Virtual Curtain Limited
and
CSIRO Land and Water

Turning Wastewater Into Rainwater

July 2022

Corporate details

Virtual Curtain Limited
("VCL")

ABN: 30 129 687 029
Registered 19 February 2008

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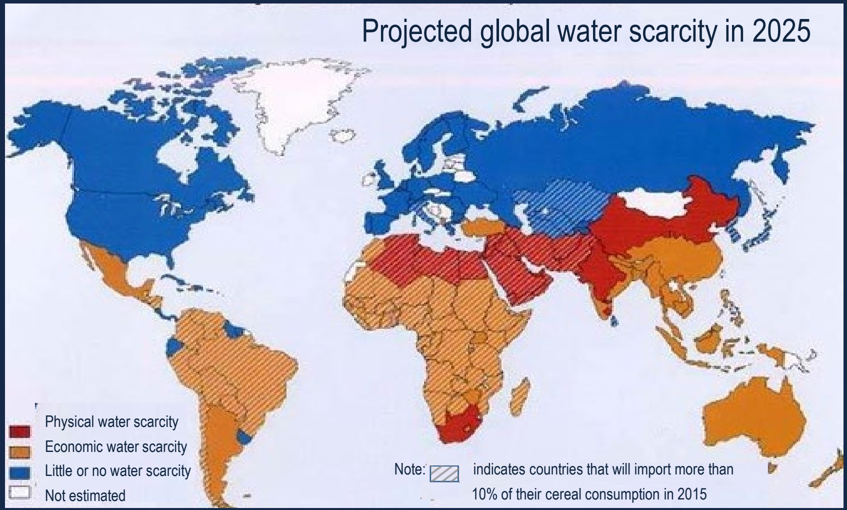
Contaminated wastewater
THE PROBLEM

Water security is a growing global issue

Enormous global volumes of contaminated wastewater generated from mining, minerals/materials processing, power plants, paper making, printing, dyeing …. with annual cost to industry of billions of dollars



China is the largest producer of wastewater with 68.5 billion tonnes of wastewater produced annually

In a single industry sector in Inner Mongolia, acid and contaminated wastewater from coal-to-chemicals plants is forecast to exceed 100 million tonnes per annum by 2020

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WHAT WE DO

Virtual Curtain technology offers proven solutions for the **treatment of contaminated industrial and mining wastewater, above-ground and in-aquifer, to a standard suitable for re-use or discharge**

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Contaminated wastewater
APPLICABLE INDUSTRY SECTORS

Virtual Curtain technology has proven suitability to the treatment of wastewaters across key industry sectors including:

- MINING/MINERALS PROCESSING *(AMD, tailings, process water)*
- NUCLEAR wastewaters *(ISL plumes, tailings, process water)*
- COAL-to-CHEMICAL industry wastewaters *(<Si and hardness)*
- POWER GENERATION
- PETROCHEMICAL plant wastewaters
- ELECTROPLATING industry wastewaters
- TEXTILE industry wastewaters
- PAPER PULP industry wastewaters ……….

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Virtual Curtain technology
INTELLECTUAL PROPERTY

Technology invented by CSIRO
and commercialised by VCL under exclusive
global licencing agreement

30 registered patents and numerous patent
applications in Australia and internationally

AU2007/000452: Remediation of groundwater

AU2010/000317: Treatment or remediation of natural or waste water

AU2015/050175: A process for treatment of and/or remediation of water

AU2018/050967: Water treatment process

AU2016/050282: Selective separation of elements or commodities of interest in aqueous streams

Based on internationally peer-reviewed science

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TECHNOLOGY and COST ADVANTAGES

1. Typically one-step process with 200-500 fold element enrichment from the wastewater solution

2. Simple to implement, low infrastructure/capital requirements, infinitely scalable

3. Uses readily available additives for broad spectrum remediation, removes most major, trace elements, radionuclides and softens water

4. Liquid-to-liquid mixing with instantaneous in-situ formation of hydrotalcite

5. Easily separable from solution, typically with 10-20% by mass of lime based (gypsum) precipitates

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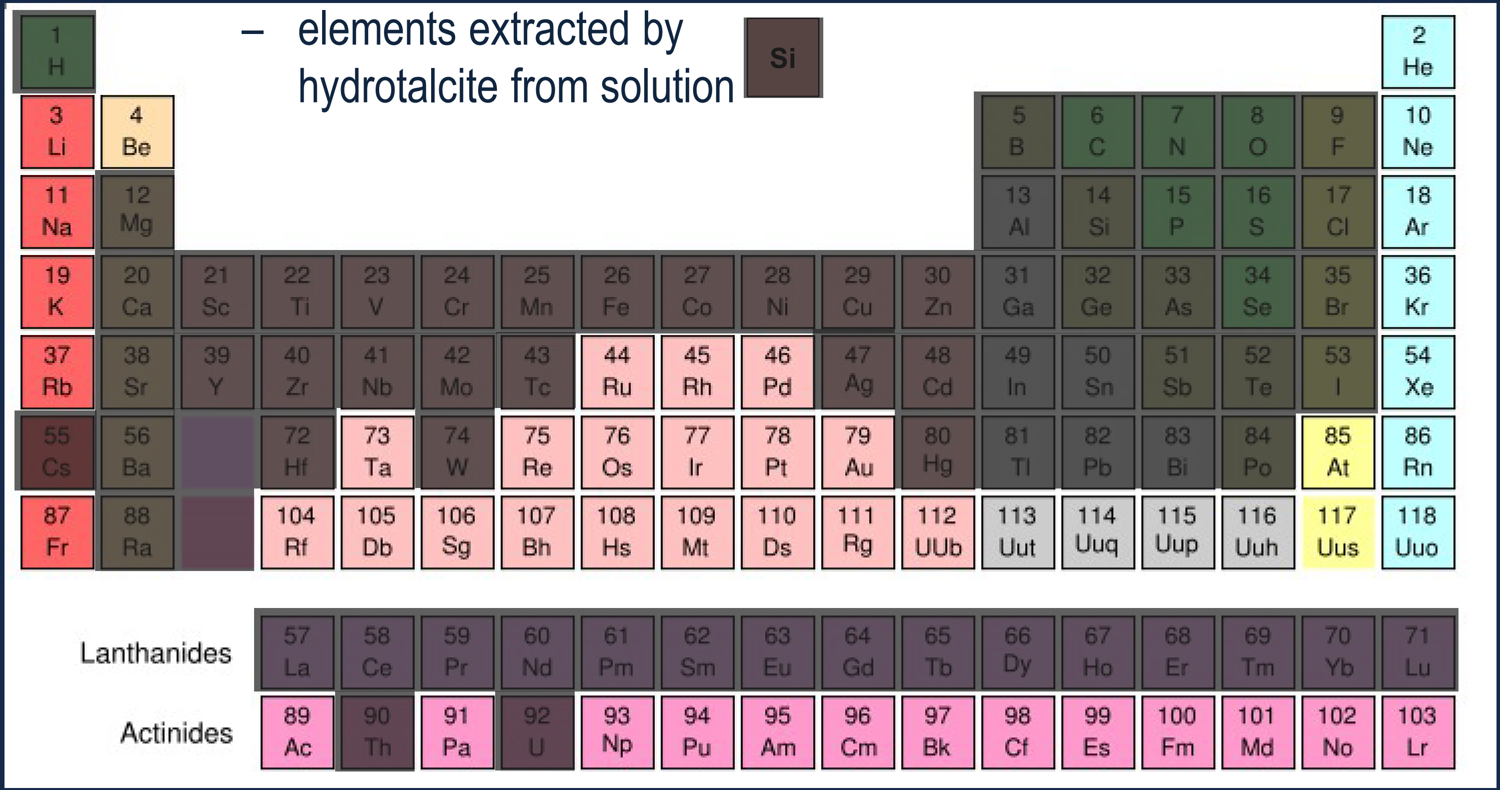
WHAT CAN BE REMOVED FROM WASTEWATER?

Elements present in hydrotalcites in cationic layers or as interlayer (oxy)anions ……



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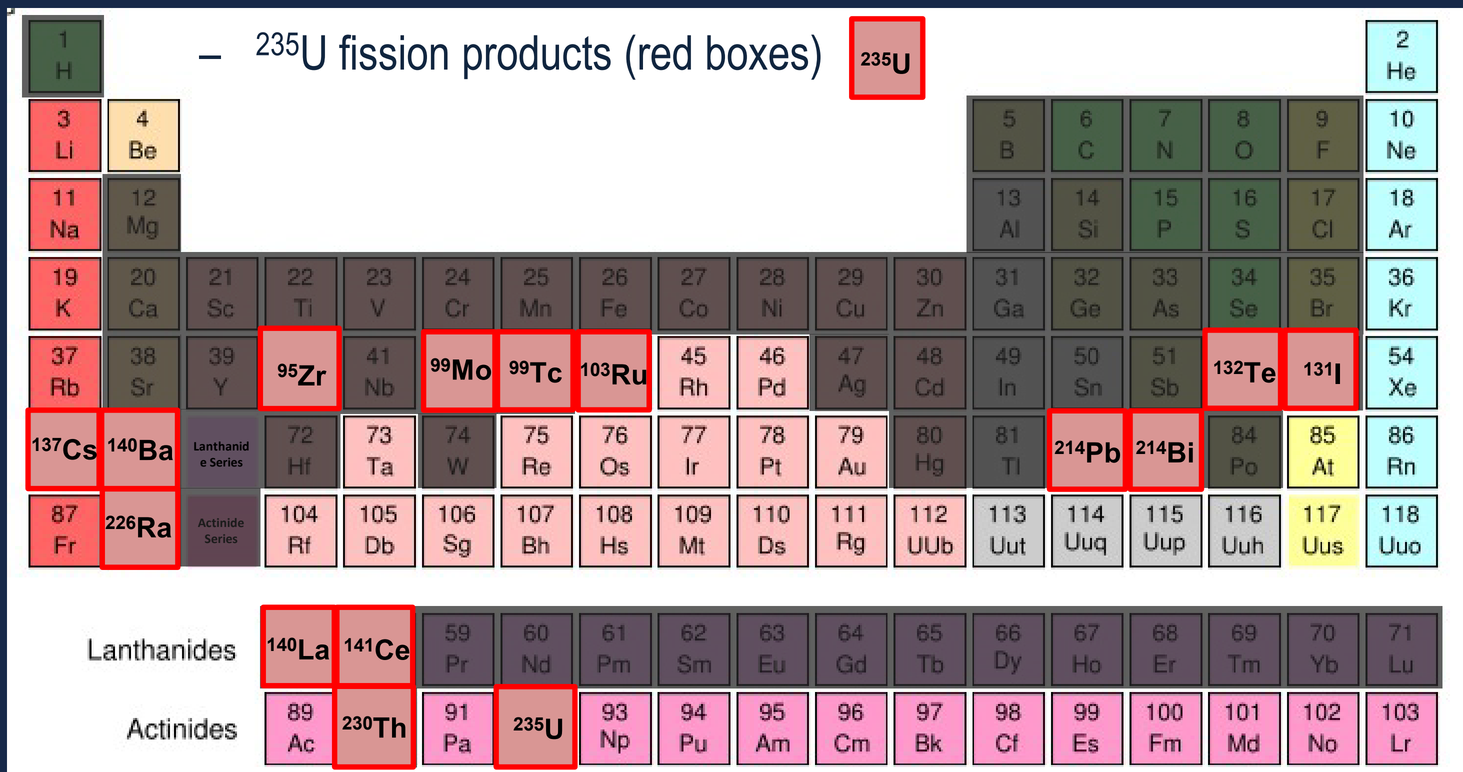
RADIONUCLIDES REMOVED FROM WASTEWATER

Radionuclides from nuclear industry wastewaters……



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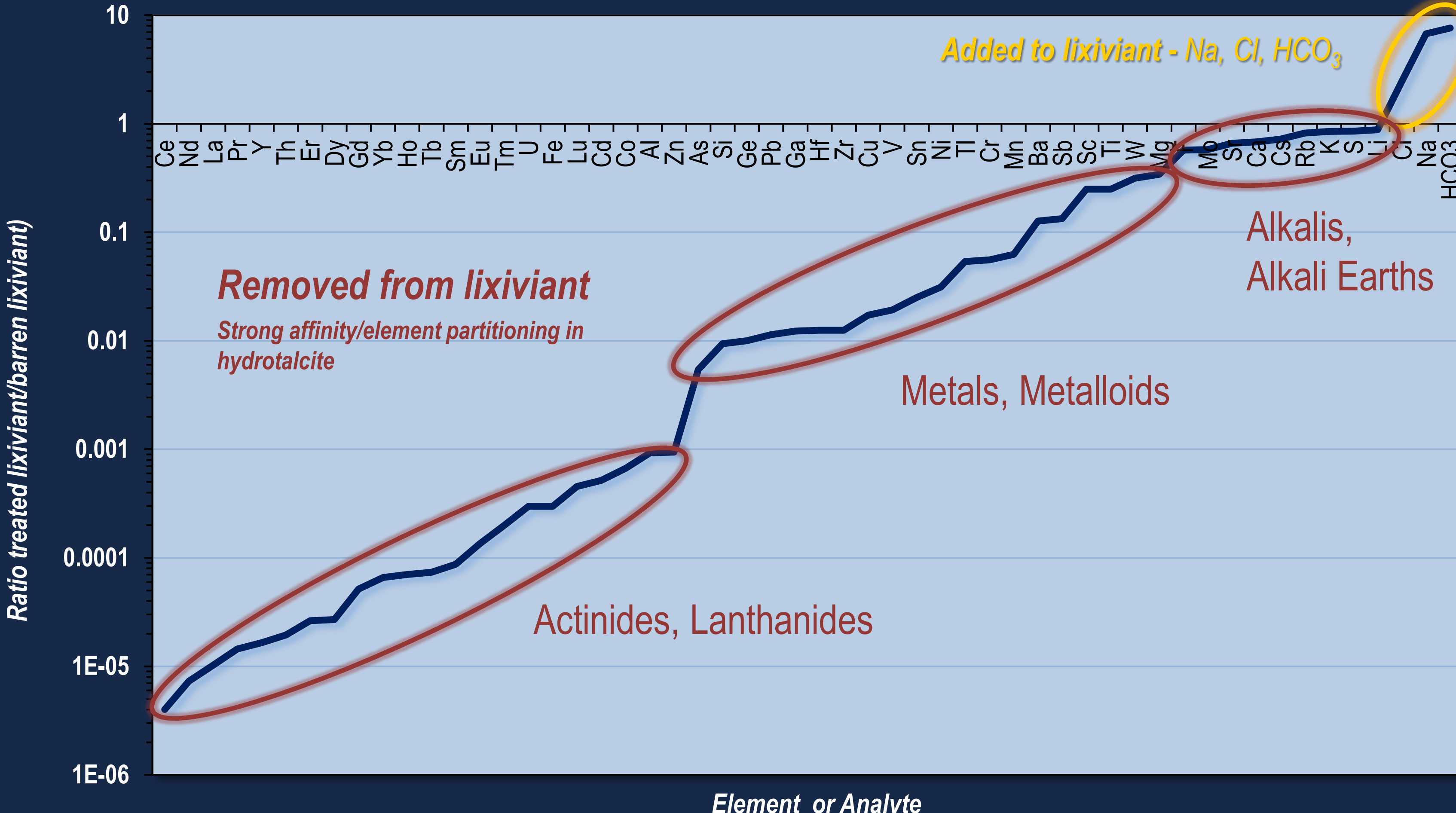
RATE of REMOVAL FROM WASTEWATER?



Virtual Curtain technology
THE SCIENCE in SUMMARY

Virtual Curtain technology is based on the in-situ formation of **Hydrotalcite** (a layered double-hydroxide mineral or anionic clay)

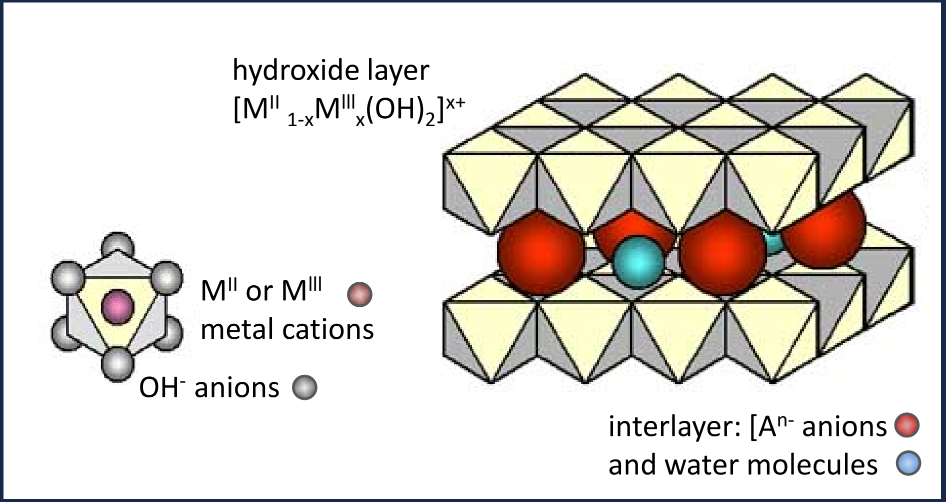
1. Think of hydrotalcite as a chemical sandwich:

   all contaminants - positively charged ions (metals) and negatively charged anions contained within the one structure

2. Simplicity:

   contaminants are building blocks
   instantaneous
   one step
   broad spectrum

3. Potential ore grade/reprocessing



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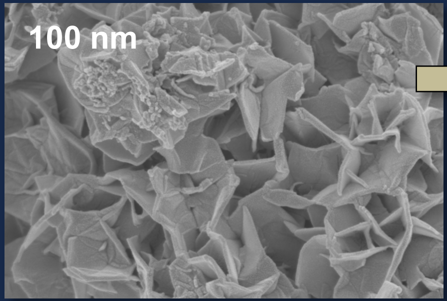
Validation of Virtual Curtain technology UPSCALING - FROM TEST TUBE TO INDUSTRY

Australian Mine Pit – from nanoscale to commercial scale



China Industrial Park – from pilot scale to industrial scale

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Virtual Curtain technology INTERNATIONAL CONTRACTS and DEMONSTRATIONS

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CHINA INDUSTRY APPLICATION
Removal of Si, Ca and Mg from Coal-Chemical Industry Wastewaters
Shaanxi

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Shaanxi coal gasification plant - the opportunity

Coal-to Chemicals industrial park in Shaanxi producing very high concentrations of silica and hardness in wastewater, caused significant operations issues due to silica/calcium fouling:

RO membranes

- operational inefficiencies due to the need for high frequency backwashing, significantly reduced RO deliverables and higher operational costs

Evaporation circuit

- operating inefficiencies strongly compromised the target of “zero emissions”

Pipework infrastrusct ure

- scaling and erosion of pipework/plumbing infrastructure

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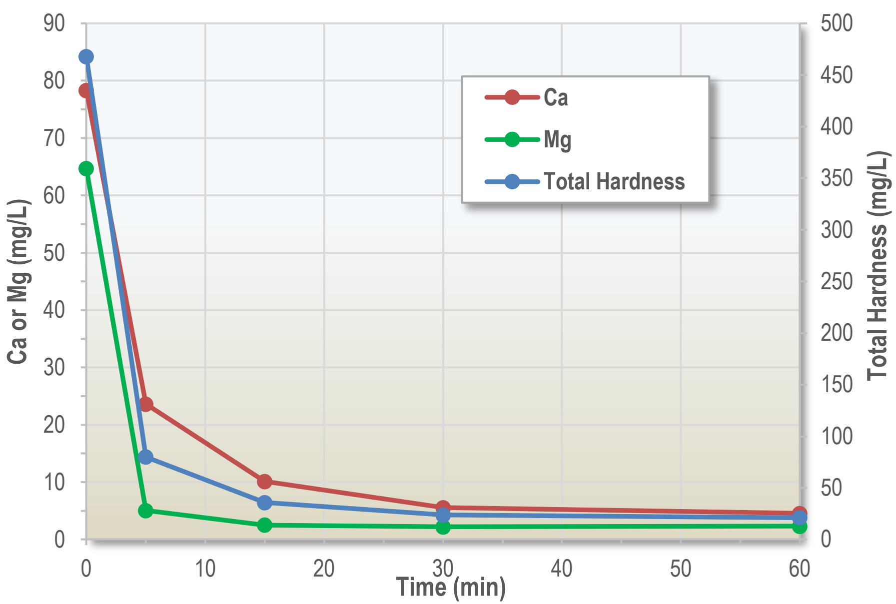
Shaanxi coal gasification plant - wastewaters pre- and post-treatment

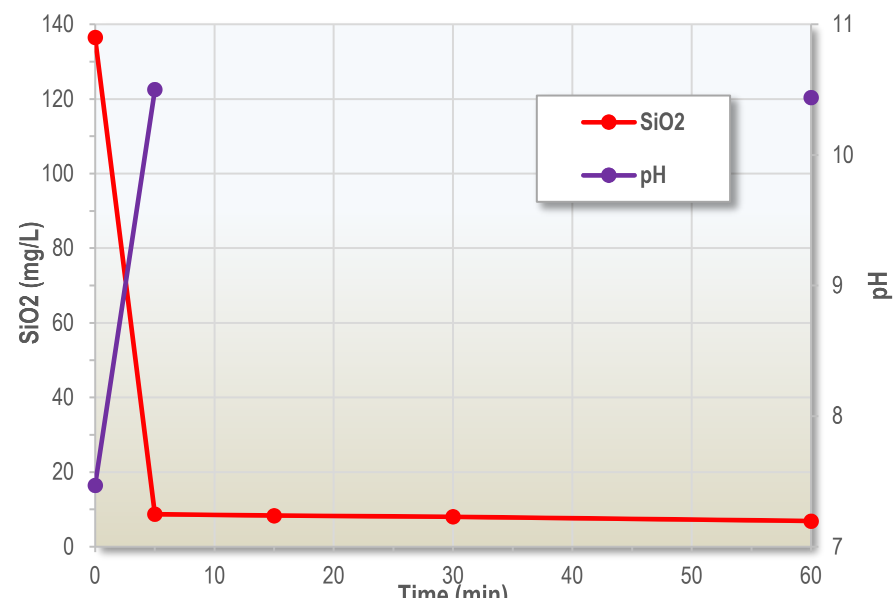
Foulant	Pre-treatment	Post-treatment	Removal (%)
Total Hardness	468	21	**96%**
Ca (mg/L)	78	4.6	**94%**
Mg (mg/L)	65	2.3	**96%**
SiO_2 (mg/L)	136	6.9	**95%**

RO Concentrate Wastewater Stream

Removal of silica (and reduction of hardness)

HT Technology enabled the Stage 3 RO to operate, improved efficiency by 50% and improved the wastewater treatment capacity from <800m^3 to 1,200m^3 per hour.





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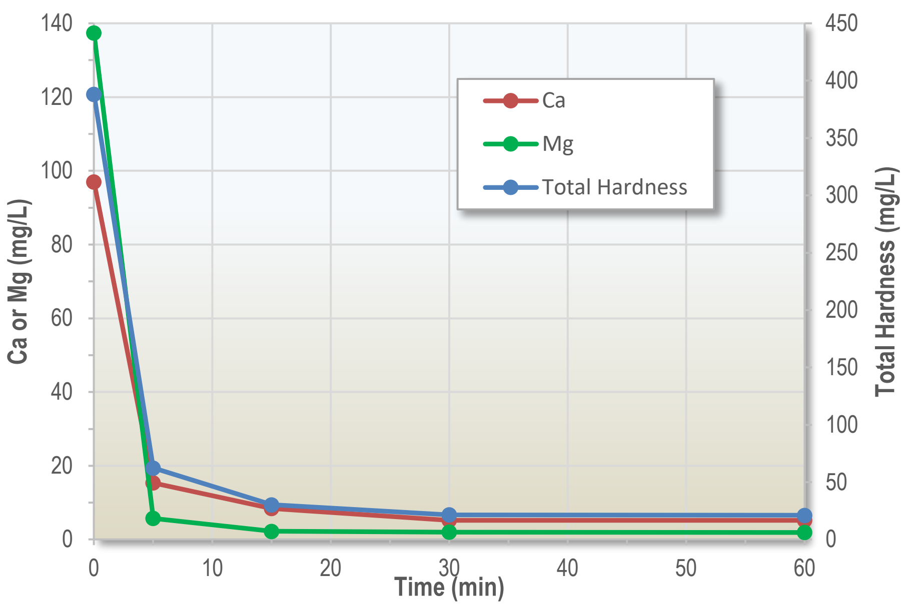
Shaanxi coal gasification plant - wastewaters pre- and post-treatment

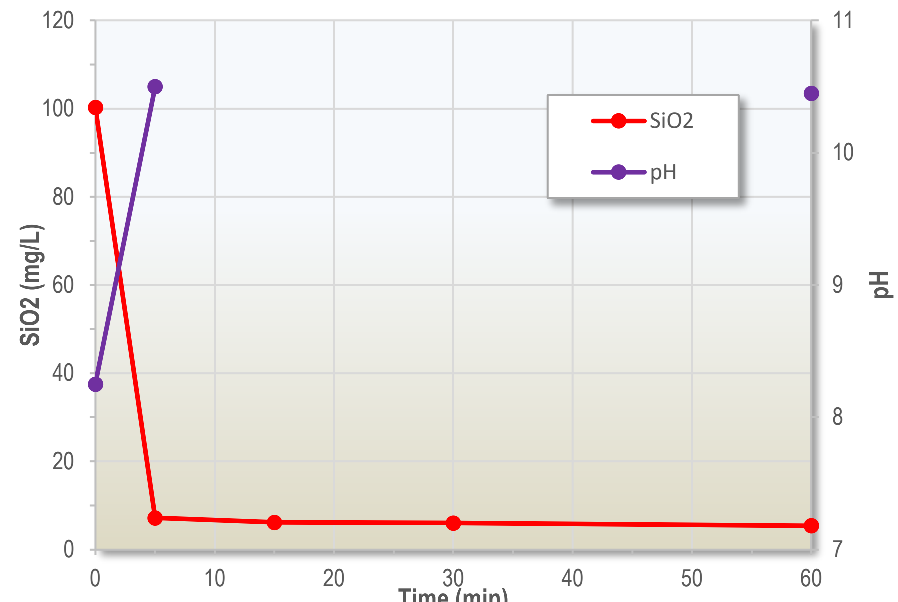
Foulant	Pre-treatment	Post-treatment	Removal (%)
Total Hardness	388	21	**95%**
Ca (mg/L)	97	5.2	**95%**
Mg (mg/L)	137	1.9	**99%**
SiO_2 (mg/L)	100	5.4	**95%**

Coal Gasification Wastewater Stream 1

Removal of silica (and reduction of hardness)

HT Technology enabled the Stage 3 RO to operate, improved efficiency by 50% and improved the wastewater treatment capacity from <800m^3 to 1,200m^3 per hour.





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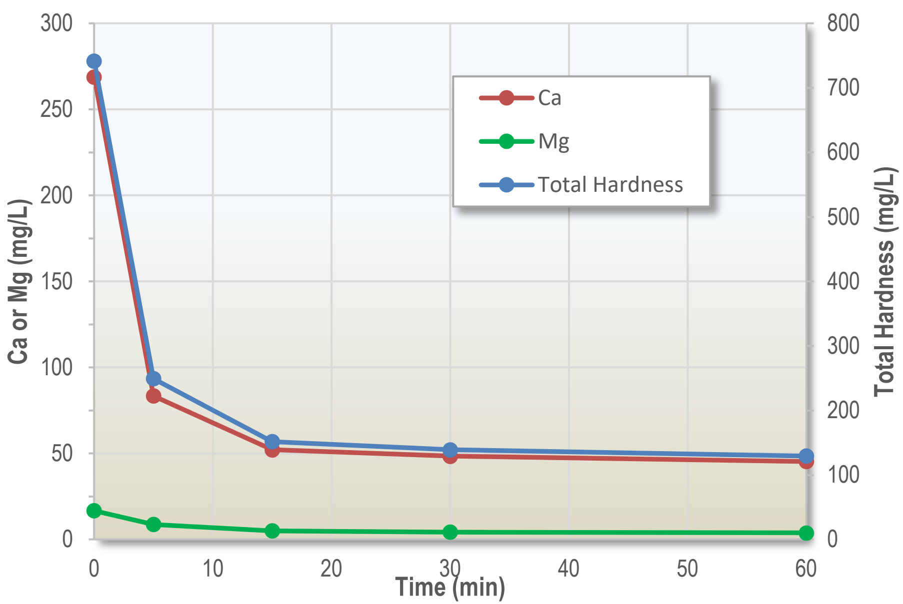
Shaanxi coal gasification plant - wastewaters pre- and post-treatment

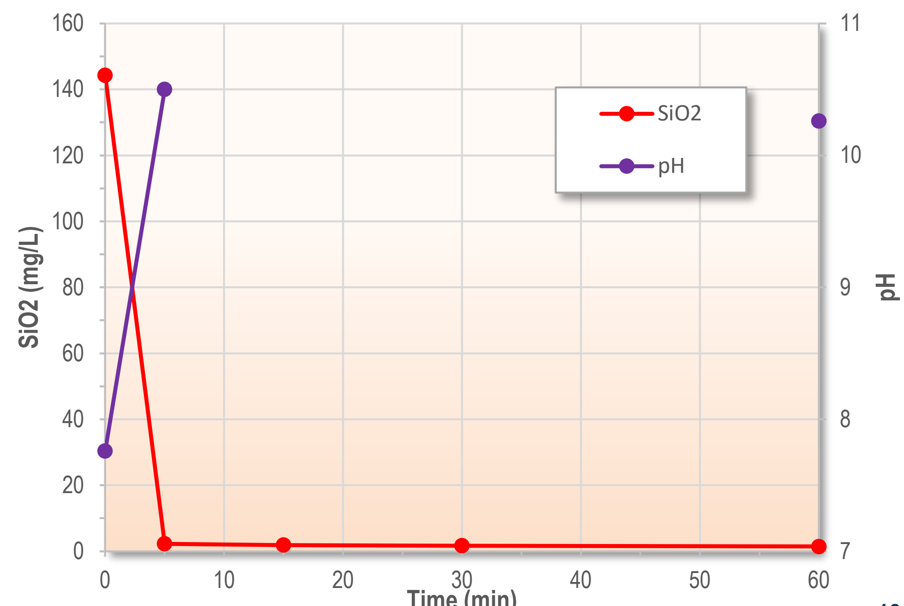
Foulant	Pre-treatment	Post-treatment	Removal (%)
Total Hardness	742	129	**83%**
Ca (mg/L)	269	45	**83%**
Mg (mg/L)	17	3.8	**77%**
SiO_2 (mg/L)	144	1.4	**99%**

Coal Gasification Wastewater Stream 2

Removal of silica (and reduction of hardness)

HT Technology enabled the Stage 3 RO to operate, improved efficiency by 50% and improved the wastewater treatment capacity from <800m^3 to 1,200m^3 per hour.





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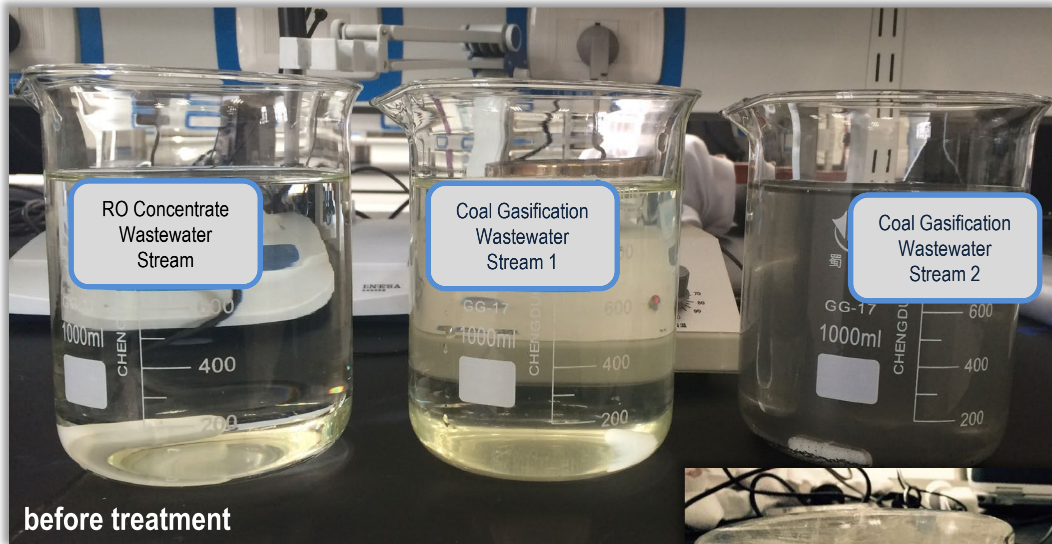
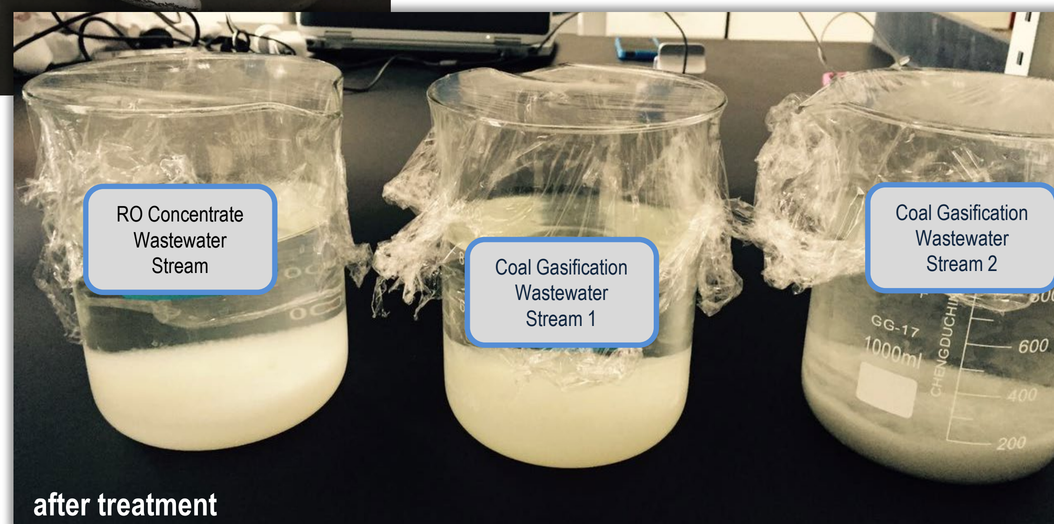
Shaanxi coal gasification plant - wastewaters pre- and post-treatment





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AUSTRALIA INDUSTRY APPLICATION
In-Situ Hydrotalcite Treatment at Baal Gammon Copper Mine Queensland

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Baal Gammon Copper Mine

Commercial application of VCL's hydrotalcite technology completed at Baal Gammon copper mine in North Queensland during 2013

Contract aim to remediate contaminated pit water with hydrotalcite, followed by RO water polishing to achieve purity that satisfied ANZECC Water Quality Guidelines for final discharge into the adjacent Jamie Creek

Analyte	pH	As (mg/L)	Cu (mg/L)	Cd (mg/L)	Co (mg/L)	F (mg/L)	Fe (mg/L)	Mn (mg/L)	Pb (mg/L)	Si (mg/L)	Zn (mg/L)
Pre-Treatment	2.9	0.04	40	0.3	0.54	59	59	16	0.13	60	22
Post-HT Treatment	**9.2**	**<0.005**	**<0.005**	**0.001**	**<0.005**	**34**	**<0.05**	**0.04**	**<0.005**	**1.3**	**<0.005**
Post-RO Treatment	7.0	<0.003	0.001	<0.0001	<0.001	0.97	<0.005	<0.005	<0.001		0.04
ANZECC Irrigation Limits	4.0-9.0	0.1-2.0	0.2-5.0	0.01-0.05		1.0-2.0	200-10,000	200-10,000	2.0-5.0		2.0-5.0

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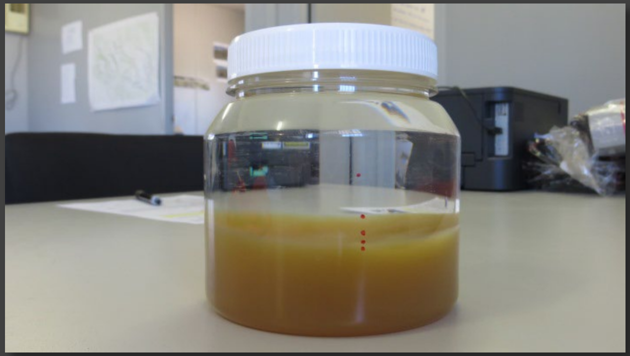
Baal Gammon Copper Mine



HT technology trial at bench top scale prior to implementation

HT technology implementation at commencement

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Baal Gammon Copper Mine

Hydrotalcite precipitate after treatment

Treatment of 56 megalitres of contaminated mine-pit water to remove metals and metalloids prior to final RO treatment and discharge into the environmentally sensitive Jamie Creek

Introduction of HT reagents at surface

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Baal Gammon Copper Mine – Wastewater treatment life cycle

Pit prior to treatment containing 56 megalitres of pH 2.9 acid mine water containing a range of contaminants

Pit during treatment with white halo highlighting hydrotalcite precipitating in-situ.

Dewatered pit with hydrotalcite residue “ore” grading 8% Cu and 4% Zn (on dry mass basis)

Recommencement of mining operations

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AUSTRALIA INDUSTRY CASE STUDY
Beverley ISL Uranium Mine
South Australia

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Beverley ISL mine - Pre & post hydrotalcite treatment of barren lixiviant

Analyte	Lixiviant (mg/L)	
	Untreated	**Treated by HT**
pH	1.6	**10.6** buffers to 8.5
EC (mS/m)	2,890	**1,920**
Si	**140**	**2**
Mg	**594**	**1**
Al	**410**	**10**
K	175	**100**
Ca	699	**483**
Na	2,190	4,290
SO_4	6,600	6,000
HCO_3	<1	24

- ✓ Confirms broad spectrum removal:
  - Mg, Al, SO_4, EC ⬇, only Na, HCO_3 ⬆
  - 10 of 19 trace elements <detection limits
  - most other trace elements >99% ⬇
  - U 99.7% ⬇ (+ daughter radionuclides)
- ✓ Treated lixiviant similar to original groundwater *(plus minor Na and SO_4)*

Analyte	Lixiviant (mg/L)	
	Untreated	**Treated by HT**
As	0.005	**<0.005**
Cd	0.17	**0.007**
Co	9.9	**0.003**
Cr	0.41	**0.004**
Cu	0.75	**<0.002**
Fe	170	**0.023**
La	1.6	**<0.005**
Mn	1.8	**0.006**
Ni	5.9	**<0.005**
P	4.8	**<0.1**
Pb	0.29	**<0.005**
Sc	1.1	**<0.010**
Se	0.08	**0.06**
Th	3.5	**<0.005**
Ti	0.048	**<0.002**
U	**21**	**0.07**
V	1.2	**0.11**
Zn	7.6	**<0.005**

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Beverley ISL mine - Hydrotalcite precipitate chemistry and calcination

Major Elements	Precipitate (%)	**Calcined (%)**
SiO_2	7.45	**9.91**
TiO_2	<0.002	**0.01**
Al_2O_3	25.80	**34.14**
Fe_2O_3	3.86	**4.99**
MnO	0.19	**0.26**
MgO	18.79	**24.77**
CaO	1.36	**2.03**
Na_2O	1.31	**1.71**
K_2O	0.06	**0.09**
P_2O_5	0.30	**0.38**
Sum	70.11	**92.33**

- ✓ Calcination: Hydrotalcite ➡ spinel
- ✓ 30% mass loss (de-H_2O) ➡ enrichment
- ✓ Ore grade **≈1%U (1.1% eU_3O_8** plus **≈2.5% REE**
- ✓ Potential for reprocessing/cost offset

Trace Elements	Precipitate (µg/g)	**Calcined (µg/g)**
As	22	**29**
Cd	28	**26**
Co	2,432	**3,125**
Cr	96	**116**
Cu	179	**218**
Mo	18	**24**
Nb	16	**22**
Ni	1,175	**1,527**
Sc	290	**405**
Th	431	**569**
V	470	**647**
Zn	1,859	**1,717**
U	**7,162**	**9,778**
La	**317**	**448**
Ce	**1,896**	**2,708**
Nd	**2,068**	**2,894**
Sm	**946**	**1,308**
Yb	**640**	**875**
Y	**4,731**	**6,403**

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Beverley North uranium deposit - Hydrotalcite precipitate chemistry of radionuclides

Radionuclide	Lixiviant (Bq/L)		Removal (%)	HT precipitate (Bq/kg)
	Untreated	Treated by HT		
^{238}U	225	2	99.1%	67,194
^{234}Th	557	0	99.9%	120,986
^{230}Th	8,683	66	99.2%	1,955,469
^{226}Ra	324	26	92.0%	55,282
^{214}Pb	326	26	92.1%	53,822
^{214}Bi	322	26	92.0%	57,013
^{210}Pb	2,193	4	99.8%	488,302

✓ Radionuclide activities at Beverley North uranium deposit:

- In barren and treated lixiviant (Bq/L)
- In HT-based precipitate (Bq/kg)

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PRESENTATION SUMMARY

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Hydrotalcite precipitate - general characteristics

- ✓ Typically 200-500 fold element enrichment over the solution
- ✓ One step, broad spectrum remediation technology
  - **Simultaneously removes many major, trace elements, and radionuclides**
- ✓ Simple to implement, low infrastructure/capital requirements using "off the shelf" reagents
- ✓ Typically 10-20% mass of lime-based (gypsum) precipitates
- ✓ Easily separable from solution
- ✓ Potential cost offset – contained metal values
- ✓ Further stabilisation (long-term repository)

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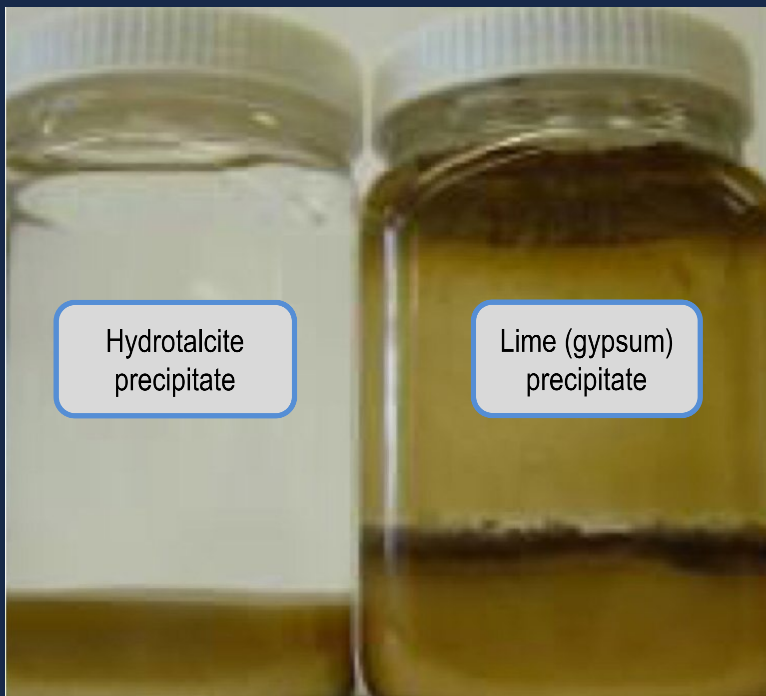
HT precipitates compared to lime precipitates



Dewatered hydrotalcite precipitate

Dewatered lime (gypsum) precipitate

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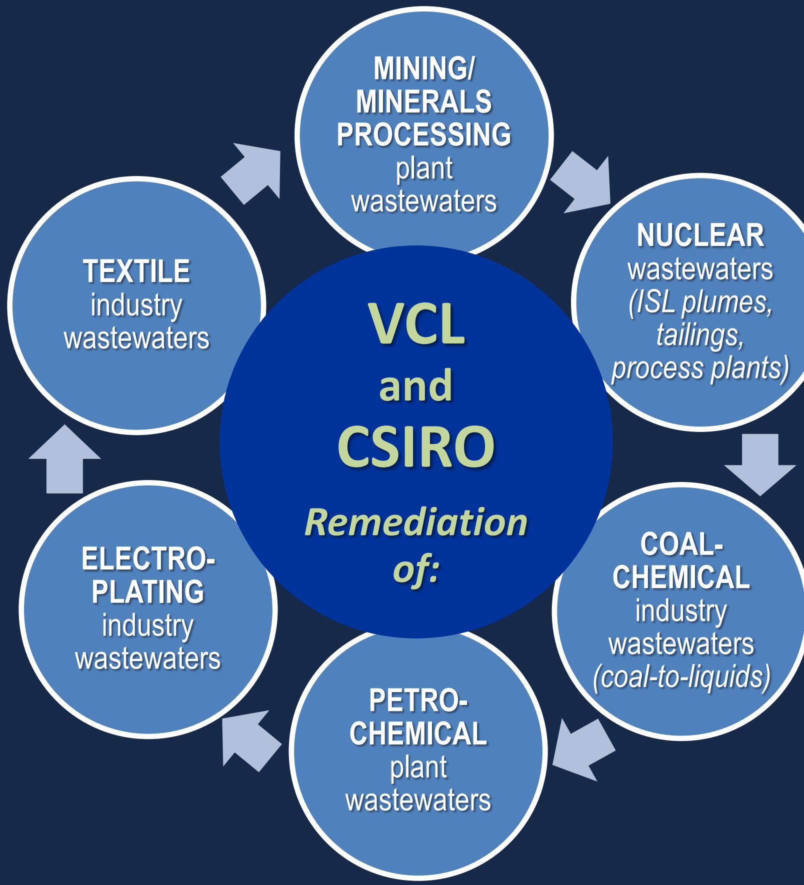
Hydrotalcite water remediation capability

VCL and CSIRO collaboration to deliver hydrotalcite water remediation technology to industry



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Technology partnerships

VCL

- ✓ Australian public company with expertise and relationships in natural resources and mineral processing markets
- ✓ Exclusive international licence to commercialise, sub-licence and implement CSIRO hydrotalcite technology
- ✓ Numerous registered and provisional patent applications globally
- ✓ Licence agreement includes exclusive access to inventor and CSIRO facilities to undertake testwork and evaluation/ modelling of technology applications

CSIRO

- ✓ Australia's national science agency and one of the largest & most diverse in the world
- ✓ Ranked in top 1% in 14 research fields
- ✓ Inventors of wi-fi, plastic bank notes, atomic absorption spectroscopy, breathable contact lenses ……
- ✓ Over 160 active licences of CSIRO innovation

VCCL

- ✓ Commercial technology rights for the Greater China Region under sub-license from VCL
- ✓ Jointly-owned by VCL and Triangle Capital Partners

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