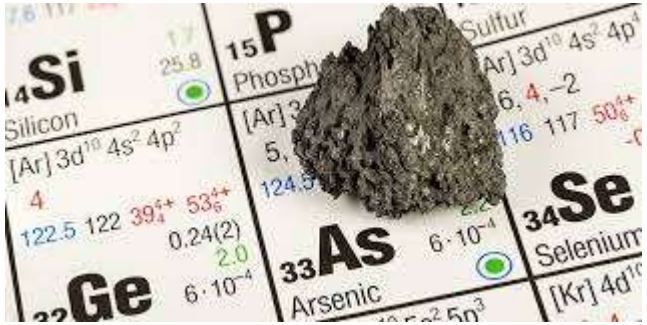
Arsenic Bioavailability and Tier 2 Risk Assessment – A case study



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Disclaimer

The work presented is still in the process of being peer reviewed. The results will not be final until approved for release and are not to be republished as a definitive result until such time that it is formally published. Please contact the author Nicola Peacock if you wish to reference this work.

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Site Description

- Approximately 5 ha rural site to be developed for residential
- Location is Christchurch but is currently anonymous as consent has not yet been lodged
- Generally flat
- Silty and sandy loam soils

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Site History

- 1926 aerial – pasture farmland
- 1965 aerial – small animal pens and haybarn in one corner
- 1994 aerial – a dwelling and garage is now built
- Local knowledge – area has a long history of dairying, cattle rearing and hay making
- Animal pens seen in aerial still exist and is a small cattle sized holding pen with truck loading ramp. No sign of potential dip structures.

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Site Characterisation

- No known or likely HAIL activities on the site were identified
- However, multiple nearby sites had had elevated arsenic levels found across extensive areas with no known previous history of a risk
- A DSI was recommended

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DSI Summary

- The DSI was progressive as it became apparent that arsenic levels were elevated above the 'residential 10% produce' Soil Contaminant Standard (SCS) of 20mg/kg
- Over the investigation period a total of 102 surface samples, 55 at 250-300mm depth and 13 at 500mm depth were tested
- Arsenic levels were generally in the range of 30-40mg/kg across more than half of the site, with spikes of 110mg/kg and 132mg/kg at two locations
- Levels of arsenic at 500mm depth were generally at expected background levels

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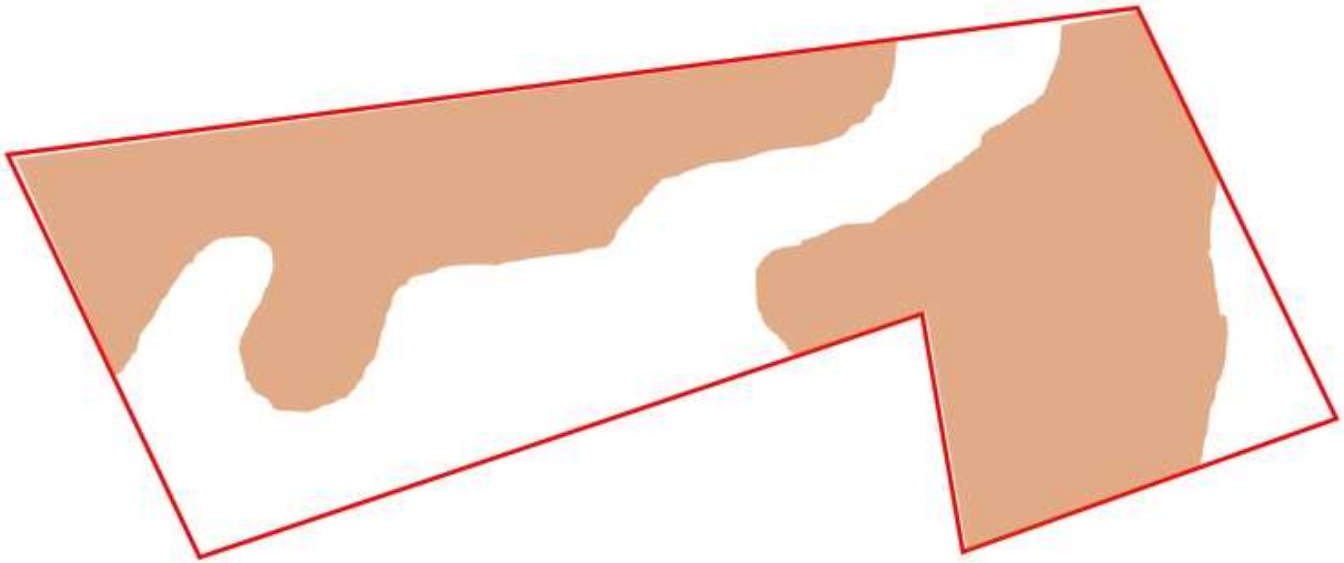
Areas affected by arsenic over 20mg/kg



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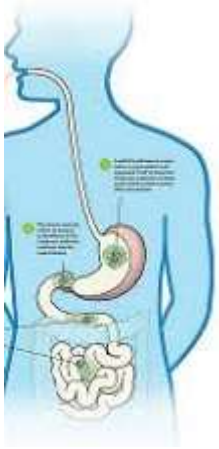
Bioavailability testing



- During the DSI 10 samples were tested for gastric extractable arsenic to determine whether a Tier 2 Assessment based on a reduced bioavailability was a potential option
- The results indicated very low bioavailability so a full detailed assessment in order to obtain a land use consent for residential use was commenced
- Initial meeting was held with ECan and CCC staff and Sampling and Analysis Plan was approved prior as this will be the first Tier 2 assessment based on bioavailability to cross these authorities desks

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Multiple lines of evidence approach

- The study involved assessing a wide suite of chemical and physical properties of the soils to support the laboratory gastric extraction results received
- Chemical analysis included assessing key arsenic binding phases such as clay content and iron, and key competitors such as phosphorus
- Particle size analysis was undertaken as well as mineralogical analysis
- The results were compared with a number of similar NZ studies
- QA/QC included field replicates, lab replicates, spikes, blanks and interlab replicate testing.
- Statistical analysis included looking at correlation between the various parameters, using appropriate statistical tests for normality and outliers, and using the UCL_{95} of the data as the final value for the site

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Results

- The calculated UCL $_{95}$ relative bioavailability percentage was 14%
- Iron and manganese levels were moderate to high and as key binding phase elements support the low bioavailability result ✓
- Total phosphorus was generally lower than typically expected and as an arsenic competitor this supports the low bioavailability result ✓
- Clay levels were low with an average of 8% and did not correlate with arsenic which supports the low bioavailability result ✓
- Mineralogical analysis did not identify any arsenic particles. No particular mineral phase was identified that would contradict the low bioavailability result ✓

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Comparison to other NZ studies

Site	Consultant	Date	Arsenic source	UCL95 RBA %
Moanataiari	Golder Associates	2012	Mining	27
Mt Rosa	HAIL Environmental	2017	Geogenic	6
Mapua Orchards	HAIL Environmental	2017	Pesticides	14/47
Matamata	Golder Associates	2017	Geothermal?	11

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Tier 2 Site-specific Soil Guideline Value

- The calculated bioavailability of 14% was applied to the soil ingestion pathway of the derivation equation set out in the Methodology for Deriving Standards for Contaminants in Soil to Protect Human Health (MfE 2011)
- There is also potential to apply the bioavailability percentage to the 'soil entrained on vegetables' pathway, however as the NZ derivation of SGV's includes a predetermined Bioconcentration factor (BCF) from empirical data which already allows for soil entrainment it would require significant work to apply this. The mathematical equation in the Methodology assumes a soil loading factor of zero so applying any factor to zero is zero. The result is a conservative 'combined pathways' result.
- When 14% is applied and the result rounded in accordance with the Methodology, the 'residential 10% produce' SGV for this site is 70mg/kg
- This site only has two small areas over this value

Non-threshold substance

$$SGV_{ing} = \frac{RHS \times 27375 \times 10^{6}}{IR_{adj} \times EF} mg/kg$$

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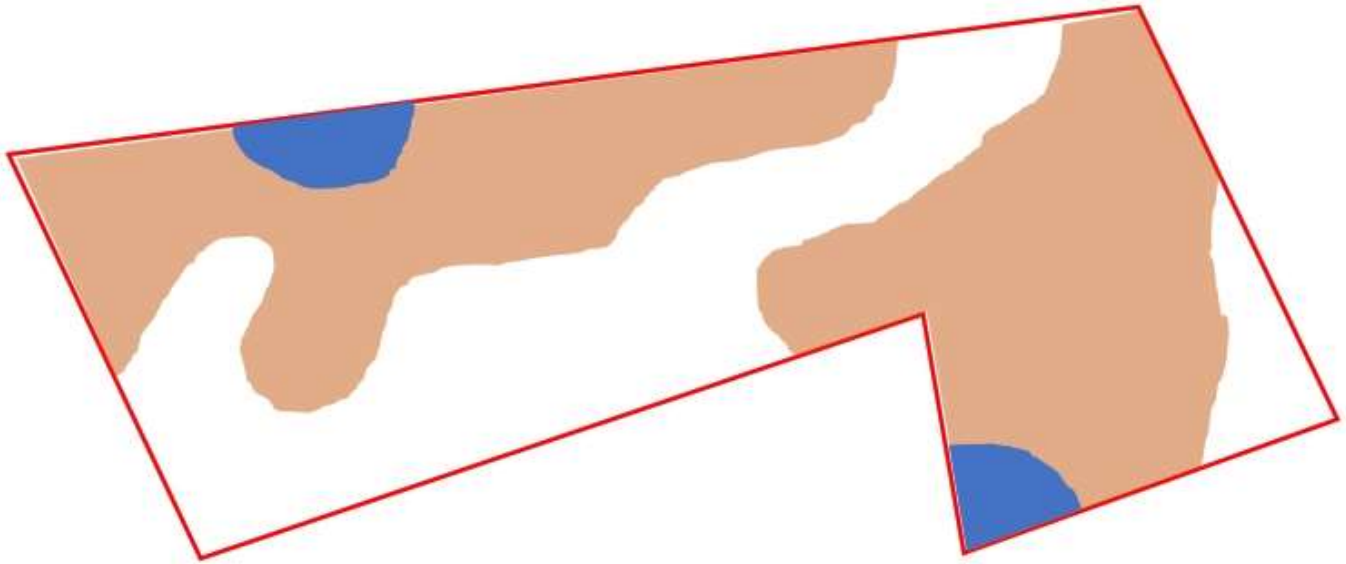
Area affected by arsenic above 70mg/kg (blue)



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Comments on Arsenic SGV's

- The site specific SGV for this site is 70mg/kg, 3 ½ times greater than the Soil Contaminant Standard
- Knowledgeable clients know that the Australian Health Investigation Level is 100mg/kg
- Our NZ arsenic SCS is one of the lowest in the world
- The studies starting to come through in NZ are showing that bioavailability can make a huge difference to the SGV

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Next steps for the client

- At first glance, it may seem its all good news for the client – a great result means remediation of about 5% of the area rather than 60% …. BUT
- All developments create excess soil for disposal
- Although the site-specific SGV is 70mg/kg and is considered safe for a residential use, the soil will still have to be disposed of as contaminated waste at great expense
- We have explored the leachability of the arsenic from the soil by SPLP and TCLP testing of ten samples and results show the arsenic concentrations in the leachate are less than the NZ Drinking Water (DWS) MAV of 0.01mg/l and the Water Quality Guidelines (WQG)95% protection value for freshwater of 0.024mg/l
- Potential solutions that we are exploring include finding another site that would take the soil and obtaining a variation to an existing clean fill site consent to allow the material to be disposed.
- The best solution is for any variation to the clean fill guidelines to include allowing for soils from a site consented under the NESCS with a Tier 2 SGV based on bioavailability , subject to leachate testing to confirm no environmental risk

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Next steps for bioavailability

- Now its your turn!
- We don't have guidelines on how to go about this process yet, but there is lots of supporting info out there that can be sourced such as other jurisdictions derivation methodologies and multiple research papers. If you are an experienced practitioner with a full understanding of the Methodology and how our guideline values are derived then I encourage you to give it a go.
- Start off with testing a few samples for bioaccessible arsenic – this only costs around $100-200 per sample and if the result is favourable, consider the potential benefits of a detailed study.
- The more we do this the more evidence we will have to allow MfE to include a reduced bioavailability in our derived arsenic SCS in the future

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References

DWS: *Drinking-water Standards for New Zealand 2005 (revised 2008).* Ministry of Health, Wellington

Golder 2016: *Accounting for Bioavailability in Contaminated Land Site-Specific Health Risk Assessment.* Report 1542820.003-R-Rev0 for Ministry for the Environment. Golder Associates

HAIL Aug 2017: *Arsenic Bioavailability Assessment, Former Pipfruit orchards on Mapua and Ranzau Soils, Tasman District for Tasman District Council.* HAIL Environmental Ltd

HAIL Feb 2017: *Arsenic Bioavailability Assessment, Land at Mount Rosa, Queenstown Lakes District, for Davis Consulting Group.* HAIL Environmental Ltd

MfE. 2011. *Methodology for Deriving Standards for Contaminants in Soil to Protect Human Health.* Ministry for the Environment, Wellington

WQG 2018: *Australia and New Zealand Guidelines for Fresh and Marine Water Quality*, Online resource http://www.waterquality.gov.au/anz-guidelines Accessed on 25.10.18