area. One sample from each site

PAHs in background soils from Western Europe: Influence of atmospheric deposition and soil organic matter
Jae Jak Nam et al. Chemosphere 70 (2008) 1596–1602

•53 Soil Samples from Norway and UK

Comparison with Published Literature

Broadly, our results are similar to the observations made elsewhere:

UK soils – Geometric Mean BaP 46 ug/kg – range 1.8 – 1600; (our data Geo. Mean 52 range 6-1724, after high end outliers were excluded)

Chicago soils – BaP 95 Percentile 2,100 ug/kg; (our data 2,500 including outliers, 1,700 excluding)

Highly spatially variable – orders of magnitude differences within 300 metres of each other.

New England Study – BaP range 40 – 13,000 ug/kg, and 95 percentile 1,800 ((our data 2,500 including outliers, 1,700 excluding)

Implication for Remediation

						Approximate Screening Value		
Samples Analysed	Number of Detects	Minimum	Maximum	Mean	95% UCL	HPA BMD10	GAC	Fitzgerald et al.
						500	1000	5000
5	5	680	8500	4514	8068.7			
5	2	12	66	26	47.9			
4	3	12	1724	649	1534.6			
4	4	22	954	366	883.2			
4	3	12	880	275	752.9			
4	4	51	390	139	335.9			
6	2	12	28	15	20.4			
4	2	12	69	36	69.3			
5	5	52	8700	2177	5698.6			
4	2	12	340	101	289.2			
6	5	12	2300	638	1422.9			
5	3	12	142	45	98.5			
4	4	91	390	200	364.4			

D. James Fitzgerald,Neville I. Robinson,and Beverly A. Pester. Application of Benzo(a)pyrene and Coal Tar Tumor Dose–Response Data to a Modified Benchmark Dose Method of Guideline Development

Conclusions – Points for Discussion

Stationary and mobile anthropogenic sources account for the majority of PAHs, with great variability regionally and locally.

Remediation should not commence without establishing / assessing a site-specific background, if possible.

The impracticality and infeasibility of remediation to guideline levels if naturally occurring background exceeds the maximum allowable value is self evident. It deems remediation unnecessary and unproductive in such scenarios.

ALARA principal is a vital consideration (setting cleanup levels as low as reasonably achievable). Assessment and consideration of background would be imperative.

A tier-based guideline system may be very beneficial, where the central tendency and maximum values are compared with relevant background numbers (95% UCL), (95th percentile). This is particularly relevant in the current times, given the broader issues of greenhouse gas emissions, and need for efficient utilisation of economic resources.