Acute Risks

Health Risks from Short-term Exposure to Soil Contamination

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SoBRA
The Society of Brownfield Risk Assessment

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Introduction to SoBRA

- Society of Brownfield Risk Assessment
- Learned society for individuals from private, public, voluntary and academic sectors
- Not for profit organisation
- Our goals are to:
  - improve technical knowledge in risk-based decision-making related to land contamination applications; and
  - enhance the professional status and profile of risk assessment practitioners
- We have ≈ 400 members (individuals) - £10 annual subscription
- Executive Committee of 10 people with 3 replaced each year
- Summer workshop + December conference held each year

SoBRA Subgroups

- Subgroups formed with the aim of providing guidance and tools of potential benefit to land contamination practitioners
- We currently have four active sub-groups:
  - SoBRA accreditation scheme
  - Groundwater vapour modelling
  - Asbestos risk assessment
  - Acute generic assessment criteria

Acute vs chronic risks

- **Acute risk:** risk (to human health) from short-term/sudden exposure
  - Exposure duration = seconds to days
- **Acute health effects:** health effects resulting from short-term/sudden exposure
  - E.g. nausea/vomiting, skin irritation, carbon monoxide poisoning, death
  - Often reversible (apart from death!)

- **Chronic risk**: risk (to human health) resulting from prolonged or repeated exposure
  - Exposure duration = months to years
- **Chronic health effects**: health effects resulting from long-term exposure
  - E.g. Cancer, chronic kidney disease
  - Often irreversible

Why consider acute?

- Most human health risk assessments focus on chronic risks arising from long-term exposure to specific substances
  - E.g. CLEA model compares average daily exposure, averaged over long duration (one or more years), with health based guidance value for chronic health effects
- But what about acute risks from infrequent high dose events, could these be significant?
  - E.g. child eats a one off large quantity of contaminated soil
  - Worker over-whelmed by vapours from excavation arisings
- In some cases averaging infrequent exposure over a long period or using average exposure to apply to a large area make acute risks more significant than chronic risks
  - Eg. risks to Construction workers? Or assessment of "hotspots"
- Lots of one-off assessment have been made but currently there is no agreed methodology or standardisation of parameters

Acute GAC sub-group

- Objectives:
  - Develop methodology to derive generic assessment criteria protective of acute health effects from short-term exposure (AGAC) for various acute exposure scenarios
  - Test methodology on example contaminants

- Participants:
  - Barry Mitcheson (AMEC) – subgroup manager
  - Simon Firth (Firth Consultants) – Executive Committee champion
  - Tim Rolfe (Aecom)
  - Gareth Wills/Steven McMullen (PB)
  - Sarah Bull (ERM)
  - Mike Quint (Environmental Health Sciences)
  - Ros Crocker (Ecologia)
  - Geoff Hood/Lauren Boydell (Jacobs)

Overview of methodology

- Subgroup has developed methodology to derive Acute Generic Assessment Criteria (AGAC) for contaminants in soil
- AGAC intended to be used as part of Generic Quantitative Risk Assessment (GQRA) and represent the soil concentrations below which acute risks to human health are acceptable
- Algorithms have been developed to calculate AGAC for various short-term exposure scenarios
- Overall approach to derivation of AGAC:
  - Step 1: Toxicity screening - which exposure scenarios could be of potential concern for the contaminant
  - Step 2: Collation and selection of relevant acute toxicity reference values
  - Step 3: Use of relevant algorithms to calculate AGAC
  - Step 4: Sense check AGAC

Caveats

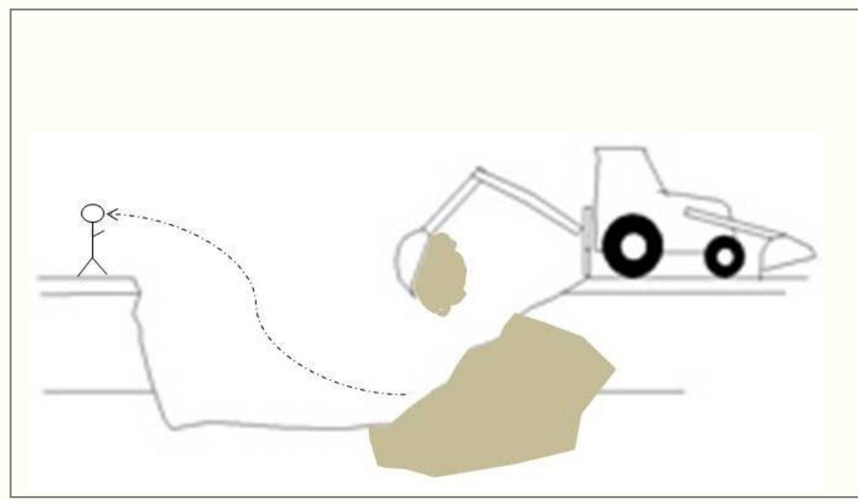
- **Fire and explosion** - The methodology is based on health risks not the acute effects arising from explosive or fire risks.
- **Odour effects** - In some cases odours themselves can lead to effects such as headaches and nausea etc. These are not specifically assessed in the current methodology.
- **Free product** - The assessment is focussed on soil bound substances not free product which can be have quite differently (and for instance can lead to skin damage due to defatting the skin)
- **Legal duties** - Irrespective of the results of the acute risk assessment users should remain aware of their duties to ensure that the compliance (e.g. Control of lead and Works act or asbestos regs.) and the need to minimise risk under the health and safety legislation.
- **Verification** – The use of the AGAC should not replace monitoring to confirm the risks.

Acute risk scenarios considered

- Oral exposure
  - Child resident/trespasser - ingests single bolus of soil (soil pica)
  - Adult worker (e.g. ground worker) – incidental ingestion of soil (via hand to mouth contact, smoking, eating, biting nails etc.) over an 8hr shift
- Dermal exposure
  - Child resident/trespasser – soil on skin for up to a few hours
  - Adult worker (e.g. ground worker) – soil on skin for up to a few hours

Acute risk scenarios considered

- Inhalation exposure
  - Member of public – inhalation of dust/vapours released during excavation from near-by site
  - Adult worker (e.g. ground worker) – inhalation of dust/vapours released during excavation



Toxicity screening

- Toxicity screening used to identify which exposure scenarios could apply to contaminant – AGAC derived for these scenarios
- Use risk phrases (Dangerous Substances Directive) or hazard phrases (CLP Regulation) for contaminant
- For hazard phrases see European Chemicals Agency (ECHA) Classification and Labelling (C&L) inventory:
  - http://www.echa.europa.eu/information-on-chemicals/cl-inventory-database

Acute toxicity hazard phrases

Acute Toxicity	Category 1	Acute Tox. 1	 GHS06	Danger	H300 H310 H330	Fatal if swallowed Fatal in contact with skin Fatal if inhaled
	Category 2	Acute Tox. 2				
	Category 3	Acute Tox. 3			H301 H311 H331	Toxic if swallowed Toxic in contact with skin Toxic if inhaled
	Category 4	Acute Tox. 4	 GHS07	Warning	H302 H312 H332	Harmful if swallowed Harmful in contact with skin Harmful if inhaled
Specific target organ toxicity (single exposure)	Category 1	STOT SE 1	 GHS08	Danger	H370	Causes damage to organs [6,7]
	Category 2	STOT SE 2		Warning	H371	May cause damage to organs [6,7]
	Category 3	STOT SE 3	 GHS07	Warning	H335	May cause respiratory irritation
					H336	May cause drowsiness or dizziness

Toxicity screening - examples

- Cyanide
  - Hazard phrases for acute toxicity: H300/310/330 - Fatal if swallowed, fatal in contact with skin, fatal if inhaled
- Trichloroethene
  - Hazard phrases for acute toxicity: STOT SE3 – May cause drowsiness or dizziness (inhalation)
- Arsenic
  - Hazard phrases for acute toxicity: H301/331 - Toxic if swallowed, toxic if inhaled

Soil ingestion - methodology

- Based on widely used method in US (Washington State, Florida, New York, New Jersey). Also used by HPA to calculate acute risks from cyanide in soil (Macklin et al - SoBRA December conference, 2012)

$$AGAC_{oral} = \frac{BW.ARfD_{oral}}{MSI.RBA_{oral}} \times 1000 g.kg^{-1}$$

Where,

- $AGAC_{oral}$ = acute GAC for oral exposure ($mg.kg^{-1}$)
- BW = body weight (kg)
- $ARfD_{oral}$ = acute reference dose for oral exposure ($mg.kg(BW)^{-1}$)
- MSI = mass of soil ingested in short-term exposure event (g)
- RBA_{oral} = relative bioavailability between contaminant in soil and contaminant in study that $ARfD_{oral}$ is based on

Soil ingestion parameters

- Mass of soil ingested

  Children
  - Soil pica (purposeful ingestion of soil) common in 1 to 3 yr old children.
  - Most children under 3 expected to ingest > 1 g of soil as a single bolus at some point, some children may eat up to 50 g
  - Recommended values for assessing acute risks to children are typically 5 to 10 g soil

  Adults
  - Soil pica not expected in adults. Exposure through inadvertent soil ingestion (nail biting etc).
  - Upper bound estimates of soil ingestion per day for an adult range from 200 mg to 480 mg
- Body weight
  - CLEA average for 1 to 2 year old female child ≈ 10kg
  - CLEA average for working female adult = 70 kg
- Relative bioavailability
  - Conservatively assume 100%?

Reference dose for acute oral exposure

- Range of sources for deriving acute RfDs, e.g.
  - CLEA TOX reports (e.g. 2002 TOX report for cyanide - http://webarchive.nationalarchives.gov.uk/20140328084622/http:/www.environment-agency.gov.uk/research/planning/64002.aspx)
  - ATSDR MRLs for acute exposure (http://www.atsdr.cdc.gov/mrls/mrllist.asp)
  - USEPA 1 day Drinking Water Health Advisories (http://water.epa.gov/action/advisories/drinking/upload/dwstandards2012.pdf)
- **Need to consider severity of health effect end point: e.g. nausea, dizziness or death?**
  - E.g. Inorganic arsenic: use of ATSDR acute MRL of 0.005 $mg.kg^{-1}.d^{-1}$, BW of 10kg, RBA of 1, MSI of 5g, results in AGAC of 10 $mg.kg^{-1}$ (SGV resi land-use= 32 $mg.kg^{-1}$)
  - Acute MRL based on LOAEL of 0.05 $mg.kg^{-1}$ for gastrointestinal effects and facial edema in Japanese people

Dermal contact - methodologies

- Reviewed approaches have focussed on adverse effects to the skin (i.e. not systemic effects)
- New York State (NYSDEC, 2006) derived method for assessing risk of contact dermatitis:

$$AGAC_{dermal} = \frac{ARfD_{dermal}}{ABS_d \times AF} \times 10^6 \, mg.kg^{-1}$$

  - $ARfD_{dermal}$ = acute reference dose for dermal exposure from patch test ($mg.cm^{-2}$)
  - AF = soil to skin adherence factor ($mg.cm^{-2}$)
  - ABS_d = dermal absorbed fraction from soil

(NB: Environment Agency cite this method in SGV report for nickel [2009])

Dermal contact parameters

- Dermal absorbed fraction from soil (ABS_d) – chemical specific - same value as used for dermal chronic exposure
- Soil to skin adherence factor (AF) - USEPA (2004), 95^{th} percentiles = 3.3 $mg.cm^{-2}$ (children playing in wet soil), 0.4 $mg.cm^{-2}$ (farmers), 0.6 $mg.cm^{-2}$ (rugby players)
- Reference dose for acute dermal exposure – measured from patch tests (mg contaminant per cm^2)

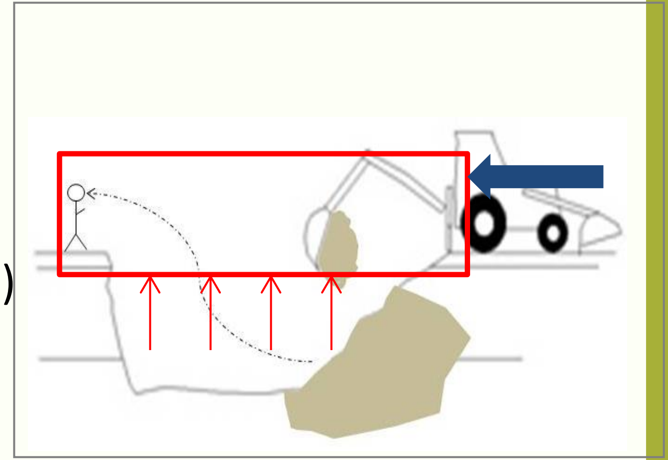
Inhalation - methodology

- Based on combination of box dilution model + models to estimate contaminant emission rate from excavated soil
- Box model calculates average concentration in a box above emission area:

$$C_{air} = \frac{ER \times l}{A \times h \times u} \times 1000 mg.g^{-1}$$

Where,

- C_{air} = concentration in air ($mg.m^{-3}$)
- ER = emission rate ($g.s^{-1}$)
- l = length of box model in direction of wind (m)
- A = surface area over which emissions occur (m^2)
- h = mixing zone height for box model (m)
- u = wind speed ($m.s^{-1}$)



Inhalation - methodology

- USEPA (1997) - calculation of emission rates for vapours :

$$ER = ER_{ps} + ER_{diff}$$

Where,

- ER_{ps} = emission rate from pore space ($g.s^{-1}$)
- ER_{diff} = emission rate from diffusion ($g.s^{-1}$)

$$ER_{ps} = C_{soil\_air} \times E_a \times Q_{exc} \times 0.001 g.mg^{-1}$$

C_{soil_air} = soil pore air concentration ($mg.m^{-3}$)
E_a = air filled porosity
Q_{exc} = excavation rate ($m^3.s^{-1}$)

$$ER_{diff} = \frac{C_s \times 10^4 \times A}{\left(\frac{E_a}{K_{eq} \times k_g}\right) + \left(\frac{\pi \times t}{D_e \times K_{eq}}\right)}$$

C_s = mass loading in bulk soil (g/cm^3)
A = emitting surface area (m^2)
t = time to achieve best curve fit [60]
K_{eq} = equilibrium coefficient [0.613]
k_g = gas phase mass transfer coefficient [0.15]
D_e = effective diffusivity in air (cm^2/s)

Inhalation - methodology

- Proposed method for emission rates for dust:

$$ER = f \times Q \times \rho_b \times C_{soil} \times 0.001 g.mg^{-1}$$

Where,

- f = fraction of fines in soil that can become airborne dust
- Q = excavation rate ($m^3.s^{-1}$)
- ρ_b = bulk density of soil ($kg.m^{-3}$)
- C_{soil} = concentration of contaminant in soil ($mg.kg^{-1}$)

Reference Concentrations in Air for Acute Exposure

- Worker scenario
  - Workplace exposure limits (WELs) – EH40/2005
  - Use short-term limit (15 minute exposure) where available
  - If not, EH40 recommends use of 3 x long-term exposure limit
- Child scenario (member of public)
  - Acute exposure guideline levels (AEGLs)
    - AEGL1 – Receptor could experience notable discomfort, irritation – reversible effects
    - AEGL2 – Irreversible or other serious long-lasting adverse health effects
    - AEGL3 – Risk of death

Worked example – Free cyanide

For illustration purposes only (DO NOT RELY ON THESE VALUES!)

- Oral exposure
  - ATSDR MRL intermediate oral = 0.05 $mg.kg^{-1}.d^{-1}$ (reproductive effects)
  - HPA chose LOAEL of 0.4 $mg.kg^{-1}.d^{-1}$ (death) for Pt2A site (Macklin, SoBRA December 2012 conference)
  - Assume child ingests 5 g, worker ingests 0.48 g
  - $AGAC_{child}$ = 100 to 800 $mg.kg^{-1}$, $AGAC_{worker}$ = 7300 to 58,000 $mg.kg^{-1}$, depending on end point chosen
- Dermal exposure
  - Contact dermatitis not relevant – AGAC not calculated (NB: could calculate a value for systemic effects)
- Inhalation exposure
  - 15 minute WEL for hydrogen cyanide = 11 $mg.m^{-3}$, 30 min AEGL1 = 2.75 $mg.m^{-3}$
  - Assume that all vapour phase HCN in excavated soil released to atmosphere
  - Assume 1m x 2m x 2m deep trial pit dug in 30 minutes
  - Assume light wind (3 $m.s^{-1}$)
  - $AGAC_{child}$ = 1780 $mg.kg^{-1}$, $AGAC_{worker}$ = 14,200 $mg.kg^{-1}$

Worked example – Chromium VI

For illustration purposes only (DO NOT RELY ON THESE VALUES!)

- Oral exposure
  - ATSDR MRL intermediate oral = 0.005 $mg.kg^{-1}.d^{-1}$
  - USEPA 10 day drinking water advisory = 0.144 $mg.kg^{-1}.d^{-1}$
  - HPA cite a lethal dose range of 2.5-195 $mg.kg^{-1}$
  - Assume child ingests 5 g, worker ingests 0.48 g
  - $AGAC_{child}$ = 10 to 5000 $mg.kg^{-1}$, $AGAC_{worker}$ = 875 to 437000 $mg.kg^{-1}$, depending on end point chosen
- Dermal exposure
  - Contact dermatitis
  - HPA (Kowalczyk, 2013) used $BMDL_{10}$ estimated at 0.08 $\mu g/cm^2$ from Nethercott *et al.* (1994)
  - Assume soil adherence factor of 1 to 5mg/cm^2 for child and 0.9mg/cm^2 for construction worker
  - $AGAC_{child}$ = 16 to 80 $mg.kg^{-1}$, $AGAC_{worker}$ = 88 $mg.kg^{-1}$

Worked example – Chromium VI

For illustration purposes only (DO NOT RELY ON THESE VALUES!)

- Inhalation exposure
  - ATSDR MRL intermediate inhal = 0.003 $mg.m^{-3}$
  - 8hr WEL for chromium VI = 1.5 $mg.m^{-3}$, No AEGL
  - Assume that soil is 1% fines in excavated soil released to atmosphere
  - Assume 1m x 2m x 2m deep trial pit dug in 30 minutes
  - Assume light wind (3 $m.s^{-1}$)
  - $AGAC_{child}$ = 0.015 $mg.kg^{-1}$, $AGAC_{worker}$ = 15$mg.kg^{-1}$
  - Method highly conservative? Take account of air dispersion?

Next steps

- Currently testing methodology on a number of substances:
  - Arsenic
  - Phenol
  - Vinyl Chloride
  - Cadmium
  - Cyanide
  - Trichloroethene
  - Lead
  - Hexavalent Chromium
  - Benzene
- Is it practical? Are the AGAC workable?
- Peer review + publish SoBRA report

Want to get involved?

Contact:
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