University of South Australia | Future Industries Institute

Surface-tailored organoclays alter bacterial community and metabolic activity in hydrocarbon-contaminated soil

Bhabananda Biswas, Binoy Sarkar, Muhammad M. Rahman, Ravi Naidu

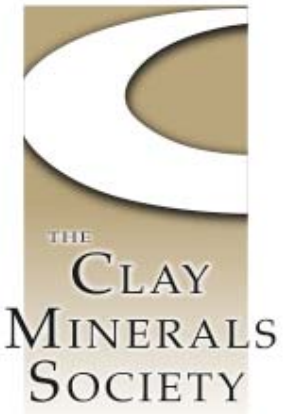
Future Industries Institute, University of South Australia

Cooperative Research Centre for Contamination Assessment and Remediation of the Environment

05 June 2017

LIVING CLAYS
From nano-scale interactions to incorporation in everyday life

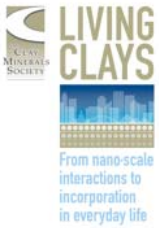
Acknowledgment



- Student Research grant, 2016
- Travel grant

- Support facilities for research

- Bacterial DNA sequence data

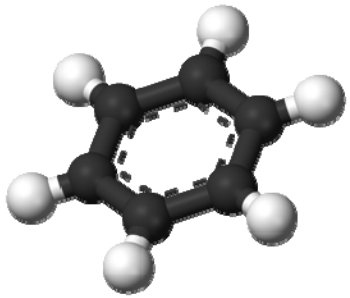


Outline

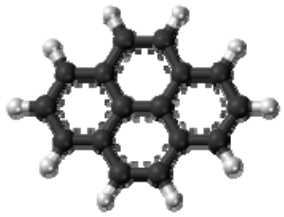
- Mixed contaminated situation
  - What are they?
  - Environmental and health impact?
- Metal-immobilizing organoclay (surface-tailored organoclay)
  - Synthesis and mechanism as adsorbent?
  - Applicability in PAH biodegradation from mixed contaminants
- Biocompatibility of surface-tailored organoclay
  - Microbial degradation & metabolic activity
  - Soil bacterial metagenomes test
- Take-home message

University of South Australia | Future Industries Institute

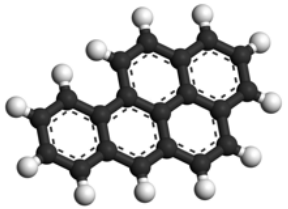
Mixed contaminants



Phenanthrene



Pyrene



Benzo[a]pyrene

Hamilton gas works site leaching toxic chemicals

JOANNE McCARTHY
28 Sep 2015, 10 p.m.

AGL gas works remediation long time coming

ONE of the Hunter's most contaminated sites – the former Hamilton AGL Gasworks – is leaching carcinogenic and toxic materials, including cyanide, ammonia and lead, into groundwater and poses a risk to human health and the Hunter River, documents with the NSW Department of Planning show.

The Clyde Street site, which has been derelict for 30 years, was "a significant source of contamination that is migrating off site via groundwater towards residential areas and Styx Creek", reports say.

The Planning Assessment Commission found remediation "has the potential to be environmentally polluting given the highly toxic and carcinogenic contaminants on site".

"The remediation project is highly complex and the location of the site in close proximity to residents adds to the complex nature of the project," the commission found.

A report prepared for Jemena found the old gasworks site had a range of known carcinogens, potentially carcinogenic compounds and toxic compounds including benzene, polycyclic aromatic hydrocarbons (PAHs), total recoverable hydrocarbons (TRH), benzo(a)pyrene, cyanide, ammonia and lead.

More than 65,000 cubic metres of overburden to a depth of four metres below ground level was found to be contaminated.

"The site is heavily contaminated and needs to be remediated to reduce the risk to human health and enable the site to be used for commercial and industrial purposes," the report said.

A Jemena spokesperson said the company had been communicating with affected residents since June last year.

"Remediation of contaminated sites is a highly regulated and independently monitored process, so Hamilton North residents can be assured the clean up of the Clyde Street site will proceed safely," the spokesperson said.

"We are fully committed to fully remediating the Clyde Street site to Environmental Protection Authority standards."

Australian Gas Light Company (AGL) opens Newcastle Gasworks on 7.4 hectare site at Clyde Street, Hamilton North in 1913 to produce town gas.

- The site contained tanks to store gas, naptha and tar, a boiler house, tar conditioning plant, oil separator, gas holders, an ammonia house and purifier beds.
- Gasworks close in 1985.
- Soils and groundwater significantly contaminated with benzene, hydrocarbons, cyanide and other heavy metals exceeding human health criteria, and left untreated for 30 years.
- In 2004 a trial remediation of 300 cubic metres of contaminated soil is proposed. The gasworks site appears on a state register of contaminated lands.
- In August 2011 the NSW Environmental Protection Authority declares the site significantly contaminated, requiring Jemena to launch a remediation process or risk prosecution.
- Jemena (formerly known as AGL), carries out investigations under a voluntary management proposal in

- Soils and groundwater significantly contaminated with benzene, hydrocarbons, cyanide and other heavy metals exceeding human health criteria, and left untreated for 30 years.
- In 2004 a trial remediation of 300 cubic metres of contaminated soil is proposed. The gasworks site appears on a state register of contaminated lands.

On September 15 the NSW Planning Assessment Commission recommended the 7 hectare former gasworks be declared a state significant area after Newcastle City Council expressed concerns about its capacity to assess the highly technical and complex remediation.

The former gasworks land was strategically significant because it was adjacent to the Woodville junction site which was the original Newcastle transport interchange site before the NSW Government settled on the Wickham interchange.

Remediation work, which Jemena hopes to start in late 2016 following assessment of the proposal, could include a process that has not been used in Australia before.

Getting to meet new people

Hi I am very new to the area and know absolutely no one. I would like to meet a...

Best burger nearby?

Everyone seems burger obsessed at the moment. Any recommendations for the best o...

Garage sale Saturday morning

We are having a massive clean out. Lots of bargains including handbags and cloth...

Good fish and chips nearby?

Recently returned to the suburb after 4 years and struggling to find a good fish...

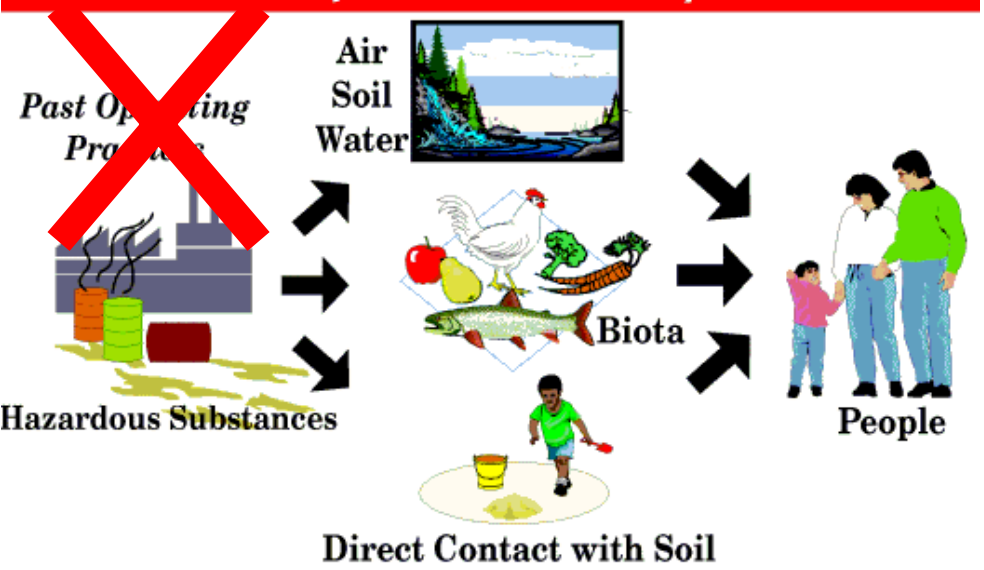
Clay Minerals Society

LIVING CLAYS

From nano-scale interactions to incorporation in everyday life

University of South Australia | Future Industries Institute

Exposure Pathways



Cause many diseases

- skin,
- respiratory,
- gastrointestinal,
- urinary system
- cancer in chronic exposure.

www.atsdr.cdc.gov/spl/

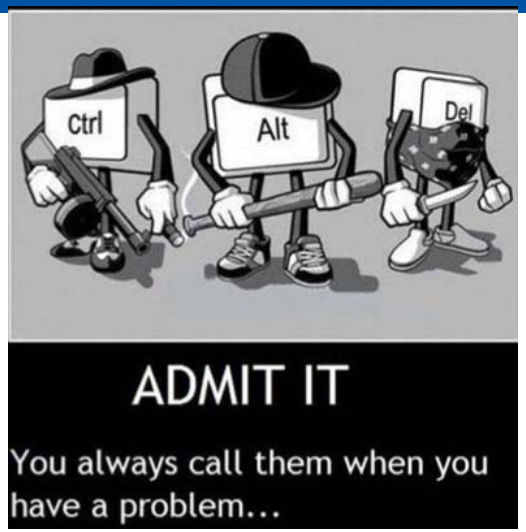
ATSDR Agency for Toxic Substances & Disease Registry

Priority List of Hazardous Substances

The Priority List of Hazardous Substances That Will Be the Subject of Toxicological Profiles

2015 RANK	SUBSTANCE NAME	TOTAL POINTS	2013 RANK
1	ARSENIC	1671.6	1
2	LEAD	1529.4	2
3	MERCURY	1458.6	3
4	VINYL CHLORIDE	1358.9	4
5	POLYCHLORINATED BIPHENYLS	1345.1	5
6	BENZENE	1327.6	6
7	CADMIUM	1318.8	7
8	BENZO(A)PYRENE	1304.4	8
9	POLYCYCLIC AROMATIC HYDROCARBONS	1279.1	9
10	BENZO(B)FLUORANTHENE	1249.7	10
11	CHLOROFORM	1202.4	11
12	AROCLOR 1260	1190.0	12
13	DDT, P,P'-	1182.0	13
14	AROCLOR 1254	1171.3	14
15	DIBENZO(A,H)ANTHRACENE	1155.6	15
16	TRICHLOROETHYLENE	1153.4	16
17	CHROMIUM, HEXAVALENT	1146.8	
18	DIELDRIN	1142.9	
19	PHOSPHORUS, WHITE	1141.3	
20	HEXACHLOROBUTADIENE	1128.2	

LIVING CLAYS
From nano-scale interactions to incorporation in everyday life

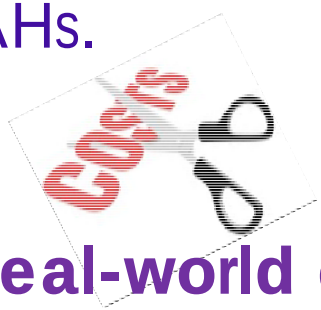


OR

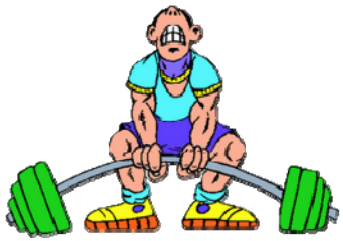
So, need to remove them?

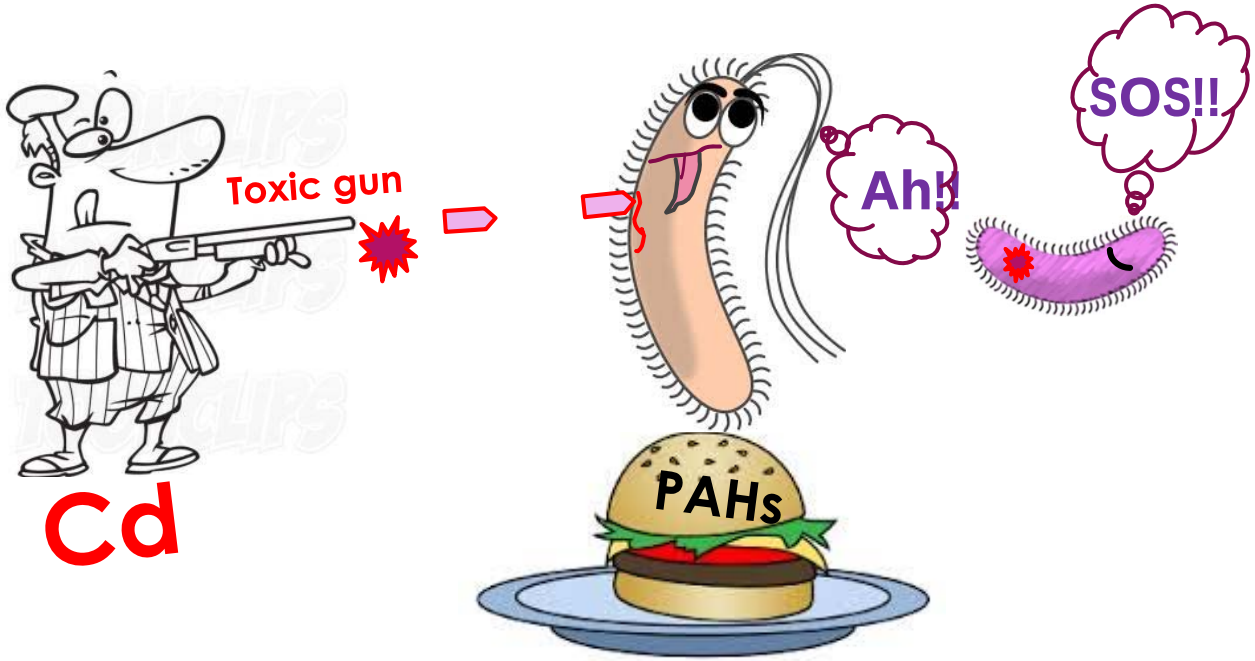
need to change lifestyle?

- Complete removal of PAHs by **bioremediation**
- Microorganisms (e.g. bacteria, fungi) are potential degrader of PAHs.
- Cost effective.



BUT, Not easy in real-world clean-up in MIXED contaminants.



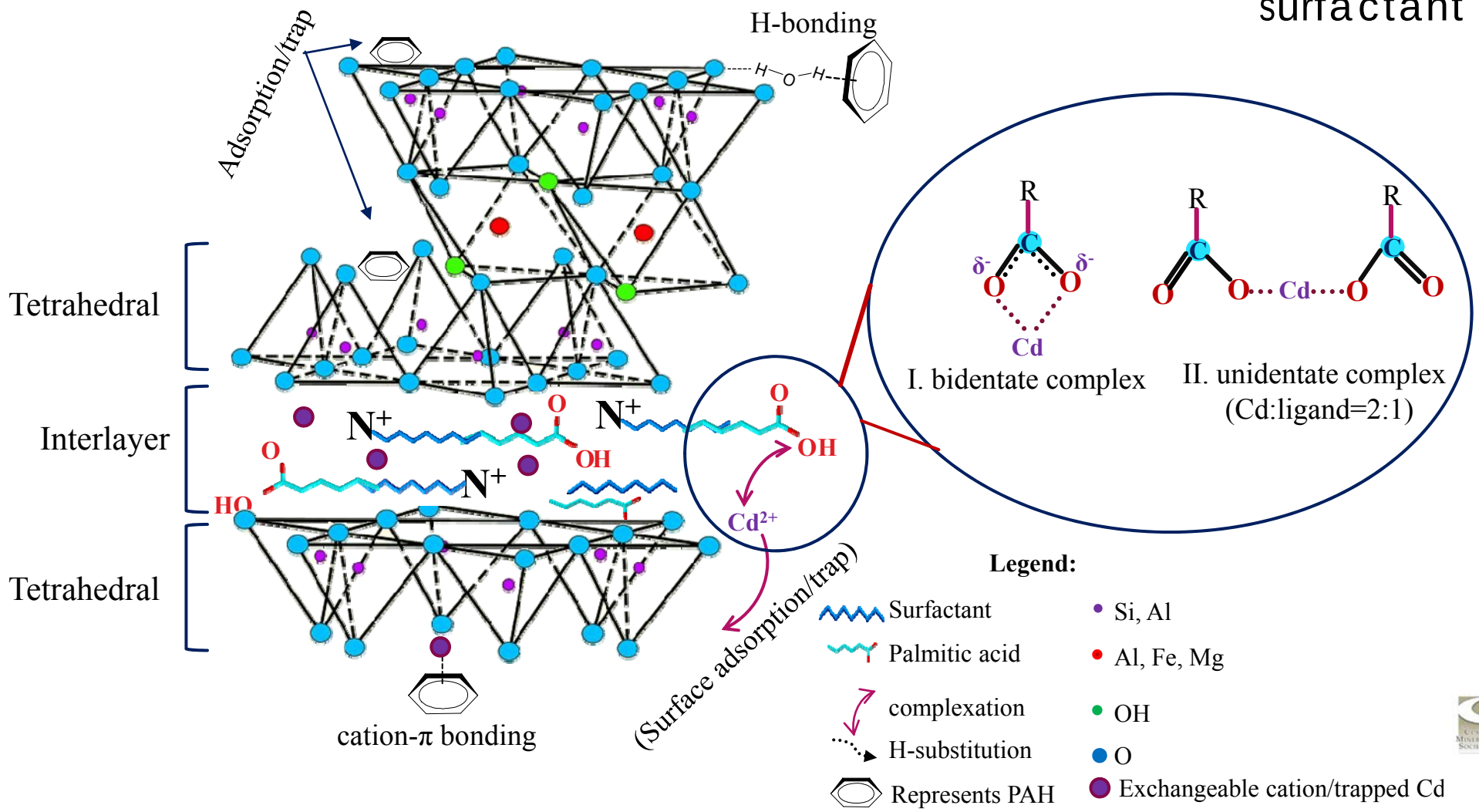


Mixed contaminants challenge

Mitigate using single modified clay product

University of South Australia | Future Industries Institute

Surface-tailored organoclays

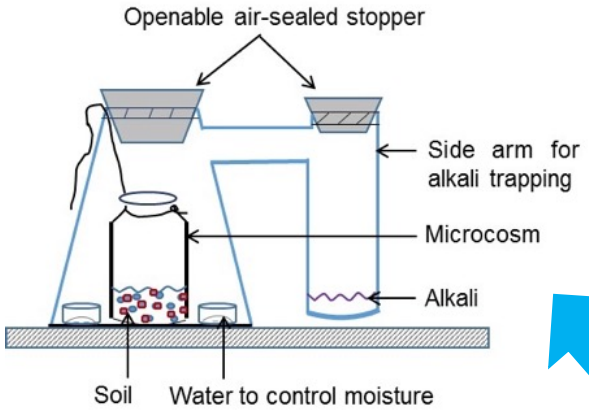


Biswas et al., ***Water Res.* 2016**, 104: 119-127.

University of South Australia | Future Industries Institute

Biocompatibility: Experimental

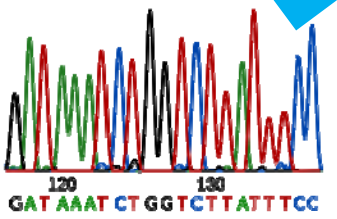
NC=control, B=bentonite, AB=Arquad-bentonite, ABP=Arquad-bentonite-palmitic acid



Biodegradation experiment

Soil bacterial genomic DNA

DNA sequencing



Sequencing quality

Results analysis & presentation

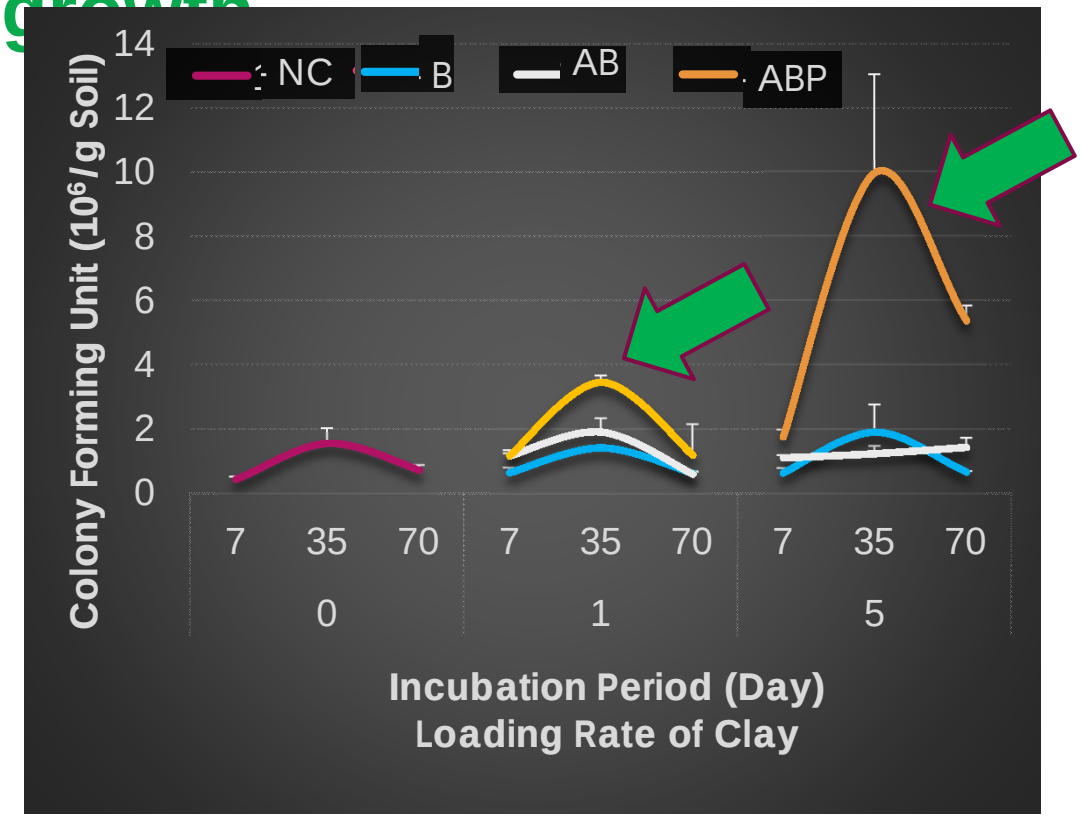
NC, B, AB, ABP

Clay-mixed contaminated soil

Metabolic activity by CTC-staining

University of South Australia | Future Industries Institute

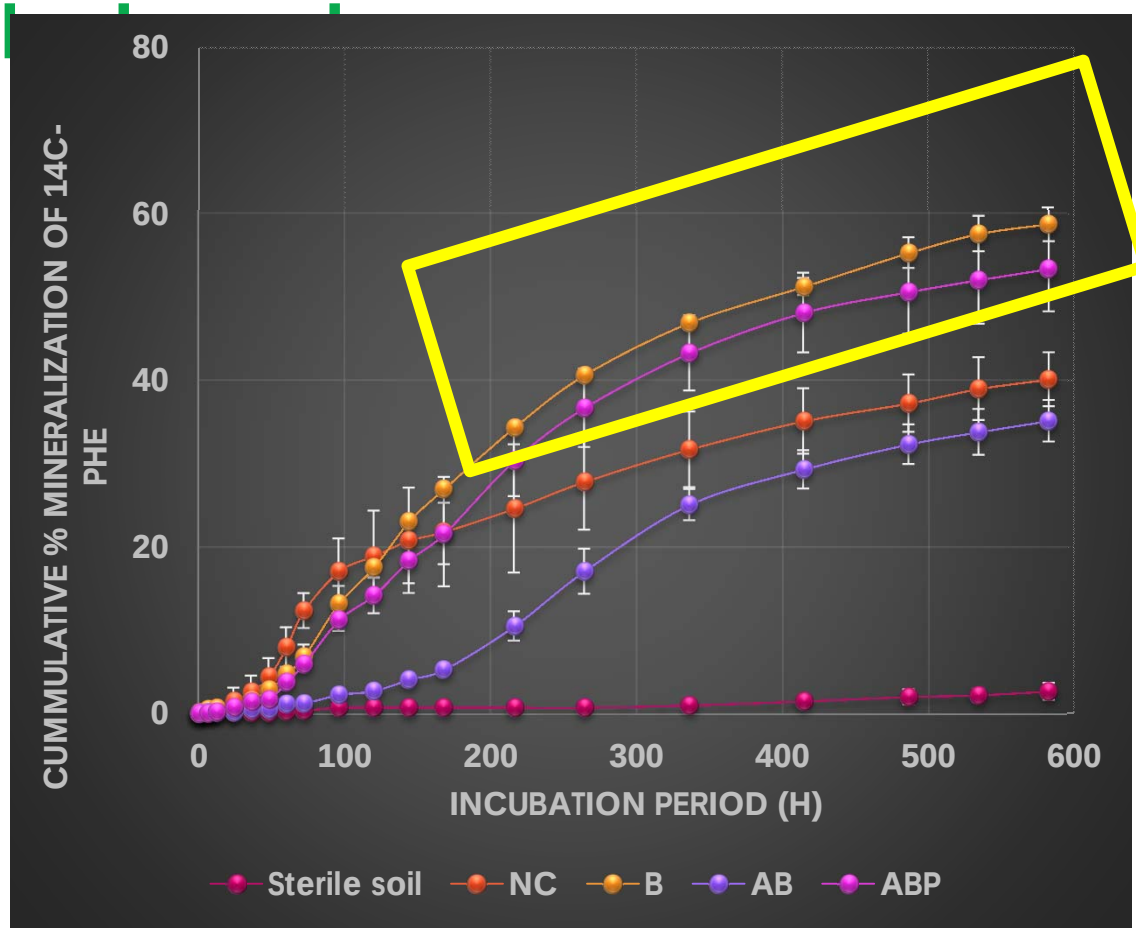
Biocompatibility: Bacterial growth



Surface-tailored organoclay (ABP) increased bacterial growth in clay-amended soil.

LIVING CLAYS
From nano-scale interactions to incorporation in everyday life

Biodegradation of



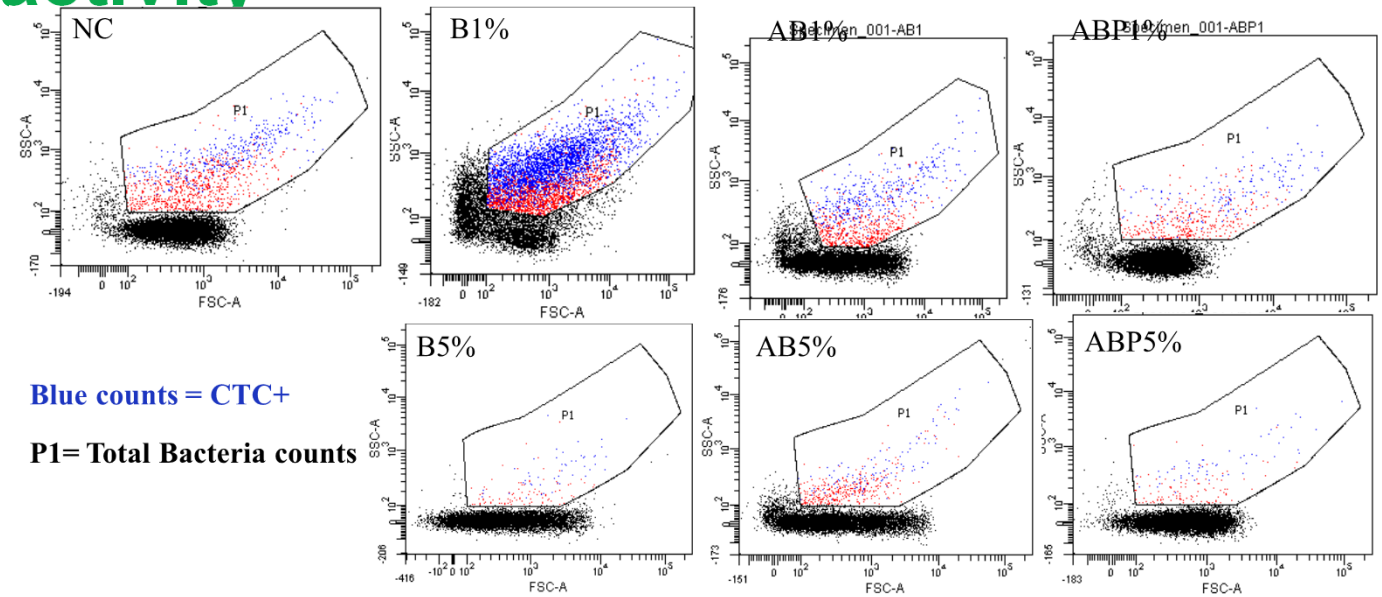
But surface-tailored organoclay (ABP) was not aligned with the degree of bacterial growth observed in clay-amended soil.

Is it due to:

- Metabolic active cells?
- Microbial diversity?

Microbial Diversity

Biocompatibility: Metabolic activity



Blue counts = CTC+

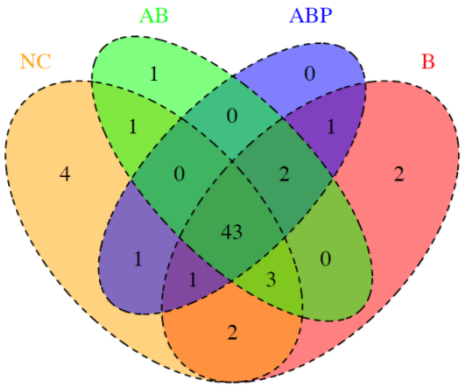
P1= Total Bacteria counts

Clay-soils	Ratio (inactive/active cells)
NC	3.264 ± 0.412
B1%	1.841 ± 0.310
AB1%	2.188 ± 0.192
ABP1%	2.559 ± 0.624
B5%	3.192 ± 0.554
AB5%	4.962 ± 1.232
ABP5%	3.200 ± na

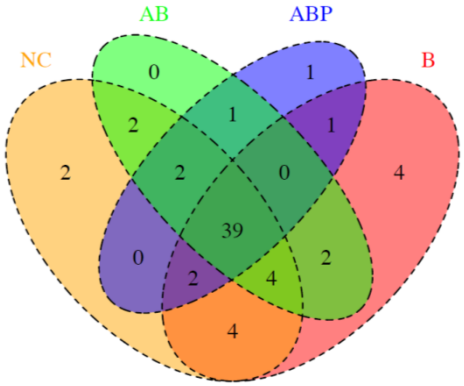
Organoclay imposed more toxicity on microbial activity than that of surface-tailored organoclay.

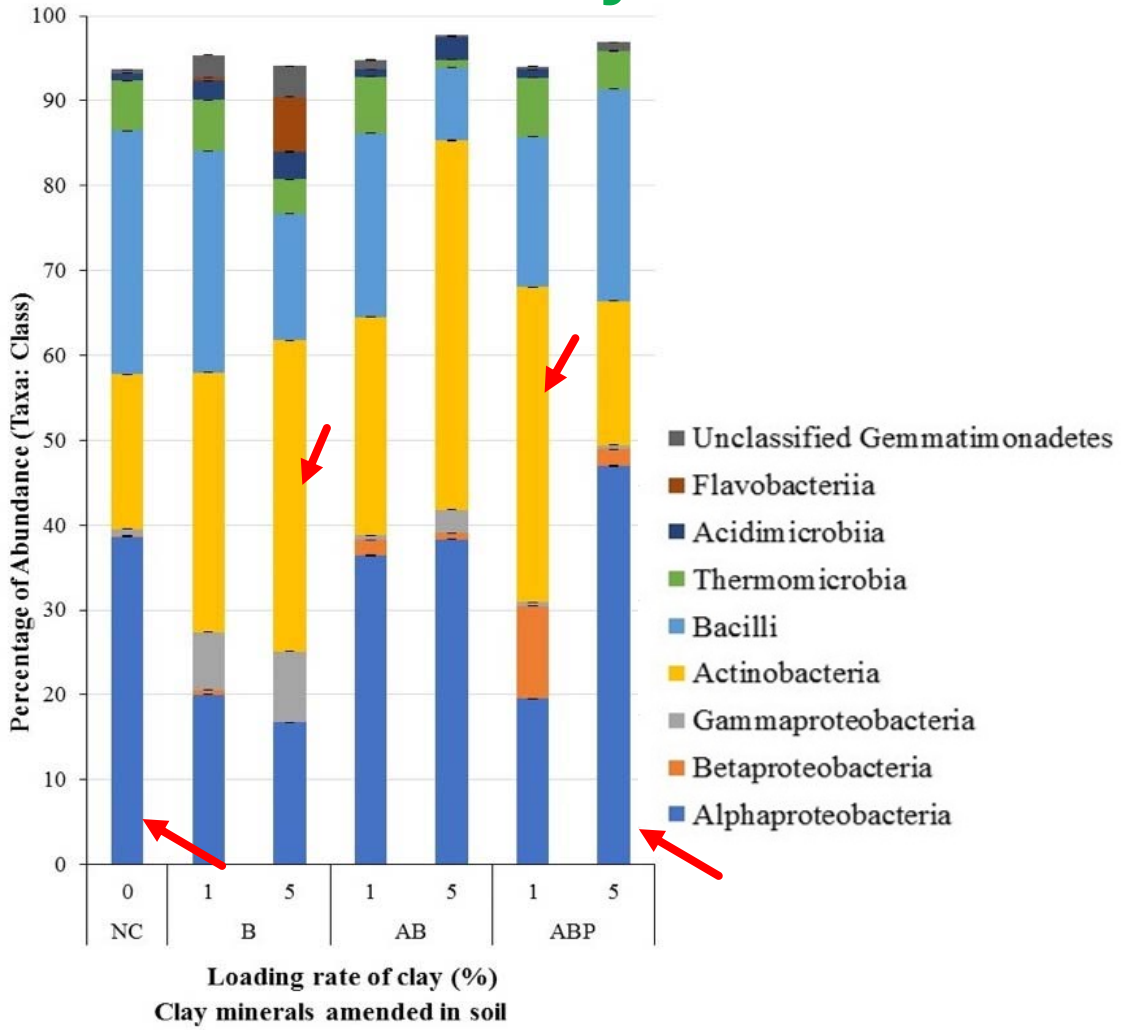
Biocompatibility: Bacterial diversity

Loading: 1%



Loading: 5%





Clay products could dictate bacterial diversity and abundance

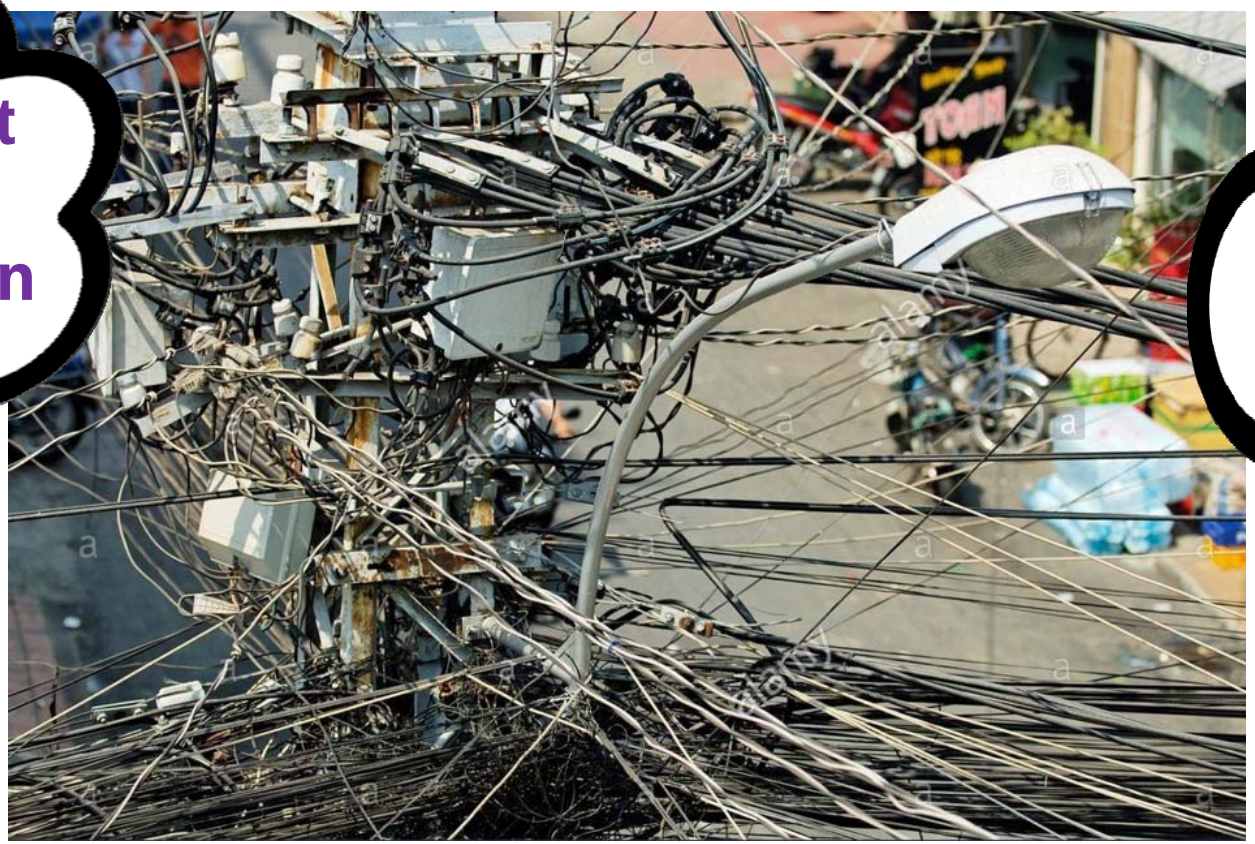
LIVING CLAYS
From nano-scale interactions to incorporation in everyday life

Take-home message and Future Research

- Surface-tailored organoclay-effective selective adsorbent for mixed contaminants,
- Biocompatibility of modified products-key issue as bioremediation is desired,
- The relation of bacterial growth and biodegradation is not generalized, maybe **due to variation in metabolic active cells,**
- Dominant bacterial species remains high in the surface-tailored organoclay-**indicates the congenial microhabitat?**
- Multiple omics tools could be in the future research for assessing the impact of modified clay products in microbial viability and bioremediation
- **Yet** clay-microbial interaction is **complex** to understand at a molecular level -maybe due to highly site specific in soil.

University of South Australia | Future Industries Institute

Mate! I got the hub of connection

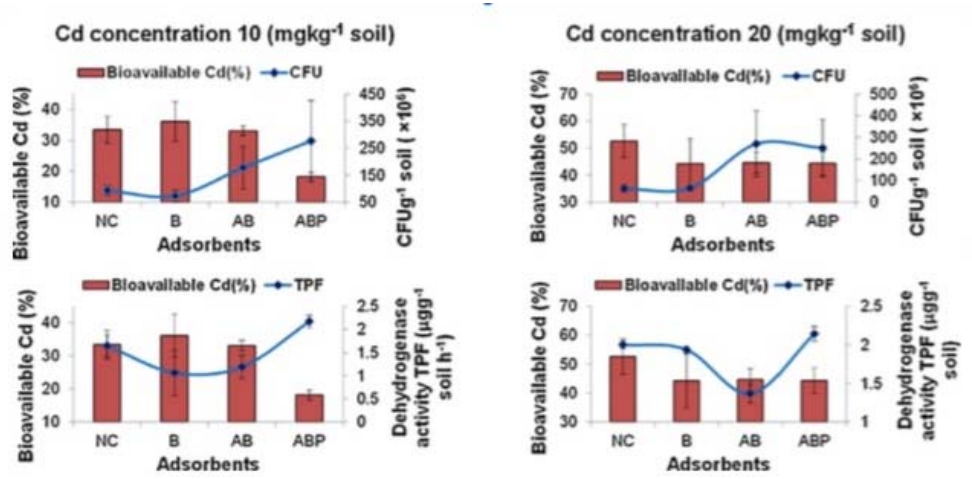


No worries! Easy job, just find where to start

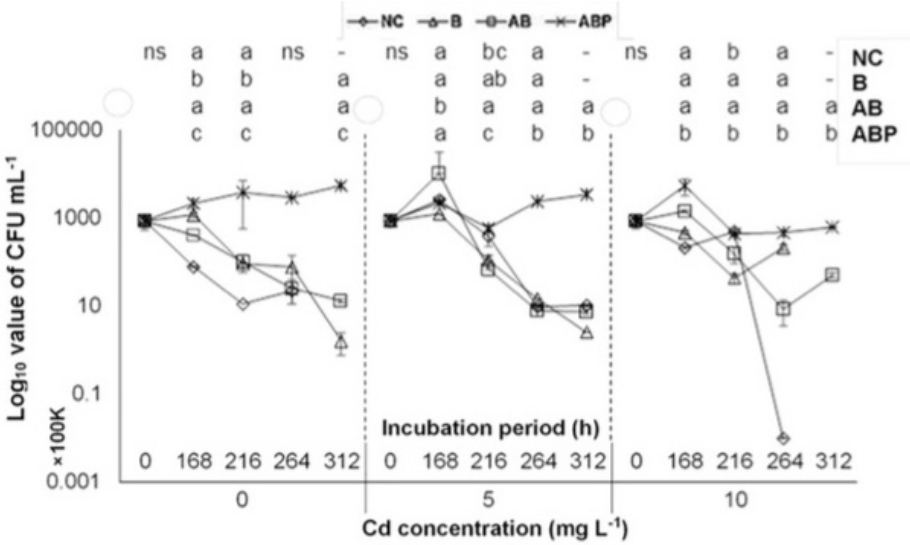
Thanks to ALL

LIVING CLAYS
From nano-scale interactions to incorporation in everyday life

University of South Australia | Future Industries Institute



Journal of Hazardous Materials 298 (2015) 129–137



Science of the Total Environment 550 (2016) 611–618