Identification of research and developments in the measurement occurrence of Polyaromatic Hydrocarbons in dusts and particulates

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Supplementary Material

The literature search was carried out using the Thompson Reuters Web of Science search engine with search criteria as follows:

TOPIC: (PAH$ OR "poylcyclic aromatic hydrocarbon$" OR "polyaromatic hydrocarbon$")

AND TOPIC: (dust$ OR particulate$ OR PM10 OR PM2.5 OR "geogenic dust$")

NOT TOPIC: (cosmic OR interstellar OR galactic OR diesel OR sediment$ OR leaf OR leaves OR leafy)

Refined by: [excluding] WEB OF SCIENCE CATEGORIES: (ASTRONOMY ASTROPHYSICS)

Timespan: All years. Indexes: SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, ESCI.

Table S1 Information supplied with each reference from the literature search

Authors/Editors	Title	Keywords	Page count
Abstract	Times Cited	Source Abbreviation	Research Areas
Addresses	Cited Reference Count	Web of Science Categories	Usage count
ISSN/ISBN	Language	Author Identifiers	
IDS number	Accession Number	Conference information	
Funding Information	Source	Conference Sponsors	
PubMed ID	Document type	Publisher information	

Table S2 Summary of research themes derived from bigram plots

	Chemical Compounds	Analytical Chemistry methods	Application areas	Health and Toxicology	Types of particulates	Geographical Location
All refs	1 hydroxypyrene	Liquid Chromatography Gas Chromatogrphy coupled Mass spectrometery Thermal Desorption GC	seasonal variation wood and biomass combustion links with heavy metals source apportionment	health and cancer risk assessments	airborne urban and indoor	
Environmental Sciences and Ecology	PCB PCDD chlorinated PAH oxygenated PAH nitro PAH	mass spectrometry	atmospheric transport dry deposition particle size segregation	lung cancer risk assessmet personal exposure	house and road dust tobacco smoke hydrocarbons bound to pm10 and pm2.5 particles dry deposition	World Trade Centre North and South China Guangzhou Tianjin Bejing Shanghai
Engineering			waste and tyre incineration diffusion flame soot formation coke oven coal and pellet combustion fluidised bed combustion		settled house dust	
Meteorology and Atmospheric						Mexico City
Chemistry	1 nitropyrene	HPLC fluoresence detection Liquid/gas chromatography tandem mass spectrometry time of flight mass spectrometery solid phase micro extraction microwave assisted extraction accelerated solvent extraction supercritical fluid extraction time of flight multi-photon ionisation mass spectrometery	sea surface microlayer wastewater treatment			
Toxicology			coal dust mouse lung a549, hepg2 and epithelial cells	acellular assay PAH dna adducts oxidative stress damage mutagenic activity gene expression chromosomal aberrations		Czech Republic Rio de Janeiro
Occupational Exposure	mutagenic aldehydes		road paving workers bitumen fumes foundry workers Norwegian aluminium smelter umbilical cord blood	cohort study 1 hydroxy pyrene urinary metabolites		New York City
Other		laser desorption	traffic related kitchen workers cattle farms	heart rate variability		Guwahati City Chiang Mai

Table S3 Analytical chemistry methods used in the selected literature

Title	Authors	Sample matrix	Sample Collection and preparation	Particle size	Sample Storage	PAH Extraction	PAH Analysis	Internal Standards	Reference	Reference
Environmental										
Polynuclear aromatic hydrocarbons in the United Kingdom environment: A preliminary source inventory and budget.	Wild & Jones	Particulate matter.	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Characterization of the Dust/Smoke Aerosol that Settled East of the World Trade Center (WTC) in Lower Manhattan after the Collapse of the WTC 11 September 2001.	Lioy et al.,	Dust.	Samples collected using the protocols established for soil sampling in previous publications (Kitsa et al., 1992); Bulk dust samples from thick deposits (10-15 cm), settled on cars. Mechanical seperation to isolate <53 μm particles and separation of aerodynamic particles using cyclonic re-suspension and filtration.	<53 μm samples,10-53 μm, 2.5-10 μm and <2.5 μm.	n/r	Ultrasonic extraction in DCM, separation on fluorsil column.	GC/MS.	Not reported.	NIST Standard Reference 1649a.	n/r
Aggregate exposures of nine preschool children to persistent organic pollutants at day care and at home.	Wilson et al.,	Soil/dust, indoor and outdoor air .	Air sampling over a 48 h period at 4 l min^{-1} using a URG sampler (4 l min^{-1} with a URG sampler (University Research Glassware Corp., Chapel Hill, NC, USA) and 10 μm filter size). Floor dust collected with a High Volume Small Surface Sampler (HVS3; Cascade Stack Sampling Systems Inc., Bend, OR, USA) using a standard ASTM method. Soil samples scraped from the top 0.5 cm of exposed soil over a 0.1m^2 (1 ft^2) area.	10 μm.	Stored in glass jars at -20°C or lower.	Ultrasonic extraction using using diethyl ether in hexane, separation on fluorsil column.	GC/MS.	Spiking with pyrene-d10, chrysene-d12, DDE-13C, DDT-13C, 2,20,4,5,50-pentachlorobiphenyl, and fenchlorfos.	n/r	n/a
Concentrations of PAHs in atmospheric particles (PM 10) and roadside soil particles collected in Kuala Lumpur, Malaysia.	Omar et al.,	Soil, indoor and outdoor air.	Particulate sampler with conditioned glass fibre filters, for an average of 24 h. Roadside soil particles were collected using a small brush and a trowel.	10 μm.	Sealed in aluminium foil and frozen.	Ultrasonic extraction using using diethyl ether in DCM.	GC/MS with fused silica capillary column coated with 5% phenylmethylsiloxane (HP-5MS, 30 m, 0.25mm i.d., 0.25 mm film thickness).	Roadside soil particles spiked with anthracene-d10 and perylene-d12 with recoveries of 74.9% and 83.0%.	n/r	n/a
Emission of Polycyclic Aromatic Hydrocarbons and Particulate Matter from Domestic Combustion of Selected Fuels.	Oanh et al.,	Smoke particulates.	Air/particulate sampling using thermally insulated flue hoods with fixed height sampling collection ports and an Anderson-Graseby Auto5 semivolatile sampling train containing four impingers and XAD-2 sorbent trap XAD-2.	n/r	In glass jars on filter material in preservation fluid (DCM) .	Ultrasonication.	HPLC - Fluoresence detector/UV detection.	n/r	n/r	n/a

Title	Authors	Sample matrix	Sample Collection and preparation	Particle size	Sample Storage	PAH Extraction	PAH Analysis	Internal Standards	Reference	Reference
						Chemical				
In-injection port thermal desorption and subsequent gas chromatography-mass spectrometric analysis of polycyclic aromatic hydrocarbons and n-alkanes in atmospheric aerosol samples.	Ho et al.,	Roadside seasonal (winter and summer) aerosol samples.	Particulates collected on 100 mm Teflon-impregnated glass fibre filters over a 12-24 h period and at a flow rate of $0.228 - 0.285$ m^3.	n/r	Stored in Uline metallic Zip Top static shielding bags at -4°C prior to analysis.	Thermal desorption (filter material placed nto a TD vessel (pre- baked at 550°C and stoppered with glass wool) and as an integrated part of the analysis (within the injection port and tested at 200°C, 250°C, 275°C and 300°C). Chemical extraction (filter material soxhlet extracted with DCM for 6 h (and 5 cycles per h).	GC/MS with silica capilliary column.	n-$C_{24}D_{50}$ and phe-d10 in dichloromethane, $C_{24}D_{50}$ (to monitor losses over the whole analytical procedure).	n/r	n/a
Optimization and validation of a low temperature microwave-assisted extraction method for analysis of polycyclic aromatic hydrocarbons in airborne particulate matter.	Karthikeyan et al.,	Aerosol.	Collection on quartz filters (pre-heated to 400°C). Particles were collected over 10 days using a high volume sampler set on a rooftop for 24 h and over a one week period using mini-vol portable samplers.	2.5 μm	Solvent rinsed Al foil.	Used pre-baked and spiked filter strips spiked with the EPA 610 PAH mixture to optimise the extraction methodology and two NIST materials for testing. PAH extracted from filter paper using a closed microwave digestion system using Teflon vessels, 20 ml of solvent, and a microwave energy in the range of $50 - 300$ W for $10 - 60$ minutes. Once cooled to room temperature the vessels were opened, the extracts were filtered through a PTFE auto vial membrane filter (0.45 μm).	Prior to analysis sample residues were re-dissolved in 1 ml of 1:1 acetone:hexane. GC/MS with silica capilliary column.	n/r	NIST SRMs 1648-urban particulate matter and 1649a urban dust.	PAHs recoveries between 79 and 122% with relative standard deviation ranging from 3 to 21%.
Quantification of polycyclic aromatic hydrocarbons in the NIST standard reference material (SRM 1649a) urban dust using thermal desorption GC/MS.	Waterman et al.,	Urban dust.	As received.	As received.	n/a	Thermal desorption.	GC/MS. Column information n/r.	phe-d10.	NIST SRM 1649a.	n/a
Extraction rates of spiked versus native PAHs from the heterogenous environmental samples using supercritical fluid extraction and sonication in methylene-chloride.	Burford et al.,	Sludge, soil, airborne particulate matter.	Collection n/r; railroad bed sample was air dried overnight and sieved to <2 mm to remove any sticks and other debris, particulate matter and waste sludge were analysed/tested as received.	<2mm and as received.	n/r	Sequential extraction using pure supercritical C0$_2$ for 30 minutes, followed by modified (10% v/v methanol) supercritical C0$_2$ extraction for 30 minutes and a 14 h sonication step using pesticide-grade methylene chloride. Residual solid from the sequential extraction procedure was then sonicated for 14 h in 6 ml of pesticide-grade methylene chloride.	GC/MS with silica capilliary column.	2-, 3-, 4-, and 5-membered ring deuterated PAHs (d-PAHs).	NIST Standard Reference 1649a.	Calculated PAH ranges with 95% confidence limits, except Chrysene.
Seasonal variation and their characterization of suspended particulate matter in the air of subway stations.	Furuya et al.,	Underground station suspended particulate matter.	Sampling on benches located around the central region of each station platform and set at $60 - 70$ cm above floor level. Above ground sampling was carried out near the air intake for each station. Personal air samplers fitted with quartz filters were used to collect particulate material at a flow rate of 3 l min^{-1} for a total of three hours.	n/r	n/r	Extraction in an ethanol/cyclohexane mix and centrifuged for 20 minutes at 2000 rpm. The resulting supernatant was dried under a stream of N$_2$ and dissolved in acetonitrile prior to PAH quantification.	HPLC with a silica column and fluorescence detection.	n/r	n/r	n/a

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Title	Authors	Sample matrix	Sample Collection and preparation	Particle size	Sample Storage	PAH Extraction	PAH Analysis	Internal Standards	Reference	Reference
					Engineering					
Polycyclic aromatic hydrocarbons and polychlorinated biphenyls in air at an urban and rural site near Lake Michigan.	Cotham et al.,	Air particulates.	Collection by drawing air (260 – 390 m3) through Gelman AE binderless glass fibre filters (GFF) coupled to polyurethane foam plugs (PUF).	n/r	Samples / filters were wrapped in solvent rinsed aluminium foil. Stored at ≤ -10°C.	Reflux with DCM and the chlorinated solvent removed before analysis by refluxing with hexane.	GC/MS -DB 1301 column.	n/r	NIST Standard Reference 1649a.	PAH recovery ranged between 82% and 147%.
Molecular, seasonal, and spatial distributions of organic aerosols from fourteen Chinese cities	Wang et al.,	Air particulates.	Glass Fibre Filters were used to collect particulate samples at a flow rate of 5 l min^{-1}.	n/r	Tissue quartz filter containers stored at ≤ -10°C.	Particulate PAH extracted using DCM and ultrasonication. Post concentration, the extracts were reacted with 50 µl of bis-(trimethylsilyl)trifluoroacetamide, 1% trimethylsilyl chloride and 10 µl pyridine at 70 °C for 3 h.	GC/MS -DB-5MS column.	n/r	n/r	n/a
PM-10 high volume collection and quantitation of semivolatile and nonvolatile phenols, methoxylated phenols, alkanes, and polycyclic aromatic hydrocarbons from winter urban air and their relationship to wood smoke emissions.	Hawthorne et al.,	Air particulates.	High volume samplers (68 m^3 h^{-1}) containing GFF or PUF were placed at ground level to collect PM10 air samples.	10 µm.	Glass jars stored at 4°C and in the dark.	Particulate PAH extracted using DCM/acetone and ultrasonication.	GC/MS -DB-5MS column.	Isotopically labelled pyrene.	n/r	n/a
Polycyclic aromatic hydrocarbons (PAHs) in indoor and outdoor air of Hangzhou, China.	Liu et al.,	Air particulates.	Small low noise samplers (MP-15CF mini pump, Shibita, Japan) were placed in individual rooms (and balconies where present) at a flow rate of 1.0 l min-1 and placed at a height representative of the human breathing zone to collect particulate material on GFF.	n/r	n/r	Particulate PAH extracted using DCM/acetone and ultrasonication.	HPLC containing a Supelco 5C-18 pre-column for PAH condensation and clean-up and a Wakosoil, 5C-18 main column with fluorescence detection.	nr	n/r	n/a
Gas/particle partitioning of semivolatile organic compounds to model inorganic, organic, and ambient smog aerosols.	Liang et al.,	Air particulates of synthetic smog.	Particulate material extracted from smog chamber (after 1 h) by the insertion of a 30 cm length of copper tubing and collection in adsorption/thermal desorption (ATD) cartridges containing 1 g of Tenax-GC.	n/r	Sealed in a screw capped culture tube and stored at <-20°C.	Immediately after sampling, each PUF and GFF plugs were spiked with acenaphthene-d10, phenanthrene-d10, and chrysene- d12 immediately after sampling and then Soxhlet-extracted overnight with 400 and 250 ml, respectively, of methylene chloride.	GC/MS -DB-5MS column.	acenaphthene-d10, phenanthrene-d10, and chrysene- d12.	n/r	n/a
					Atmospheric					
Atmospheric polycyclic aromatic hydrocarbons in Seoul, Korea.	Park., et al	Air particulates.	24 h ambient air PM2.5 and PAH samples collected from a height of 18m. Sampling periods of 7-13 days, in summer and winter. Collection using a PUF sampler (GrasebyGPS1) with Whatman 10mm quartz fiber filters and polyurethane foam plugs.	PM 2.5	n/r	Filters were extracted with DCM in an ultrasonic bath followed by mechanical shaking for 30 min and filtration through a 0.45 µm filter. PUF samples were extracted with DCM for 30 min using supercritical fluid extraction apparatus.	GC/MS.	d10-phenanthrene.	NIST Standard Reference 1649a	Certified values were within 2 x sd of 6 replicates
Distribution of particulate- and vapor-phase n-alkanes and polycyclic aromatic hydrocarbons in urban atmosphere of Guangzhou, China.	Bi et al.,	Air particulates.	A high-volume air sampler at a flow rate of 0.4–0.6 m^3 min^{-1}. Glass fibre and PUF filters in series used to collect particulate and vapour phase PAH.	n/r	PUF samples were stored in glass jars with aluminum foil-lined lids in a freezer. Filters were wrapped in baked aluminum foil.	Soxhlet extraction in DCM for 72 h.	GC/MS in electrode impact mode.	naphthalene-D8, acenaphthene-D10, phenanthrene-D10, chrysene-D12 and perylene-D12.	n/r	n/a
A comparison of air particulate matter and associated polycyclic aromatic hydrocarbons in some tropical and temperate urban environments.	Panther et al.,	Air particulates.	Particulates were collected on teflon coated glass fibre filters using a high volume sampler passing ca. 1700 m^3 over a 24 h perion.	n/r	n/r	Filter extraction using acetonitrile.	HPLC - UV detection.	n/r	NIST Standard Reference 1649a	n/r
Concentrations, trends and vehicle source profile of polynuclear aromatic hydrocarbons in the UK atmosphere	Smith et al.,	Air particulates.	Daily 24 h particulate and vapour phases were trapped on teflon filters by polyurethane foam plugs using hiand medium volume Andersen samplers (0.05 – 0.6 m^3 min^{-1}).	PM 2.5	Glass jars in complete darkness at - 70°C.	Soxhlet extraction for 24 h in DCM and clean-up using solid phase extraction cartridges, reduction in volume to ca. 1ml and redissolved in acetonitrile.	HPLC - UV detection.	n/r	NIST Standard Reference 1649a	Within 5% of the certified values
Characterization of the solvent extractable organic compounds in PM2.5 aerosols in Hong Kong.	Zheng et al.,	Air particulates	Samples collected over a 24 h period on glass fibre filters using a high-volume sampler at a flow rate of 1.1-1.5 m^3 min^{-1}.	PM 2.5.	Refrigerated in glass bottles (~0°C) with 5 ml of methylene chloride.	Ultrasonic extraction in DCM.	HPLC - UV detection.	n/r	n/r	n/a

Table S4 General overview of the selected papers

Title	Authors	Year	Journal	Aim	Sources	Outcomes
				Environmental		
Polynuclear aromatic hydrocarbons in the United Kingdom environment: A preliminary source inventory and budget.	Wild & Jones	1995	Environmental Pollution	To use previously published PAH data to quantify the production, cycling, storage and loss of PAHs in the UK environment in relation to the PAH burden on UK soils.	Domestic coal burning, unregulated fires and vehicle emissions.	PAH burden on on UK natural environment, at time of study was estimated at ~ 54,000 tonnes; Soil is an important repository for PAH contamination with >90% of the national burden; There are significant gaps in knowledge for this area, especially when compared to contaminants such as PCDD/F's which although more difficult to analyse are more understood.
Characterization of the Dust/Smoke Aerosol that Settled East of the World Trade Center (WTC) in Lower Manhattan after the Collapse of the WTC 11 September 2001.	Lioy et al.,	2002	Environmental Health Perspectives	To understand human exposure types in relation to the particulate plume of resuspendable dust and smoke resulting from the explosion and subsequent collapse of the World Trade Centre in 2001.	Smoke damage to buildings and building collapse.	Smoke and dusts samples, undifferentiated by particle size contained 40 typical PAH; Higher molecular weight PAH in range 200-300 $\mu g\ g^{-1}$; Samples collected 3 weeks after the attacks on the WTC contained similar PAH type and concentrations as those samples collected immediately after the attacks on the World Trade Centre; Higher concentrations of PAH were measured in the larger particle size material the mass of the smaller particle size was greater.
Aggregate exposures of nine preschool children to persistent organic pollutants at day care and at home.	Wilson et al.,	2003	Journal of Exposure Analysis and Environmental Epidemiology	evaluating and refining methods to study the exposure of pre-school children (aged 2-5 years) from a suite of organic pesticides and other persistent organic pollutants in associated with soil/dust and commonly found in the home and school environment.	Indoor and ourdoor floor dusts from soil.	Although present in lower concentrations exposure to particulate bound PAH is greater in the indoor compared to outdoor environment. Soil is an important respository for contaminants and the function of the individual PAH present. Exposure was very low for most pollutants. Small but significant differences found in samples from low and middle income households.
Concentrations of PAHs in atmospheric particles (PM 10) and roadside soil particles collected in Kuala Lumpur, Malaysia.	Omar et al.,	2002	Atmospheric Environment	Provide a baseline reference data to improve air quality in the city of Kuala Lumpur from the measurement of PAH from roadside soil particles.	Atmospheric and roadside soil particles.	Roadside soil particulates were more enriched in lower molecular weight PAHs and high molecular weight PAHs were more abundant in atmospheric particles. The total PAH concentrations in Kuala Lumpur were lower than those found in other studies. The dominant source of PAH in atmospheric particles was considered to be vehicular emissions because of positive correlation between BgP and the total PAH concentration. The significant amount of PAH in raodside soils reslted from source other than but including vehicular emission.
Emission of Polycyclic Aromatic Hydrocarbons and Particulate Matter from Domestic Combustion of Selected Fuels.	Oanh et al.,	1993	Environmental Science & Technology	Look at PAH associated with particulate matter resulting from wood fuel burning in south-east Asia.	Domestic fuel burning of three fuel types (wood, charcoal, brickette).	The different fuels tested resulted in a range of PAH detedted, with wood fuel burning realeasing more idividual PAH than charcoal and brickette burning. This was considered to be related to the volatile content of each fuel. Wood burning produced a higher mass of particulate material with higher PAH concentrations than the other fuels tested.
				Chemical		
In-injection port thermal desorption and subsequent gas chromatography-mass spectrometric analysis of polycyclic aromatic hydrocarbons and n-alkanes in atmospheric aerosol samples.	Ho et al.,	2004	Journal of Chromatography A	The development and optimisation of approaches for PAH extraction and analysis.	Roadside aerosol.	Demonstrated the feasibility of using in-injection port thermal desorption for analysis of PAHs collected on aerosol filters, which does not require any modification of existing GC–MS. TD/GC-MS "has unique advantages of reduced labour and time by avoiding sample pre-treatment and requiring less filter material for analysis".
Optimization and validation of a low temperature microwave-assisted extraction method for analysis of polycyclic aromatic hydrocarbons in airborne particulate matter.	Karthikeyan et al.,	2006	Talanta	The development and optimisation of approaches for PAH extraction and analysis.	Outdoor PM samples from Singapore.	The sum of particulate-bound PAHs in outdoor PM was lower than that found in cooking emissions from indoor sampling locations. The concentrations of PAHs in the Singapore atmosphere were comparable to those in Hong Kong and Germany, and are, at the time of publication, lower than those reported for other urban areas.
Quantification of polycyclic aromatic hydrocarbons in the NIST standard reference material (SRM 1649a) urban dust using thermal desorption GC/MS.	Waterman et al.,	2000	Analytical Chemistry	The development and optimisation of approaches for PAH extraction and analysis.	NIST 1649a.	Direct analysis eliminates the use of solvents as part of the sample preparation (reducing volatile component losses), significantly reducing the sample preparation time (no extraction procedure). The technique has linearity for contaminants including 10 NIST priority PAHs, is sensitive for PAH concentrations of 2-6 mg kg^{-1} and reproducible.
Extraction rates of spiked versus native PAHs from the heterogenous environmental samples using supercritical fluid extraction and sonication in methylene-chloride.	Burford et al.,	1993	Analytical Chemistry	Data comparison of the extraction rate of native and spiked PAH in solid heterogenous environmental samples.	Petroleum waste sludge, urban air particulate matter (SRM 1649), and a soil from a railroad bed.	Spike recovery studies are not suitable for the development of quantitative extraction methods as their results showed similar results across the spiking procedures and to those obtained using conventional methylene chloride sonication. Differences in extraction rates of the spiked and native PAHs were most dramatic for the lower molecular weight PAHs, indicating that relatively volatile species such as naphthalene must be tightly bound in order to remain associated with a real-world sample.
Seasonal variation and their characterization of suspended particulate matter in the air of subway stations.	Furuya et al.,	2001	Journal of trace and microprobe techniques	Fundamental data collection.	Suspended particulate matter (elemental and PAH) at Japanese underground stations.	There is a need for more comprehensive studies of artificial space such as subway stations as at the time of publication work in this area was sparse. Thermal desorption method can accurately quantify PAH in airborne particulate matter.

Title	Authors	Year	Journal	Aim	Sources	Outcomes
Engineering						
Polycyclic aromatic hydrocarbons and polychlorinated biphenyls in air at an urban and rural site near Lake Michigan.	Cotham et al.,	1995	ES&T	To measure PAH in the gas and particulate phase in a rural and urban environment.	Steel mills, incinerators, landfills and coke ovens.	Geometric mean of total PAHs with a molcular weight >166 were 195 ng m^{-3} in Chicago and 14 ng m^{-3} at the University of Wisconsin Green Bay. Atmospheric transport resulted in depletion of some labile components (determined using among PAH ratio's). Application of the Junge-Pankow adsorption model showed that measured particulate percentages in the two locations were within a factor of 2 of those predicted.
Molecular, seasonal, and spatial distributions of organic aerosols from fourteen Chinese cities.	Wang et al.,	2006	ES&T	To measure PAH in the gas and particulate phase in Chinese cities.	Developing cities.	PAHs were a relatively minor component of the collected samples. Benzo(b)fluoranthene was thedominant detcted, suggesting a large contribution from fossil fuel (mainly coal) combustion. The contaminants detected were 1-3 orders of magnitude higher than those reported for developed countries.
PM-10 high volume collection and quantitation of semivolatile and nonvolatile phenols, methoxylated phenols, alkanes, and polycyclic aromatic hydrocarbons from winter urban air and their relationship to wood smoke emissions.	Hawthorne et al.,	1992	ES&T	To measure PAH in the gas and particulate phase.	Hard and softwood burning.	A broad range of PAHs can be efficiently collected using a conventional PM-10 high-volume air sampler with a simple modification to include PUF sorbent sheets. Average weight percent contributions of PAH was 11%. PAHs were associated with all types of sampling locations. Vehicle exhaust appears to be a significant source of PAHs.
Polycyclic aromatic hydrocarbons (PAHs) in indoor and outdoor air of Hangzhou, China.	Liu et al.,	2001	ES&T	To survey PAH pollution in indoor and outdoor air and source apportion the indoor sources for PAHs in Hangzhou, China.	Coal and wood burning.	Indoor PAH concentrations were higher indoors than outdoors (partcicularly napthalene) and in autumn compared to summer. Dominant PAH in the vapor phase were two-, three-, and four-ring PAHs, compared to five-ring PAHs in the particulate phase.
Gas/particle partitioning of semivolatile organic compounds to model inorganic, organic, and ambient smog aerosols.	Liang et al.,	1997	ES&T	To measure PAH in the gas and particulate phase to examine the partitioning of PAHs and n-alkanes in different model aerosol materials.	Chemical smog.	Gas-Particle partitioning of Semi-volatile Organic Carbons into urban particulate material in summer smog is dominated by absorption into the organic fraction in the aerosol
Atmospheric						
Atmospheric polycyclic aromatic hydrocarbons in Seoul, Korea.	Park., et al	2002	Atmospheric Environment	Long term study to provide quantitative, seasonal data for PAH in the Seoul urban environment.	Traffic, industrial activities and coal burning power generation.	Seasonal trends in contaminants were considered to be the result of the degree of fossil fuel burning in winter. Both temperature and relative humidity larger effects on the semi-volatile rather than heavier PAH concentrations.
Distribution of particulate- and vapor-phase n-alkanes and polycyclic aromatic hydrocarbons in urban atmosphere of Guangzhou, China.	Bi et al.,	2003	Atmospheric Environment	Comparison of concentrations and sources of vapour and particle/gas distributions of n-alkanes and PAHs from different heights .	Traffic, industrial activities and coal burning power generation.	Above ground aerosol had lower PAH concentrations compared to those collected from near ground level. This was considered to be a result of aerosol dilution with incresing height. The higher molecular weight PAH were associated with the particulate rather than vapour phase.
A comparison of air particulate matter and associated polycyclic aromatic hydrocarbons in some tropical and temperate urban environments.	Panther et al.,	1999	Atmospheric Environment	Long term studies to provide quantitative, seasonal data for PAH in the Hong Kong, Bangkok, Jakarta and Melbourne urban environments.	Traffic, industrial activities and coal burning power generation.	Particulate and PAH levels in the tropical climate were lower than in other environments/seasons, but statistically significant correlations between rainfall levels and pollutant concentrations were not seen. Evidence of increased fossil fuel burning seen during the winter months.
Concentrations, trends and vehicle source profile of polynuclear aromatic hydrocarbons in the UK atmosphere.	Smith et al.,	1996	Atmospheric Environment	Long term study to provide quantitative, seasonal data for PAH in the Birmingham urban environment.	Traffic, industrial activities and coal burning power generation.	Winter PAH concentrations were five times higher than those measured in the summer months. Urban PAH concentrations were higher at urban rather than rural locations.
Characterization of the solvent extractable organic compounds in PM2.5 aerosols in Hong Kong.	Zheng et al.,	2000	Atmospheric Environment	Long term studies to provide quantitative, seasonal data for PAH in the Hong Kong urban environment.	Traffic, industrial activities and coal burning power generation.	Semivolatile extracted organic contaminants in the 2.5 µm particle fraction were considered to be of vehicular, biogenic and microbial origin. There was a marked seasonal variation in measured PAH concentrations: Higher values were found during the winter months.

Title	Authors	Year	Journal	Aim	Sources	Outcomes
Occupational Health						
Statistical modelling of the determinants of historical exposure to bitumen and polycyclic aromatic hydrocarbons among paving workers.	Brunstyn et al.,	2000	Annals of occupational hygiene	To use published material to build a theoretical model of PAH exposure among paving workers.	Asphalt.	Bitumen fume, vapour and PAH all have different determinants of exposure and the measurement of BaP associated with inhalable dust was a good predictor of PAH exposure as a whole.
Significance of dermal and respiratory uptake in creosote workers - exposure to polycyclic aromatic hydrocarbons and urinary excretion of 1-hydroxypyrene.	Elovaara et al.,	1995	Occupational and environmental medicine	To carry out an exposure measurement study.	Creosote.	See biomarker section.
Biomonitoring of polycyclic aromatic hydrocarbons in highly exposed coke plant workers by measurement of urinary phenanthrene and pyrene metabolites (phenols and dihydrols).	Grimmer et al.,	1993	International archives of occupational and environmental health	To carry out an exposure measurement study.	Coke.	See biomarker section.
Correlation between work process related exposure to polycyclic aromatic hydrocarbons and urinary levels of alpha-napthol beta-napthylamine and 1-hydroxy pyrene in iron foundary workers.	Hansen et al.,	1994	International archives of occupational and environmental health	To carry out an exposure measurement study.	Foundary.	See biomarker section.
Cytochrome P450 1A1 MspI polymorphism and urinary 1-hydroxypyrene concentrations in coke-oven workers.	Wu et al.,	1998	Cancer epidemiology biomarker & prevention	To carry out an exposure measurement study.	Coke.	See biomarker section.
Other						
Identification and emission factors of molecular tracers in organic aerosols from biomass burning: Part 1. Temperate climate conifers.	Oros et al.,	2001a	Applied Geochemistry	To report the organochemical composition of smoke/particulate matter and identify molecular tracers in organic aerosols from burning of temperate climate conifers.	Controlled burning of grass/wood.	PAH were only a small component of the grass aerosol/particulate content, they are variable and dependent on combustion temperature. The variability is dependant on the source of material/species combusted.
Identification and emission factors of molecular tracers in organic aerosols from biomass burning: Part 2. Deciduous Trees.	Oros et al.,	2001b	Applied Geochemistry	To report the organochemical composition of smoke/particulate matter and identify molecular tracers in organic aerosols from burning of deciduous trees.	Controlled burning of grass/wood.	PAH were only a small component of the grass aerosol/particulate content, they are variable and dependent on combustion temperature. The variability is dependant on the source of material/species combusted.
Identification and emission factors of molucular tracers in organic aerosols from biomass burning: Part 3. Grasses.	Oros et al.,	2006	Applied Geochemistry	To report the organic chemical composition of smoke particulate matter emitted by flaming and smoldering combustion of various grasses (Gramineae) from different climate regions.	Controlled burning of grass/wood.	PAH were only a small component of the grass aerosol/particulate content, they are variable and dependent on combustion temperature. The variability is dependant on the source of material/species combusted. The major components are adsorbed on or trapped in smoke particulate matter and thus may be utilized as molecular tracers in the atmosphere for determining fuel type and source contributions from grass burning.
CPY1A1 and GSTM1 polymorphisms affect urinary 1-hydroxypyrene levels after PAH exposure.	Alexandrie et al.,	2000	Carcinogenesis	To evaluate the correlation between external exposure to PAH and biomarkers of exposure and to investigate whether inter-individual variation in 1-Hydroxy pyrene (1-OHP) can be explained by the extent of genetic polymorphism in metabolic enzymes.	Aluminium smelter works.	Exposure to PAH in aluminium plants is not negligable, suggesting the need for appropriate and sensitive biomarkers. Results show a highly significant correlation between exposure to BaP and urinary excretion, concluding that urinary levels of 1-OHP is a sensitive indicator of human exposure to PAH (See biomarker section for outcomes of biological study).
Personal exposures to PM2.5 and polycyclic aromatic hydrocarbons and their relationship to environmental tobacco smoke at two locations in Greece.	Georgiadis et al.,	2001	Journal of Exposure Analysis and Environmental Epidemiology	To assess the levels of bulk DNA adducts in relation to personal exposure to PM 2.5 and associated PAH in two Greek towns/cities.	Outdoor dusts.	Lower PAH exposure was reported for Halkida compared to Athens (Greece). See biomarker section for outcomes of biological study.

Bigrams for Thompson Reuters WEB OF SCIENCE™ research areas

Figure S1 Environmental Sciences/Ecology Bigram
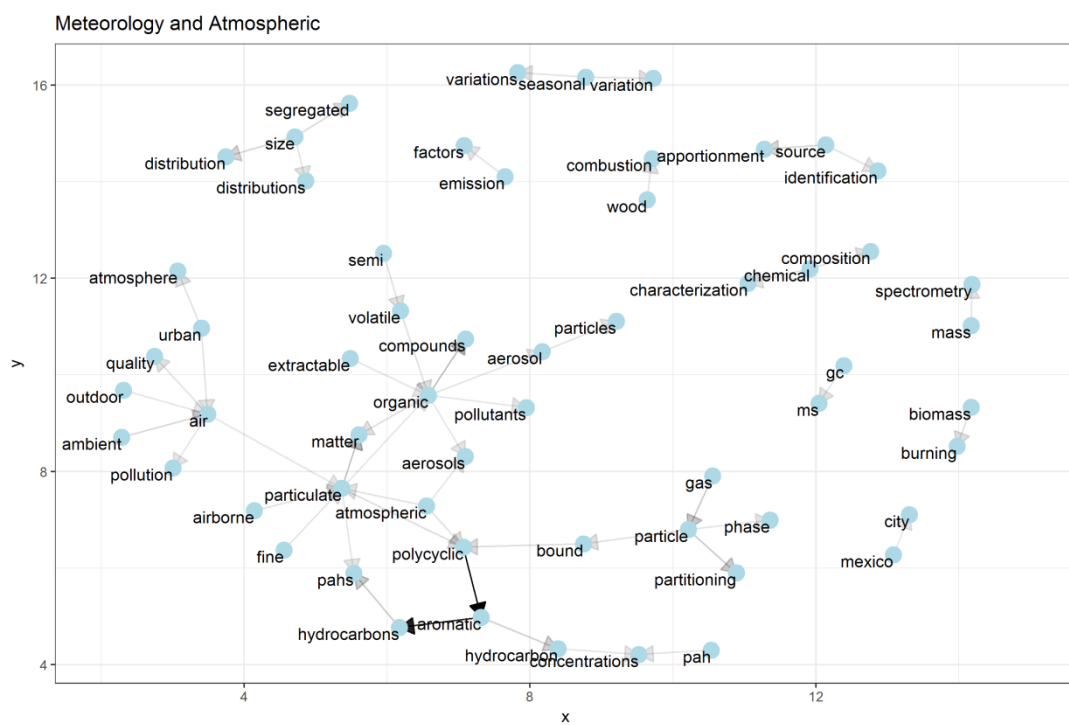

Figure S2 Engineering Bigram

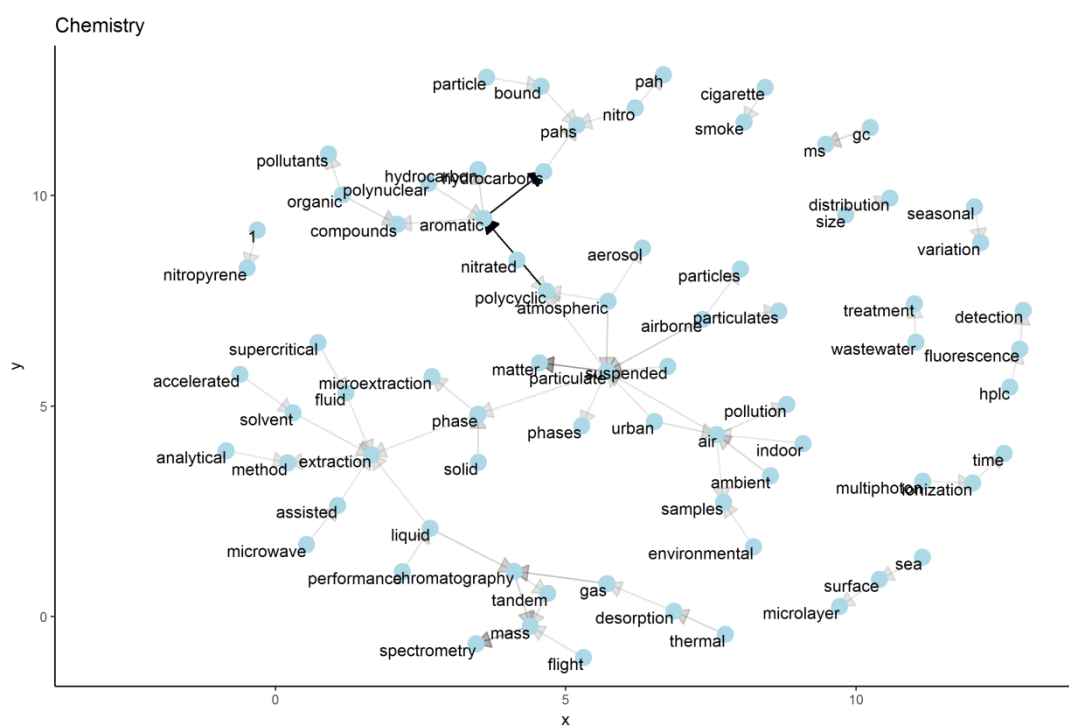Figure S3 Meteorology and Atmospheric Bigram
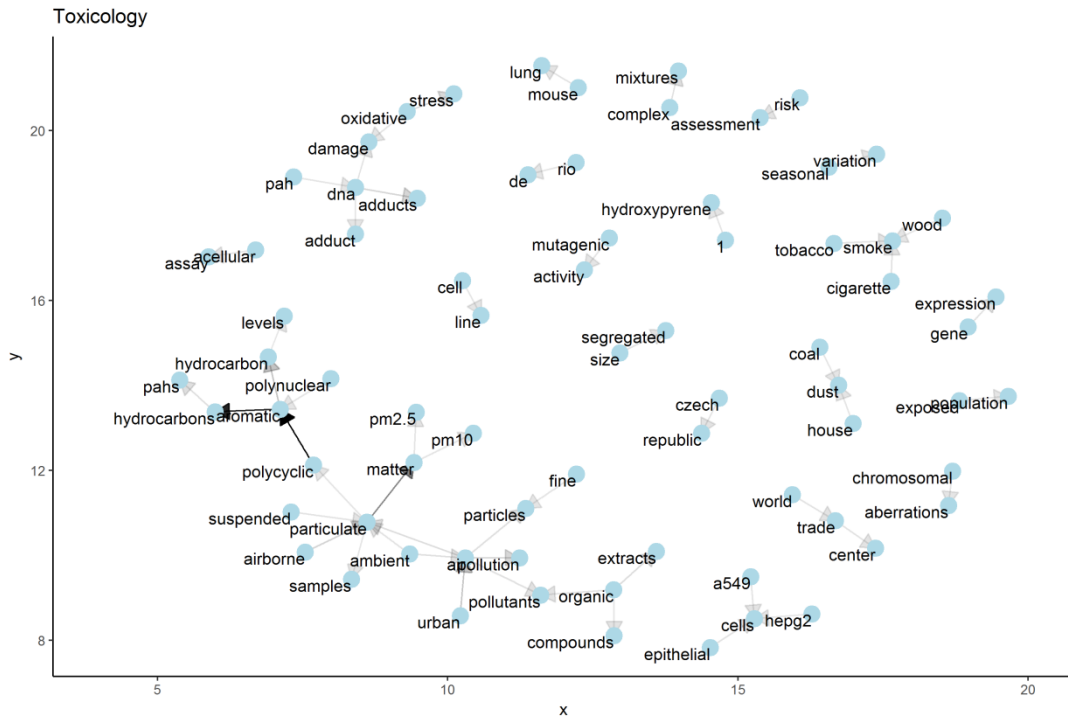

Figure S4 Chemistry Bigram
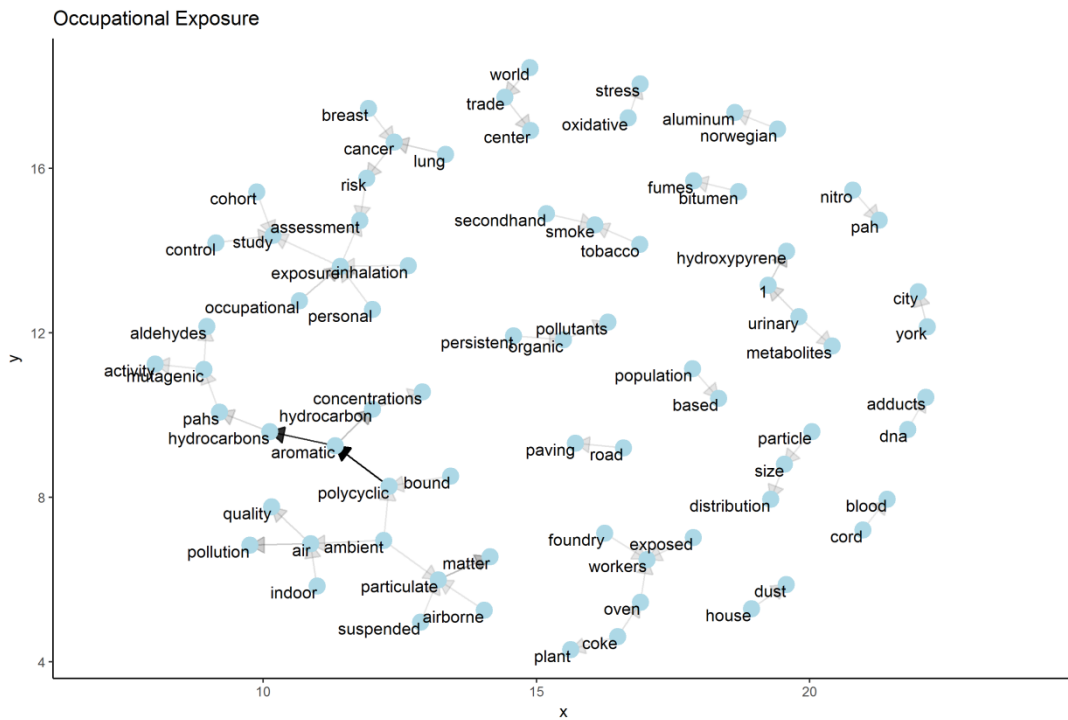
Figure S5 Toxicology Bigram
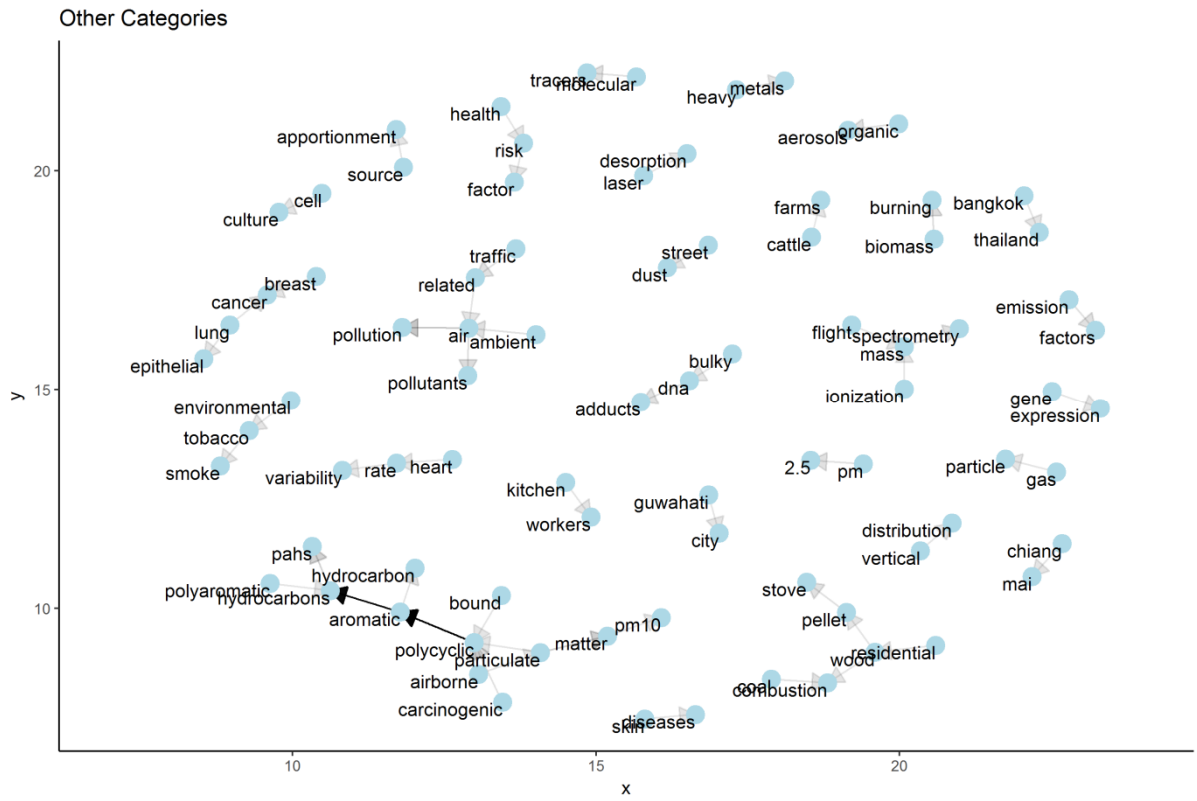

Figure S6 Occupational exposure Bigram

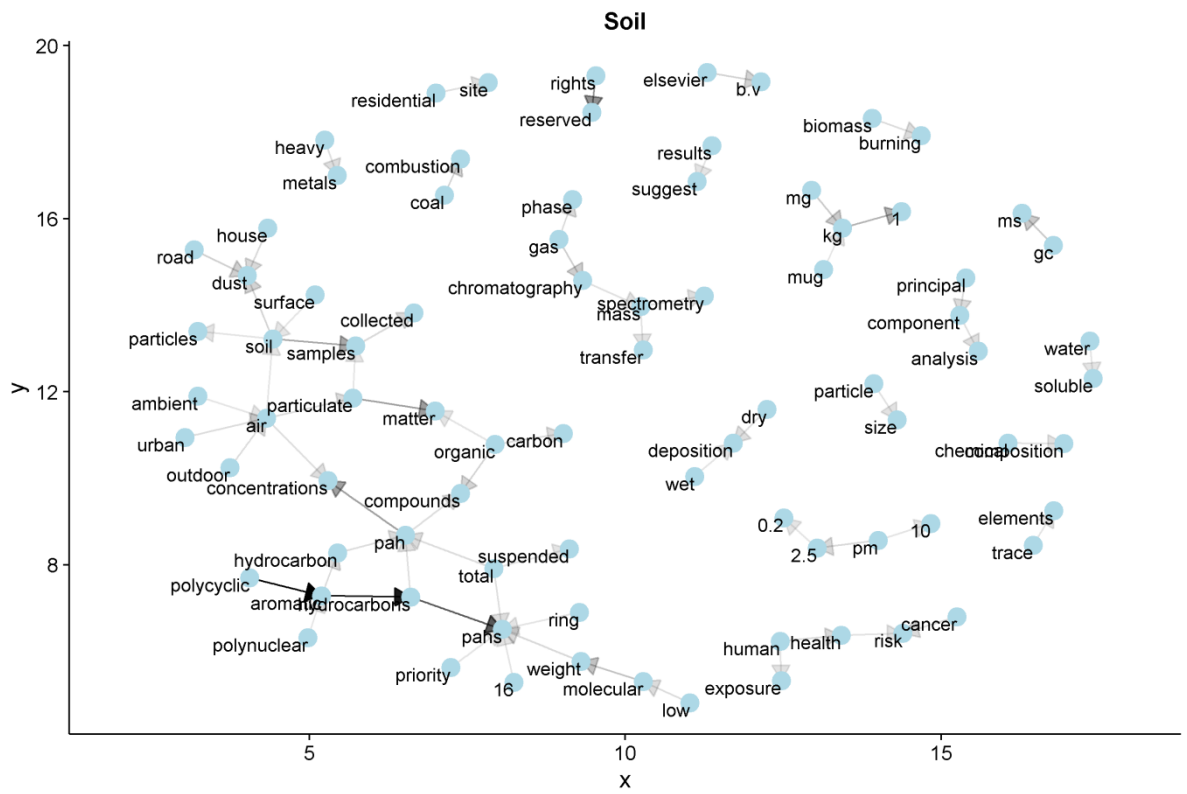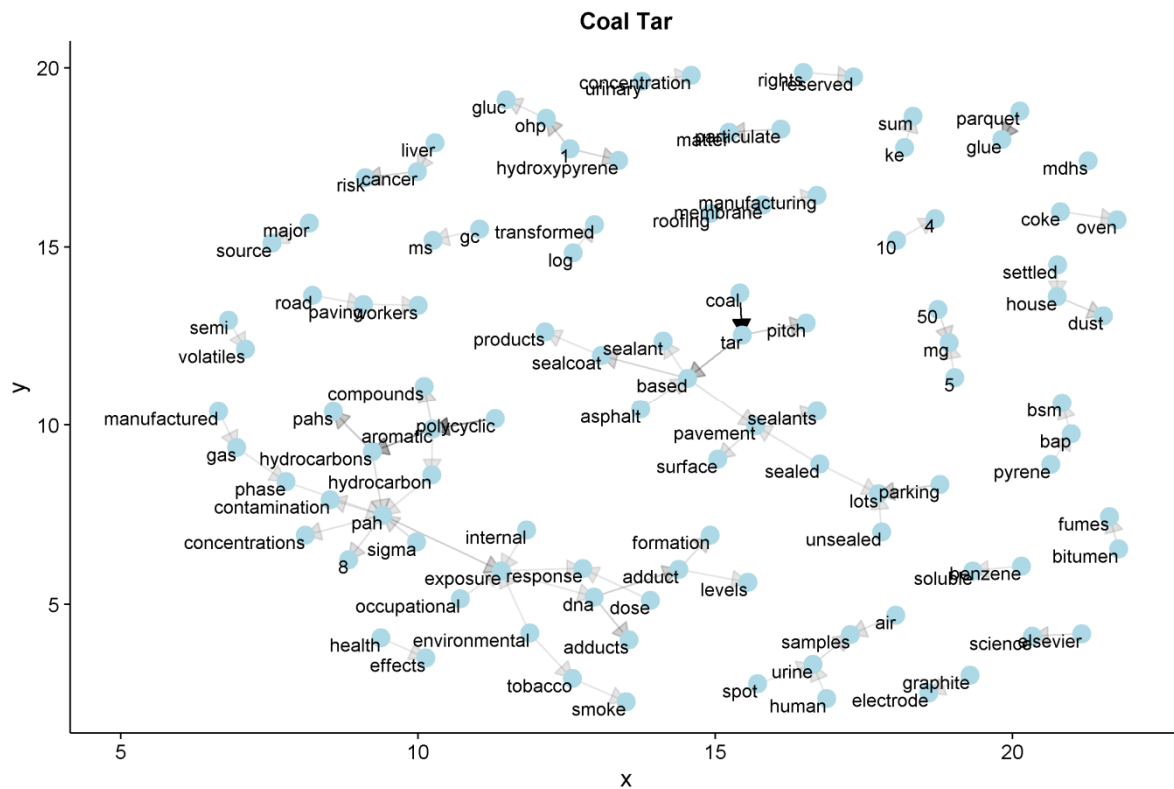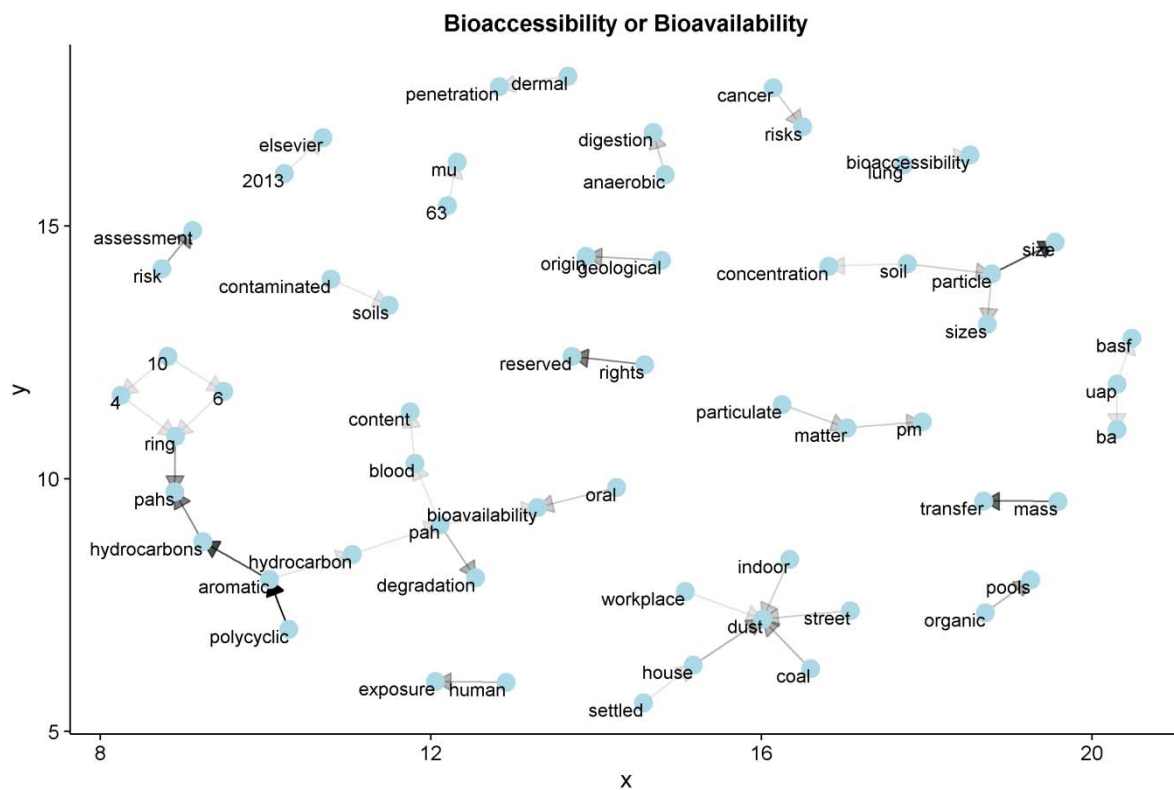Figure S7 Other categories Bigram

Figure S8 Soil Bigram

Figure S9 Coal Tar Bigram

Figure S10 Bioaccessibility/Bioavailability Bigram

Figure S11 Risk assessment Bigram

Figure S12 Gas Particle Partitioning Bigram plot